

**İSTANBUL TİCARET UNIVERSITY**  
**INSTITUTE OF GRADUATE SCHOOL**  
**DEPARTMENT OF ECONOMICS**  
**MASTER OF ECONOMICS PROGRAMME**

**A QUANTILE PANEL-TYPE ANALYSIS OF THE RELATIONSHIP  
BETWEEN THE EU-ETS AND DISAGGREGATED INFLATION  
IN THE EUROZONE**

**MA Thesis**

**Musa SAMBOU**

**ISTANBUL, 2025**

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**ISTANBUL, 2025**

## **ETHICS STATEMENT**

I dedicate all the required information to this title, 'A Quantile Panel Type Analysis of the Relationship Between the EU-ETS and Disaggregated Inflation in the Eurozone,' which has been written in accordance with academic standards and ethical commitments.

I would clarify that all the materials, sources, data, and additional inputs have been well utilized throughout the writing process of this thesis. All matters contained in this thesis represent my personal opinion and do not reflect the official view of İstanbul Ticaret University.



Musa Sambou

## ABSTRACT

This thesis investigates the disaggregated inflationary effects of the European Union Emissions Trading System (EU-ETS) within the Eurozone using a quantile panel causality approach. While the EU-ETS has emerged as a central pillar in the EU's climate policy framework, with increasing relevance under initiatives such as the 'Fit-for-55' strategy, the inflationary dynamics it induces across different sectors remain insufficiently understood. The study fills this gap by evaluating the heterogeneously varying impacts of carbon pricing on principal inflation indicators namely food inflation, energy inflation, core inflation, headline inflation, and producer price index on twenty Eurozone countries over the period from 2005 to 2020. Compared to traditional econometric estimations that are confined to average effects, quantile panel estimation employed here captures distributional information and non-symmetric causal links between EU-ETS price behavior and sectoral inflation with a broader perspective. The findings indicate that EU-ETS-driven price signals have statistically significant and heteroscedastic effects, with quantitative effects predominantly varying across the upper and lower quantiles of inflation measures, with steep inflationary pressures within energy and manufacturing prices, moderate effects on headline inflation, and subdued responses in core inflation. This implicit causality underscores the role of context-differentiated policy design to preserve environmental goals in macroeconomic stability. The research adds to the existing literature by combining the principles of environmental economics and inflation theory into a unified empirical framework. The research provides policymakers with practical recommendations to cushion the poor against the negative distributional impacts of green transition policies while maintaining price stability in the common currency area.

*Keywords:* Quantile panel causality, Eurozone, Fit-for-55, EU-ETS, GHG.

## ÖZET

Bu tez, Avrupa Birliđi Emisyon Ticareti Sistemi'nin (EU-ETS) Avro Bölgesi'ndeki parçalı enflasyonist etkilerini kantil panel nedensellik yaklaşımı kullanarak arařtırmaktadır. EU-ETS, "Fit-for-55" stratejisi gibi girişimler kapsamında giderek artan bir öneme sahip olup, AB'nin iklim politikası çerçevesinde merkezi bir sütun hâline gelmiş olsa da, farklı sektörlerde neden olduğu enflasyonist dinamikler yeterince anlaşılmamıştır. Çalışma, karbon fiyatlandırmasının gıda, enerji, çekirdek ve manşet enflasyonları ile üretici fiyat endeksi gibi başlıca enflasyon göstergeleri üzerindeki heterojen etkilerini yirmi Avro Bölgesi ülkesinde 2005-2020 döneminde değerlendirerek bu boşluğu doldurmaktadır. Ortalama etkilerle sınırlı geleneksel ekonometrik tahminlerle karşılaştırıldığında, bu çalışmada kullanılan kantil panel tahmini, AB-ETS fiyat davranışı ile sektörel enflasyon arasındaki dağılıma ilişkin bilgileri ve simetrik olmayan nedensel bağlantıları daha geniş bir perspektifle yakalamaktadır. Bulgular, AB-ETS tarafından yönlendirilen fiyat sinyallerinin istatistiksel olarak anlamlı ve heteroskedastik etkilere sahip olduğunu, nicel etkilerin çoğunlukla enflasyon ölçümlerinin üst ve alt kantilleri arasında değiştiđini göstermektedir. Enerji ve imalat fiyatlarında güçlü enflasyonist baskılar gözlemlenirken, manşet enflasyonda orta düzeyde, çekirdek enflasyonda ise daha sınırlı tepkiler tespit edilmiştir. Bu örtük nedensellik, çevresel hedeflerin makroekonomik istikrarla uyumlu şekilde korunabilmesi için bağlama duyarlı farklılaştırılmış politika tasarımı gerekliliđini vurgulamaktadır. Araştırma, çevre ekonomisi ve enflasyon teorisinin ilkelerini birleşik bir ampirik çerçevede bir araya getirerek literatüre katkı sunmakta; ortak para birimi alanında fiyat istikrarını korurken, yoksul kesimleri yeşil geçiş politikalarının olumsuz dağılımsal etkilerine karşı korumaya yönelik politika yapıcılara pratik öneriler sunmaktadır.

*Anahtar Kelimeler: Quantile panel neden-sonuç ilişkisi, Euro bölgesi, Fit-for-55, AB-ETS, GHG.*

## **DEDICATION**

This thesis is dedicated in loving memory of my late father, Yaya Sambou, and my late brother, Ousman Sambou. Their unwavering support and encouragement have profoundly shaped my academic journey and fueled my pursuit of excellence. Their guiding presence and love remain strong inspirations for me, even in their absence. I also wish to express my deep gratitude to my mother, Maimuna Jatta. Her strength, sacrifices, and unwavering belief in my potential have been vital throughout my education. Her steadfast support has significantly contributed to my accomplishments.

Additionally, I extend my sincere appreciation to my brothers. Their generous financial support was instrumental in the successful completion of my studies. Their belief in my aspirations and consistent assistance allowed me to concentrate fully on my academic responsibilities, and I am truly grateful for their commitment and sacrifices. Above all, I dedicate this work to God Almighty, whose divine mercy, guidance, and blessings have sustained me throughout this journey. His grace has empowered me to face challenges head-on and achieve the successful completion of this thesis.

Finally, I dedicate this thesis to my entire family and close circle of friends. Their unwavering encouragement and moral support have been crucial throughout this transformative journey, and I am incredibly thankful for their presence in my life.

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I would like to express my sincere appreciation to my supervisor, Assistant Professor Dr. Goodwin Oluseye Olasehinde Williams, for his exceptional mentorship, insightful guidance, and consistent encouragement. His critical feedback, scholarly input, and dedication to academic excellence have been instrumental in shaping the direction and quality of this research. I am profoundly grateful for the opportunity to learn under his supervision.

In addition, I am especially thankful to him for his patience and generous support during the data analysis phase of this study. His emphasis on analytical rigor and critical thinking has had a lasting impact on my academic growth, deepening my understanding of the subject matter.

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Musa Sambou

Istanbul, 2025

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## LIST OF SYMBOLS AND ABBREVIATIONS

EU-ETS	European Union Emissions Trading System
ETS	Emissions Trading System
ICE	Intercontinental Exchange
EUA	European Union Allowance
EEX	European Energy Exchange
FINF	Food Inflation
ENEF	Energy Inflation
CINF	Core Inflation
HINF	Headline Inflation
PPI	Producer Price Index
CPI	Consumer Price Index
GDP	Gross Domestic Product
ECB	European Central Bank
OECD	Organization for Economic Co-operation and Development
WDI	World Development Indicators
MSR	Market Stability Reserve
Q	Quantile
VAR	Vector Autoregression
IMF	International Monetary Fund
CO <sub>2</sub>	Carbon Dioxide
GHG	Greenhouse Gas
LM	Lagrange Multiplier
Granger Causality	A statistical hypothesis test for determining whether one time series is useful in forecasting another

# CHAPTER 1

## INTRODUCTION

### 1.1 Background of the Study

The increase in environmental challenges in the Eurozone has resulted from various factors ranging from air and water pollution to global warming, loss of biodiversity, and accumulation of waste. It is within this framework that the idea of radical transformation in the Eurozone economy drew so much attention, with green policies as part of the core national and international political agenda of the previous decade (Konradt, 2024). Such policies manifest themselves in the Eurozone through ambitious initiatives like the Sustainable Development Goals and the European Union Green Deal. The EU's target is climate neutrality by 2050, which indicates an economy that has net-zero greenhouse gas emissions. This aligns with the obligations under the Paris Agreement, which aims to limit the increase of global temperature to well below 2°C and to pursue efforts to limit the increase to 1.5°C (Olasehinde-Williams, 2024a).

Numerous theoretical studies have examined the macroeconomic consequences of the green transition, often modelled as an increase in carbon taxation. A common finding across this study is that tighter environmental policies do reduce emissions effectively but at the cost of having a detrimental impact on GDP (European Central Bank., 2023). Carbon pricing either in the form of carbon taxes or the imposition of binding emission trading schemes force firms to allocate some of their resources to emissions reduction, which could restrict economic output in total (Olasehinde-Williams, 2024a).

The macroeconomic aspects of carbon pricing mechanisms namely, carbon taxes and emissions trading systems have been studied in several studies. The studies suggest that European carbon taxes have neutral to mildly positive effects on employment and GDP growth, while emissions are lowered by 4-6% under a \$40/ton CO<sub>2</sub> tax covering 30% of emissions (Metcalf & Stock, 2020). The overall effect is contingent upon recycling revenue from the measures, the coverage of the policy, and accompanying measures (Warwick, 2021). The study also suggests that in general, the impact of carbon pricing on inflation is negligible. Given the implications of carbon pricing for economic growth, inflation, and trade competitiveness, its interaction with monetary policy in the Eurozone

is of great significance. A well-coordinated approach to climate and monetary policies is necessary to help mitigate macroeconomic disruptions, including inflationary threats as central banks, like the European Central Bank, begin to incorporate climate into their policy frameworks.

As established in the previous paragraph, while various macroeconomic effects of environmental policies, especially in the form of carbon pricing have been extensively investigated, the consequences of environmental policies, particularly carbon pricing, for inflation have not been investigated comprehensively. Of paramount concern to central banking authorities, this topic stands against the context of continued discussion regarding the characteristics and sustainability of recent inflationary pressures that were influenced by elevated energy prices, supply disruptions, and post-pandemic bursts in demand. Understanding the inflationary consequences of green policies is important for formulating appropriate monetary and fiscal strategies to transition toward a low-carbon economy (European Central Bank., 2022).

The 2022 Russian invasion of Ukraine triggered a sudden surge in European energy prices, which brought renewed attention to the role of carbon pricing in household energy costs. Early estimates, however, indicate that the energy price spikes experienced in 2022 were much larger than would have been generated by carbon price increases following the 'Fit-for-55' targets. For example, after supply-side disruptions, the German electricity and diesel futures price went up sharply to 4.18 euros per liter and 571 euros per megawatt-hour in August 2022 from 2.70 euros per liter and 150 euros per megawatt-hour in January 2022, a rise of 55% and 280%, respectively. Conversely, without supply shock, if the EU increased carbon prices by 112 euros per ton to 150 euros per ton in early 2022, coal prices would have been doubled, and diesel and electricity prices would have been slightly affected by about 11% and 17%, respectively. Actually, the high 2022 EU-ETS price of approximately 90 euros per ton is significantly lower than the 150 euros for 2030 in question, so carbon pricing had an even smaller part to play in raising energy prices. Ciccarelli, Kuik, and Hernández (2023) also confirm that the role of carbon pricing in energy prices in 2021 and 2022 was also virtually non-existent.

The study analyses how carbon pricing affects inflation in the euro area. The euro area presents an ideal case study for two reasons. First, it has a long-standing and extensive

carbon-pricing framework, whereby various euro area nations have imposed both national carbon taxes and the EU-ETS, making it an extraordinarily well-studied subject by the academic community. Second, the euro area provides a unique opportunity to study the impact of climate policy on the macroeconomics of the euro area, relatively free from nation-specific interferences in monetary policy. Because the ECB conducts monetary policy for the entire currency bloc instead of targeting specific responses to shocks in individual countries, this allows us to disentangle more clearly the influence of national carbon pricing schemes on inflation and other economic dynamics.

Environmental policies in the form of carbon pricing has an established historical precedent in Europe, with many countries imposing excise taxes on fuels for decades. The first explicit carbon tax implementations took place in the early 1990s, and by 2023, Europe remains a world leader in efforts associated with carbon pricing (Olasehinde-Williams, 2024a). Several countries have adopted national carbon taxation schemes with varying degrees of ambition. Additionally, the carbon price of the European Union's Emissions Trading System (EU-ETS), which accounts for approximately 40% of overall emissions in the EU, significantly rose. The carbon price included by the EU-ETS has been maintaining a comparatively high degree since the beginning of 2022 at an average price of approximately 85 euros per ton of CO<sub>2</sub> (Konradt, 2024).

The European Union's 'Fit-for-55' strategy is an ambitious policy package that will achieve at least a 55% reduction of greenhouse gas emissions by 2030 from 1990 levels, and is in line with the general goal of becoming climate neutral by 2050. A key component of the strategy is the recast and enhancement of the EU Emissions Trading System (EU-ETS), to reduce emission caps and increase carbon prices in order to push decarbonisation. In addition, the strategy extends carbon pricing to sectors such as maritime and road transport, allowing broader participation in emissions reduction. It also encourages the development of renewable energy through binding targets and investment in clean technologies and raises energy efficiency through more stringent standards for buildings, appliances, and industry. Recognizing the socio-economic impacts of the transition, the strategy includes financial support and retraining programs to facilitate a just transition for the affected communities. Ultimately, 'Fit-for-55' seeks to align EU policies with global climate commitments, in particular the Paris Agreement, and reaffirm the bloc's climate leadership (Konradt, 2024).

Governments influence carbon prices by mechanisms other than taxation. These involve indirect levies, tariffs, subsidies for alternative energies, and regulation. This discussion, nonetheless, is solely interested in carbon prices in the form of the EU-ETS. As of 2021, the implied carbon price in the euro area from both domestic carbon taxation and the EU-ETS was approximately 40 euros per ton of CO<sub>2</sub>. It is difficult to price the necessary carbon prices to reach the emission levels set under the European Union's 'Fit-for-55' strategy, as there is a significant amount of uncertainty in both the price movements necessary and other policy measures that might be needed. According to a review by (OECD, 2021), a Paris Agreement-compatible 2030 carbon price range has central projections in the 50-225 euros per tonne of CO<sub>2</sub>, with a central point estimate of 120 euros. A similar analysis in an ECB blog by Konradt (2024) assumes a carbon price of 140 euros per tonne in 2030 in order to achieve the 'Fit-for-55' objectives. Other studies, for example those of European Central Bank (2023), quote a broader range of 50 to 150 euros per ton. The current study is based on an assumption that coincides with the International Monetary Fund's October 2022 World Economic Outlook, which estimates an effective carbon price rise of 112 euros per ton from 2021 to 2030, an approximate rise of 12 euros annually.

## **1.2 Problem Statement**

The global economy of today is confronted with an unprecedented energy crisis amid strong contributions from geopolitical instability, climate change-related issues, and systemic reliance on fossil fuels (Olasehinde-Williams, 2024a). The war in Ukraine has also added to the volatility in commodity markets, resulting in historically high inflation rates in recent decades. The situation suggests a need for a hasty transition to the use of renewable resources to fight climate-induced vulnerabilities and also national security and economic stability. Renewable technologies, which are sometimes subliminally called 'freedom energies', can help liberate this addiction to fossil fuels. Investment in solar, wind, and hydroelectric power has already witnessed declining costs of electricity generation, with forecasts that by 2040, even small-scale photovoltaic systems will be less expensive than fossil fuel-fired power plants. Nevertheless, although the advantages of this change in the long run are obvious, the short-run economic adaptations necessary for the attainment of energy independence entail enormous costs.

One major inflationary force related to the green transition is "climateflation," which arises from the economic consequences of climate change itself (Schnabel, 2022). With more intense and frequent natural disasters, including prolonged droughts, agricultural production has been interrupted, causing food prices to soar. These climatic-induced interruptions create a huge economic burden and further worsen socio-economic inequalities, especially on lower-income households. The increasing costs of disaster preparations and climate change mitigation constitute inflationary pressures, creating a vicious cycle that reverberates through global supply chains and into consumer prices (European Central Bank., 2023). Thus, combating climateflation requires response mechanisms that bring resilience to climate factors into the broader monetary and fiscal policy framework.

A second major driver of inflation, "fossilflation," arises from the long-term consumption of fossil fuels and the related expense of leaving them behind (Konradt, 2024). The eurozone is fundamentally still dependent on petroleum and natural gas, with fossil fuels comprising the majority of total energy consumption. Rising carbon cost resulting from policy measures taken to reduce emissions has contributed to the inflationary impact of fossilflation. In addition, market forces of finance like the strategic selling out by institutional investors in fossil fuel firms have helped generate higher funding expenses for energy producers. The geopolitical risk of Russian oil and gas supply has also added to the pressure on prices, creating an inflationary environment that is going to persist through the near term (Olasehinde-Williams, 2024a).

A third inflationary category arises from the higher demand for critical raw materials required by green technologies: "greenflation." Electric vehicles, wind turbines, and solar panels are heavy consumers of various metals and minerals, such as lithium, cobalt, and copper. On the other hand, the availability of these resources is severely restricted, owing to the long lead times for developing a new mining operation (typically five to ten years). Thus, the increasing demand for these strategic materials has caused a dramatic rise in their prices, which are making the switch over to a low-carbon economy even more difficult. The impact of greenflation on consumer prices remains limited compared to that of fossilflation; however, its adverse effects would mount as low-V. emission technologies are adopted by more sectors, thereby generating inflationary pressures through the transition period (Spyromitros, 2023).

Since these inflationary pressures are multidimensional, it becomes important to understand how monetary policy must navigate cautiously in the face of the challenges posed by the green transition. Although environmental policies such as carbon pricing introduced to speed up the green transition have proven effective in reducing emissions, their potential negative economic impacts have raised concerns (Olasehinde-Williams, 2024b). From the outset of discussions on the implementation of market-based environmental policies such as carbon pricing, both theoretical and policy debates have acknowledged the possible adverse effects of carbon pricing on key macroeconomic indicators (Warwick et al., 2021). These concerns contributed to policymakers' reluctance in fully embrace it.

### **1.3 Aim and objectives of the study**

This study is an evaluation of the macroeconomic impact of carbon pricing in the Eurozone. The broad aim is the evaluation of the disaggregated inflationary effects of the EU-ETS in the Eurozone economies. Specifically, this study examines the causal impacts of the EU-ETS on food inflation, energy inflation, core inflation, headline inflation, and producer price index in the region. The goal of the study is to broaden the economic analysis concerned with emissions trading schemes. Most related studies done so far have principally focused on carbon pricing effectiveness with respect to emission reductions, whereas not much has yet been known and examined regarding the macroeconomic impacts. This study contributes to discussion on carbon pricing-macroeconomics nexus by analyzing the part the EU-ETS plays in opening up inflationary trends.

The specific objectives of the study are as follows.

- I. To determine whether the EU-ETS can predict food inflation patterns in the Eurozone.
- II. To determine whether the EU-ETS can predict energy inflation patterns in the Eurozone.
- III. To determine whether the EU-ETS can predict core inflation patterns in the Eurozone.
- IV. To determine whether the EU-ETS can predict headline inflation patterns in the Eurozone.

- V. To determine whether the EU-ETS can predict the producer price index in the Eurozone.

#### **1.4 Research Questions**

This research aims to examine the predictive power of the European Union Emissions Trading System (EU-ETS) over various inflation indicators within the eurozone, such as food inflation, energy inflation, core inflation, headline inflation, and producer price index inflation.

Does the EU-ETS significantly predict food inflation in the eurozone?

Does the EU-ETS significantly predict energy inflation in the eurozone?

Does the EU-ETS significantly predict core inflation in the eurozone?

Does the EU-ETS significantly predict headline inflation in the eurozone?

Does the EU-ETS significantly predict the producer price index in the eurozone?

#### **1.5 Hypothesis of the study**

The following hypotheses are used as a guide for the empirical testing to determine whether there are significant statistical relationships between the EU-ETS and various types of inflation in the Eurozone.

##### **1. Hypothesis on Food Inflation:**

H<sub>0</sub>: The EU-ETS does not have a statistically significant predictive power over food inflation in the Eurozone.

H<sub>1</sub>: The EU-ETS has a statistically significant predictive power over food inflation in the Eurozone.

## **2. Hypothesis on Energy Inflation:**

H<sub>0</sub>: The EU-ETS does not have a statistically significant predictive power over energy inflation in the Eurozone.

H<sub>1</sub>: The EU-ETS has a statistically significant predictive power over energy inflation in the Eurozone.

## **3. Hypothesis on Core Inflation:**

H<sub>0</sub>: The EU-ETS does not have a statistically significant predictive power over the core inflation rate in the Eurozone.

H<sub>1</sub>: The EU-ETS has a statistically significant predictive power over the core inflation rate in Eurozone.

## **4. Hypothesis on Headline Inflation:**

H<sub>0</sub>: The EU-ETS does not have a statistically significant predictive power over the headline inflation in the Eurozone.

H<sub>1</sub>: The EU-ETS has a statistically significant predictive power over the headline inflation in the Eurozone.

## **5. Hypothesis on Producer price Index:**

H<sub>0</sub>: The EU-ETS does not have a statistically significant predictive power over the producer price index in the Eurozone.

H<sub>1</sub>: The EU-ETS has a statistically significant predictive power over the producer price index in the Eurozone.

## **1.6 Scope of the Study**

This thesis examines the reactions of various kinds of inflation measures (food inflation, energy inflation, core inflation, headline inflation, and Producer price index) to the carbon pricing form of the EU-ETS within the Eurozone. The study focuses on analyzing how carbon pricing under the EU-ETS influences inflation levels, particularly through the inflationary variable.

The research covers the period from 2005 to 2020 to assess the causal linkages between inflation and the emission trading schemes in the Eurozone. It incorporates empirical analysis using econometric modeling to evaluate the nature of the relationship between emissions trading schemes and inflationary pressures in the Eurozone. Geographically, the research is confined to the Eurozone member states, ensuring a focused analysis within a common monetary framework.

This thesis does not assess broader environmental or social impacts of the EU-ETS but concentrates specifically on its inflationary effects. While acknowledging potential interactions with other economic policies, the study aims to isolate the responses of different measures of inflation to the EU-ETS within the Eurozone.

## **1.7 Significance of the Study**

One of the cornerstones of Europe's climate change policy is the European Union Emissions Trading System (EU-ETS). However, the economic implications, especially on inflation, remain understudied. Most studies have focused on the aggregate measure of inflation; however, there exists potential heterogeneity on how different components of inflation respond to carbon price changes. This study aims to address this gap by applying the quantile panel approach to investigate the causal linkages between EU-ETS and disaggregated inflation in the euro area. The study aims to show how the impacts of the EU-ETS will vary across different segments of the economy or price levels by probing different quantiles of inflation they hope to gain a new perspective compared to previous studies.

This research potentially advances theoretical and practical knowledge. It advances theory in the way that it demonstrates that environmental policy interacts with inflation

dynamics in disaggregated form. Practically, policymakers can make use of the results to design and reform carbon price mechanisms to protect against any adverse effects on inflation while still attaining their climate ambitions. Moreover, it is possible for businesses to use this knowledge in anticipating and adjusting their operations in line with economic challenges posed by the EU-ETS, especially in sensitive energy-intensive sectors.

This study offers a methodological innovation through quantile panel analysis to enhance the understanding of the complicated association between environmental policies and inflation. The findings will fill one of the existing critical gaps in knowledge and will also be useful for stakeholders looking to improve their position amidst climate action and economic stability.

### **1.8 Structure of the Study**

The organization of this study follows this sequence: Chapter 1 introduces the thesis. In Chapter 2, an exhaustive literature that assesses the relationship between environmental policies and inflation, as drawn from studies conducted in euro-area countries, is reviewed. In this chapter, the existing studies are evaluated, and their weaknesses as well as important findings are established. Chapter 3 describes the methodological considerations that have guided the research. Chapters 4 provide a comprehensive analysis of the disaggregated inflationary effects of various environmental policies implemented across individual Eurozone member states based on the study findings.

The final chapter, chapter 5 summarizes the results and assesses them against the environment and economic stability goals of the Eurozone from the perspective of the policymakers and stakeholders. It also highlights potential avenues for further research required to understand and address the way policies affect different groups and sectors in society to ensure equity of measures to marginal groups and industries. This chapter also analyze how environmental protection measures may likely cause inflation and possible strategies to mitigate impacts on people and businesses across the Eurozone.

## CHAPTER 2

### 2. LITERATURE REVIEW

#### 2.1 Emission Trading Schemes

The European Union Emissions Trading Scheme (EU-ETS) was established in 2005 and has expanded to become the largest carbon pricing scheme in the world, with the broad aim of reducing greenhouse gas emissions and their effects on climate change (Ellerman & Buchner, 2007). Its cap-and-trade system allows firms to trade emissions allowances within a certain limit, which has given a market-based framework for abatements (European Commission, 2019). While targeted at environmental goals, the EU-ETS has also been highly contentious in terms of its economic impacts. Research indicates that there are enormous sectoral imbalances: while sectors such as cement and steel suffer minimal impact due to structural and regulatory drivers (Sing et al., 2012), power generation industries are subject to higher volatility in costs, particularly from windfall gains due to previous allowances. Moreover, macroeconomic studies have also tested the capacity of the EU-ETS to increase financial hardship during economic crises and challenged its net effect on competitiveness and economic resilience (Olasehinde-Williams, 2024b; Vlachou, 2014).

The functioning of the EU-ETS is hindered by various issues, including inaccuracy of data, incompatible member state auctioning system preferences, and the accumulation of surplus allowances, which necessitated measures like the Market Stability Reserve (MSR) to stabilize carbon price volatility (Ellerman & Buchner, 2007). These issues indicate the complexity of harmonizing a common carbon pricing system across heterogeneous national settings. Adding to the EU-ETS's effectiveness are also the interdependencies of carbon pricing with macroeconomic drivers and external shocks such as energy crises and economic recessions (Benz & Trück, 2009; Chevallier, 2013). The literature highlights the need for more sophisticated models capturing the EU-ETS's interaction with broader economic drivers like inflation, GDP growth, and exchange rates (Bolat et al., 2023; Moradian Daghigh & Mirzaee Ghazani, 2023). Lastly, to realize its full potential, the EU-ETS must be improved further in policy and analytical methods to close the gaps in the present knowledge of its economic and environmental effects (Chevallier, n.d.; Mansanet-Bataller et al., 2007).

## **2.2. Inflation in the Eurozone**

### **2.2.1 Food Inflation**

The dynamics of food inflation in the Eurozone have garnered considerable research attention, particularly with regard to price convergence, spatial heterogeneity, and sensitivity to exogenous shocks. The early literature, such as Liontakis, (2012), offers benchmark information on convergence behavior among member states' food prices, reporting mean reversion across some periods and product categories, but emphasizing its time instability. Such temporal variability is added to by structural heterogeneity in domestic food supply chains, making efforts at homogeneous inflation management within the common currency area increasingly difficult. Even as it acknowledges the spatial interdependence of food markets, Caldeira & Freire, (2014).; Liontakis, (2012) apply spatial filtering methods to identify and characterize convergence signals and show the imperative of spatial econometric considerations when mapping inflation indicators. Lloyd et al., (2013), who refer to persistent asymmetries in food price inflation, which are attributed to asymmetries in economic development and in the structural makeup of national food systems, even within the allegedly integrated EU single market. More recently, the COVID-19 pandemic has demonstrated the sensitivity of food markets to exogenous shocks. Gutiérrez-Villar et al., (2021) report a positive relationship between mortality rates and food price increases during the first wave of the pandemic, explaining the impact of supply chain breakdowns, consumer panic, and policy divergence. Taken together, these studies highlight that food inflation in the Eurozone is organized by an intersection of structural, spatial, and temporal processes. Although convergence tendencies can be observed under certain conditions, underlying heterogeneity and periodic shocks still call for more powerful and space-aware policy designs in order to stabilize inflation effectively across diverse regional environments.

### **2.2.2 Energy Inflation**

Recent research has revealed the central role played by energy price shocks in powering the inflation dynamics of the Euro area, particularly in the context of post-pandemic recovery and geopolitical war. Corsello & Tagliabracchi, (2023); Neri et al., (2024) provide clear evidence that energy inflation accounted for more than 60% of headline inflation growth in 2022, emphasizing the structural embeddedness of energy costs along

production and consumption chains. The inflationary impact of natural gas, in particular, has been compounded in recent years by Casoli et al., (2024) highlighting its disproportionate contribution observed during the period of extreme supply disruptions. Beyond headline measures, worry is growing about the greater pass-through of energy prices to core inflation, reflecting the magnitude and persistence of recent price shocks (Neri et al., 2024). This complicates the task for central banks, as the distinction between transitory and permanent inflation becomes less clear. Leiva-Leon et al., (2019) also sharpen this debate by identifying that exchange rate shocks have been a significant determinant of energy-driven headline inflation since the early 2010s, although these have had no real effect on core inflation. Overall, these findings give rise to fundamental questions about the efficacy of conventional monetary policy tools. Corsello & Tagliabracchi, (2023) argue, interest rate adjustments are poorly suited to counter inflation that is caused by exogenous energy supply-side bottlenecks, prompting calls for a more diverse policy framework. This literature underscores the challenge of energy inflation and the urgency of policy frameworks that accommodate energy market volatility, exchange rate variability, and structural inflation determinants in the Eurozone.

### **2.2.3 Core inflation**

The concept of core inflation has been a staple in the Eurozone monetary policymakers' framework for decades, as it tries to wean away the short-term fluctuations of commodities such as food and energy to uncover more persistent inflationary trends. Exclusion-based techniques, conventionally employed to strip out volatile components to lay bare the "core" of inflation, have been common among policymakers and scholars for many years. But as Vega & Wynne, (2003) point out, such traditional methods are limited by their inability to trade off economic interpretability, smoothness, and forecasting power. In response to these limitations, a literature has emerged that describes more sophisticated techniques for measuring core inflation. For instance, Cristadoro et al., (2005) build a dynamic factor model that eliminates short-run noise from monthly price changes and delivers a more reliable core measure with improved forecasting power over longer horizons. Similarly, Matilla-García, (2005) employs a structural VAR framework that imposes long-run restrictions on macroeconomic variables to discover the cyclical character of inflation in a way that captures the underlying structural dynamics of the Eurozone economy.

Most recently, Morana, (2023) makes a contribution to the literature with a structural core inflation measure tailored to optimise smoothness, economic content, and predictive ability. This represents a radical departure from exclusion-based indicators, instead offering a richer theory and stronger empirics in an instrument for tracking inflation. Interestingly, Morana, (2023) also identifies the multivariate determinants of the post-pandemic inflationary period in the Euro region, referring to core, cyclical, and residual determinants as the prime determinants. This multivariate standpoint reflects the increasing recognition that core inflation is not a singular phenomenon but a synthesis of interrelated forces that demand multilateral analytical strategies. Despite these methodological advances, traditional measures continue to be employed, although they are behind in volatility reduction and early warning capacity (Vega & Wynne, 2003). Collectively, this emerging literature underscores the need to refine core inflation measures to ensure that they become increasingly policy-relevant in a complex and rapidly evolving macroeconomic setting.

#### **2.2.4 Headline inflation**

Recent empirical analysis of headline inflation dynamics in the Euro area has painted a more nuanced perspective of the interplay between structural, cyclical, and exogenous determinants of price developments. Morana, (2023) suggests a new core inflation measure that isolates cyclical and residual components, contending that these factors currently represent the most notable risks to price stability. This analytical subtlety reveals deficiencies in traditional exclusion-based approaches, which do not fully account for evolving drivers of inflationary pressures. To this perspective, Corsello & Tagliabracchi, (2023) provide firm affirmation of the asymmetric role of energy prices in powering over 60% of the inflation acceleration in early 2022. Their study highlights the dominance of exogenous supply-side shocks, particularly in the context of global energy volatility, and their capacity to transmit inflationary pressures to both headline and core inflation indicators.

In broader inflation determinants' analysis, Bernoth & Ider, (2021) points out the ephemeral character of most of inflationary shocks, while cautioning about long-run risks of inflation expectation shifts. The latter consideration is of particular relevance for central banks because chronically high expectations would undermine the credibility of

inflation-targeting regimes and complicate monetary policy tuning. Matilla-García, (2005) with a structural Vector Autoregression (VAR) argument argues the case for the priority of extracting core inflation out of headline volatility in order to provide policymakers a more informative measure of underlying trends. Together, these studies emphasize the multifaceted nature of Eurozone inflation, where energy-driven shocks, expectations dynamics, and unobserved cyclical components influence each other in complex ways. To the ECB, such lessons underscore the necessity of applying high-powered statistical technology in combination with advanced conceptual understanding of macroeconomic fundamentals for the ends of efficient inflation monitoring and policy development.

### **2.2.5 Producer Price Index**

The Eurozone producer price index (PPI) behavior provides a rich and profound understanding of firms' price-setting behavior, with evidence for the presence of a strong pattern of price rigidity and sectoral heterogeneity. Seminal contributions of Vermeulen et al., (2007) consistently establish that only roughly 21% of producer prices are reset every month in six Eurozone economies, reflecting high nominal stickiness in producer pricing. This behaviour rigidity is not uniformly spread across sectors; the energy prices are revised more frequently, whereas the prices of durable goods are relatively stable over time and reflect underlying differences in cost structures, market conditions, and manufacturing technologies (Vermeulen et al., 2007). Surprisingly, the distribution of price change does not exhibit signs of downward nominal rigidity, with roughly 55% of changes as price increases and 45% decreases (Vermeulen et al., 2007). This contrasts with the evidence in consumer price setting, where downward rigidity exists, indicating greater flexibility in producer prices.

Macroeconomic phenomena, particularly the introduction of the Euro, have further shaped PPI dynamics. According to Andren & Oxelheim, (2006), the first years of monetary union were characterized by the appearance of widening producer price index gaps, which emphasized the frictions of price convergence among member states. With time, the process of convergence gained momentum, initially driven by productivity differentials and later by the impact of exchange rate volatility on input and export prices. Drivers of producer price adjustments are therefore multifaceted, encompassing firm-

specific drivers such as cost pass-through, pricing strategy, and seasonality, as well as more wide-reaching drivers such as inflation expectations and global supply chain pressures (Vermeulen et al., 2007). Collectively, this literature identifies the central position that monitoring PPI occupies as both a proxy for inflationary pressures upstream and a conduit by which monetary and structural shocks make their way into the broader economy.

### **2.3 Impact of Inflation on Socioeconomic Groups**

The growing empirical evidence literature shows the uneven impact of inflation across various socioeconomic groups in the eurozone, reflecting a broader problem of distributive impacts of macroeconomic phenomena. Mitrakos & Zografakis (2005) demonstrate that poor families, pensioners, and unemployed people are most vulnerable to inflationary pressures since they allocate a higher proportion of their expenditures on essentials such as food, housing, and tobacco. These disparities have intensified due to the COVID-19 pandemic, with the 2022 inflation surge having levied substantial real income losses on the poorest households (Amores et al., 2023). Although fiscal interventions were enacted to cushion these effects, they were typically inaccurate in their targeting of vulnerable populations and occurred sporadically across countries (Amores et al., 2023). Interestingly, the adoption of the euro did not significantly alter aggregate inflation rates or inter-household inflation differentials (Sturm et al., 2009), yet inflation perceptions remain highly subjective and dependent on experience and expectations (Sturm et al., 2009). This nuance between objective inflation measures and perceived inflation suggests that policy credibility and communication have decisive effects on economic behavior across various social strata.

Environmental policies, particularly those regarding the fight against climate externalities, also contribute to the inflationary burden for low-income families. Gaber Elbasheer Elhassan, (2020) notes that environmental policies such as carbon pricing can drive up the cost of energy and food, two important spending components for poorer families, thus aggravating underlying socioeconomic inequalities. Wealthier households, meanwhile, have more diversified consumption patterns and greater penetration of energy-efficient alternatives, which insulate them from such policy-induced price shocks. Moreover, diversity in the composition of national energies and economic structures

among Eurozone countries increases such disparities, as noted by Dao, (2023a), with fossil fuel-dependent countries suffering more acute inflationary impacts from green policy implementation. Moreover, Kohlscheen et al., (2024) argued that policy design and enactment have a fundamental mediating influence on these effects; some frameworks and implementations are obviously better than others in curtailing inflationary spillovers. By and large, this literature identifies an attractive imperative towards cautious and harmonious policy design that is both encouraging environmental aims and absorbing inflationary risk to vulnerable socioeconomic sections.

#### **2.4. Theoretical Background**

The European Union Emissions Trading System (EU-ETS) is a cornerstone of EU climate policy and the largest market-based instrument for the regulation of greenhouse gas emissions in the world (Rybarczyk, 2021). According to the principles of multi-level governance, it is a hybrid institutional design that blends top-down systems of regulation with participatory stakeholder mechanisms of involvement (Buchner et al., 2007). However, academic studies of the EU-ETS reveal persistent criticisms regarding its carbon price volatility, which led its general economic effectiveness and legitimacy as a policy instrument into doubt (Fuss et al., 2018). Here, theoretical examination emphasizes the importance of assessing cap-and-trade regimes not only according to their immediate impacts but also in long-run perspectives that involve intertemporal flexibility and the risk of market distortion (Fuss et al., 2018). The right selection of analytical lenses to analyze the EU-ETS, therefore, must be based on theoretical concepts that account for institutional complexity and salience of the issue at hand, particular emphasis on path dependency and policy feedback (Zahariadis, 2013). The EU-ETS demands analysis that is history informed, conceptually developed tracing the development of emissions trading, and dependent upon theories of market failure, intervention through regulation, and learning institutionally (Rybarczyk, 2021).

Two major schools of thought within the macroeconomic debate, neoclassical and Keynesian economics, present competing but complementary explanations for the inflationary impacts of environmental regulation. Environmental policy instruments such as the EU-ETS levies a regulatory cost upon corporations in the form of unavoidable green technology expenditure or purchase of the emissions allowances that can

potentially get passed on by the firms onto the customers and trigger cost-push inflation (Kharroubi & Smets, 2024). Micro-foundational roots of the inflationary impulses are what these arguments refer towards, equating increasing cost to produce with corresponding consumer price increments. On the other hand, the Keynesian approach focuses on demand-side forces, where government-led green investments and enforcement of environmental standards drive aggregate demand, possibly beyond supply and leading to demand-pull inflation (Kharroubi & Smets, 2024). In this regard, inflation emerges not just as a spin-off of regulatory cost pressure but as a consequence of structural transformations in the economy, including alterations in labour markets, capital allocation, and remapping of sectoral production (Green, 2022).

Furthermore, the distributional effects of climate policy need to be examined closely in the broader macroeconomic framework. Cost-benefit analyses based on distributional theory emphasize the uneven socio-economic burden of environmental regulation on various income groups and sectors of industry (Döttling & Rola-Janicka, 2023). Empirical research shows that poor households are disproportionately affected by energy price shocks, while energy-intensive industries such as manufacturing have more significant operating costs that erode their competitiveness. These disproportionate impacts can potentially exacerbate already-existing inequalities, and hence policy tools necessary to reconcile environmental objectives with distributive justice principles are all the more necessary. Hence, a full theoretical account of the EU-ETS would need to marry an appreciation of inflationary theory and political economy with the reality that effective environmental policy must be economically rational, socially equitable, and institutionally adaptable (Francesco Vona 2021).

## **2.5. Empirical Evidence on Environmental Policies and Inflation**

The interaction of environmental policy instruments and macroeconomic indicators such as inflation has drawn much academic interest due to its multifaceted and context-dependent nature. Classical economics would view environmental regulations as a cost to companies that could lead to inflationary pressures and reduced competitiveness. However, this assessment has been countered by the Porter Hypothesis that contends that properly constructed environmental regulations can stimulate technological change as well as productivity, ultimately compensating costs of compliance (Kózluk & Zipperer,

2013a). Empirical research, however, offers a mixed picture. For instance, while stringent environmental policies do raise input costs, especially the price of energy, thus exercising a downward pressure on aggregate investment, these impacts are not uniformly spread across industries. Polluting sectors may respond either by innovation or by cost pass-through, while others can reduce capital formation or relocate production to foreign countries (Natasha, 2016). This heterogeneity underlines the importance of sectoral analysis when measuring the inflationary impact of environmental policy.

Additionally, macroeconomic uncertainty, particularly inflation uncertainty, has been observed to exhibit counterintuitive impacts on environmental performance. (Ahmad et al., 2021) suggest that greater uncertainty of inflation will most likely enhance environmental performance indirectly by deterring consumption and investment and thus emission abatement. However, the process is moderated through financial development, as it can provoke additional capital to enter environmentally harmful activities (Ahmad et al., 2021). These results indicate that environmental results rely on something greater than policy design in isolation, but also on overall financial and macroeconomic conditions. In the future, the empirical evidence requires more nuanced research that exploits cross-country data, differentiates between multiple types of policy tools, and employs multiple aggregation levels in a bid to capture the multi-layered complexity in the inflation-environmental policy relationship (Kózluk & Zipperer, 2013b). These methodological advances are necessary to explain the causal mechanisms by which environmental policies influence inflationary processes and vice versa.

Understanding the inflationary impact of green policy in the Eurozone entails a nuanced study of the space heterogeneity of the region. In this context, the EU-ETS has been a seminal policy tool, whose macroeconomic implications vary tremendously across temporal, spatial, and institutional scales (Olasehinde-Williams, 2024c). The evidence indicates largely a negative economic impact of the EU-ETS overall, albeit with significant heterogeneity across different economic environments. The heterogeneity makes questionable universal application methodologies and argues for the integration of environmental policy evaluation in the specific economic setting. Recent evidence further indicates that long-run inflation expectations and Eurozone core inflation are upward pressures due to EU Allowance (EUA) price increases Nishigaki, (2023), rendering the assumption of carbon price neutrality in the inflation process dubious. Such inflation

pressures are most effective for supply-side vulnerable economies or those experiencing monetary tightening phases, which lead to central questions regarding macroeconomic trade-offs underlying climate policy shocks.

The geographical nature of Eurozone inflationary dynamics is well documented, with indications of repeated area-wide inflation differentials due to area-wide shocks, national economic structures, and local idiosyncratic conditions (Hubrich et al., 2006). The multiblock nature of the description discredits the hypothesis of uniform monetary transmission mechanisms and exposes the boundaries of integrated monetary policy measures, particularly concerning geographically asymmetrical environmental policy impacts. Chakraborty & Mandel, (2022) differentiate regional clusters at the NUTS-2 level, where environment-growth relationships are strongly mediated by local industrial structures, labour market characteristics, and institutions' capacities. Such observations point towards the fundamental need of taking account of regional feedback mechanisms, wherein regulatory costs can be transferred through to consumer prices, thus further making the inflation scenario more difficult to interpret. Overall, studies are increasingly embracing the need to examine the effect of emissions trading schemes like the EU-ETS on geographically disaggregated terms, pinpointing regional economic infrastructures and price-determining activities as central pillars of policy effectiveness (Dueñas & Mandel, 2024). As environmental policy's ability to push climate goals grows stronger, regional imbalances present not only the desired, but rather the imperative question of ensuring macroeconomic as well as environmental equilibrium.

Since its inception in 2005, the European Union Emissions Trading Scheme (EU-ETS) has been a landmark in the global institutionalization of market-based environmental regulation. As an instrument to implement the EU's Kyoto Protocol obligations, the EU-ETS both imposed a binding cap on greenhouse gas emissions and introduced a cross-country allowance trading system (Kruger et al., 2007). This trailblazing framework encouraged the launch of an operational carbon market within the Eurozone, rendering the scheme a priority of EU climate policy. However, early developments within the scheme revealed inherent structural and regulatory vulnerabilities. Issues such as over-allocation of emission allowances, regulatory uncertainty post-first commitment period, and competitiveness effects particularly for energy-intensive and trade-exposed industries, took away from the scheme's initial effectiveness (Grubb & Neuhoff, 2006).

These shortcomings led to a series of policy reforms, thereby initiating a broader debate on the most desirable structure of emissions trading systems, particularly in terms of macroeconomic stability and cross-border trade dynamics.

Empirical research has begun to uncover the EU-ETS' subtle macroeconomic effects, and studies have established that the scheme has produced a statistically significant but modestly sized contractionary effect on aggregate economic performance in the Eurozone (Olasehinde-Williams, 2024c). Notably, this adverse impact appears to become smaller during periods of economic expansion, suggesting a countercyclical dimension to its economic effect. These have been responded to by suggestions from scholars and policymakers of a series of scheme design changes to enhance environmental and economic efficiency. These are, for instance, replacement of free allocation with auction-based systems, total sector-wide emissions reductions requirement, and institutionalization of post-2012 commitments (Egenhofer & Fujiwara, 2007; Grubb & Neuhoff, 2006). To address competitiveness concerns without undermining environmental objectives, proposals for the first time suggest an integration of border-tax adjustments and output-based allocation mechanisms. These actions demonstrate a firm move towards internationalising carbon governance architecture, where regulatory coherence and equitable burden-sharing are critical to ensure long-term sustainability and political acceptability of emissions trading regimes (Grubb & Neuhoff, 2006).

The relationship between environmental policy and inflation in the eurozone has garnered considerable academic attention, even though the literature remains inconclusive, particularly for disaggregated inflationary effects. Empirical studies show that the inflationary impact of environmental policies such as carbon taxation will more likely be through relative price changes rather than general price level rises (Warwick et al., 2021a). This nuance is significant in that it would imply that while sectoral prices may rise as a function of higher energy costs or costs of compliance, even aggregate inflation need not remain as high. More importantly, evidence has demonstrated how the transmission of energy price and, particularly, oil shocks with inflationary impact is contingent on the prevailing macroeconomic setting. Garzon & Hierro, (2021) demonstrate that such transmission is stronger under high-inflation environments, suggesting that the broader macroeconomic context intervenes in determining the extent to which energy-related policy interventions influence price dynamics across industries.

Such evidence reaffirms the necessity of a disaggregated analysis framework that considers industry-level sensitivities instead of relying on aggregate inflation measures alone.

In addition to macroeconomic considerations, institutional and monetary factors also play a decisive role in determining the inflationary effect of environmental regulation. Castiglione et al., (2014) observe an inverse U-shaped relationship between income levels and environmental taxation, mediated by the quality of institutional enforcement most importantly the rule of law. This would suggest that weaker institutional settings not only impair the effective operation of environmental policy but also warp their inflationary effects along income classes. The accommodative monetary policy stance of the European Central Bank, and specifically its quantitative easing schemes, adds another level of complexity to this environment. Hilmi et al., (2022) find a positive relationship between ECB asset purchases and green-labelled bond issuance, which means that monetary policy indirectly funds environmental objectives without putting inflationary pressures in the short run. Coordination at the EU level is, however, challenging, especially in standardizing environmental legislation and applying homogeneous enforcement within the member states (Castiglione et al., 2014). Together, these works demonstrate a complicated and context-dependent interaction between institutional strength, sectoral heterogeneity, and macroeconomic conditions, and disaggregated inflation, reinforcing the significance of integrative policy design.

## CHAPTER 3

### 3. METHODOLOGY AND DATA

#### 3.1 Methodology

Economic and financial analysis has traditionally utilized the Granger causality test in establishing causality, which determines predictability of one variable for another variable. The Granger test is, however, limited by its focus on the conditional mean of variables. This limitation plays a central role in the context of economic and financial data analysis, as such data usually follow fat-tailed or non-elliptical distributions, with the relations in the tails being different from those in the middle regions of the distribution Balcilar, Usman, and Ike (2023). The Granger approach can therefore not detect meaningful causal relationships, especially when there are extreme values or asymmetric relations. In this regard, with an aim to recognizing such challenges, the current study adopts a quantile panel causality approach, extending the investigation to the entire conditional distribution of variables. Such an application allows for the causal relations between emissions trading schemes and determinants of inflation to be investigated more comprehensively. Through such a methodology, the study seeks to explore the EU-ETS's heterogeneous effects on inflation across various quantiles, and therefore provide pragmatic implications for policymakers, economists, and market operators.

##### 3.1.1 The Quantile Panel Causality Model

The ability to adapt to non-linear and asymmetric dependencies makes quantile panel causality analysis ideally suited to the examination of the complex relationship between EU-ETS and inflation. Granger causality tests are primarily mean-based inference techniques, which often contradict the underlying heterogeneity that is present in financial time series data. In that contrast, the quantile panel causality framework dissects causal relationships across the entire conditional distribution of the dependent variable, thus providing a better understanding of the relationship that exists between EU-ETS and inflation. This distributional viewpoint is crucial for assessing how the policy interventions operate in different economic circumstances, such as inflationary spikes against deflationary pressures.

This methodology makes a way for tracing causal paths that are often obscured by mean analysis simply by modeling the conditional quantiles. For instance, it may help determine if EU-ETS has a stronger inflationary impact during times of economic stress or whether the reverse is true: that is, its effects may be more acutely felt during more stable inflationary times. Such knowledge is important for policymakers intending to work out more adaptive context-oriented responses to inflation changes, which will arise due to EU-ETS implementation.

Then the quantile panel causality approach is even more robust when it comes to dealing with non-normal, heteroskedastic, and heavy-tailed features of data that are often encountered in a financial time series. These characteristics pose difficulties for the classic regression techniques which naturally lead to the inference being uneven and in some cases simply, wrong. Therefore, with the quantile approach bypassing these issues to generate more consistent estimates of causation, it lays a stronger foundation for the empirical outcomes on hand.

### **3.1.2 Historical Context and Applications**

The quantile panel causality model was first introduced into quantile regression theory by Koenker and Bassett (1978) and has since received extensions for causality testing in panel data situations. This methodological advance has succeeded in economics and finance, where many have used it to identify heterogeneous causal relationships across various conditional quantiles. This can be seen in the work of Wang and Nguyen Thi (2022) who applied this model to test how financial markets causally influence economic growth, showing how various causal influence is across different states of the economy. Likewise, Chuang et al. (2020) adopted a quantile panel causality framework to analyze how macroeconomic policies affected the dynamics of exchange rates with emphasis on the distributional impact of these policies.

The quantile panel causal model is advanced to examine causal relationships at varying quantiles of the distribution in the context of European Union Emissions Trading Schemes (EU-ETS) and inflation. It is flexible enough to allow for different economic conditions, including high inflation, low inflation, and a changing economy. In contrast to traditional causality tests concerning average effect, this makes for an understanding of dependencies, which are detailed and asymmetric, in financial and economic time

series. The method will assess the nature of causality at different points in the conditional distribution, thus rendering policymaking more precise. By doing so, the method will render targeted policy interventions of EU-ETS, thus addressing specific types of inflation effects at different stages of the economic cycle.

Imparting a panel causality analysis through a quantile-based approach stands beyond the frontiers of traditional econometrics by able to account for the entire spectrum/intermediate of causal interactions between the EU-ETS and the inflation. This advancement helps the researchers tell how these interrelations vary through different economic regimes, thereby allowing deep interpretative power. This insight provides further input toward shaping the medical bases required in the formulation of policies that particularly address the heterogeneity in EU-ETS-based inflation pressure.

In the end, the quantile panel causality model becomes a highly relevant econometric tool to study the inflation-EU-ETS relationship in the Eurozone. It has the ability to capture the distributional heterogeneities noted above and allows for a practical analysis, which is a departure from standard regression techniques. This would facilitate efforts by researchers and policymakers toward the formal design of interventions to effectively offset EU-ETS-induced inflation while still allowing for sustainable growth.

### 3.1.3 Quantile Panel Causality Specification

The non-causality relationships across quantiles between two variables ( $y_t, x_t$ ) are specified as follows:

$$QLETS_{it}(\tau|LETS_{it-1}) = \beta_{01i}(\tau) + \sum_{j=1}^p \beta_{11,ij}(\tau)LETS_{it-j} + \sum_{j=1}^p \beta_{12,ij}(\tau)LFINF_{it-j} \dots \dots 5$$

$$QLFINF_{it}(\tau|LFINF_{it-1}) = \beta_{02i}(\tau) + \sum_{j=1}^p \beta_{21,ij}(\tau)LFINF_{it-j} + \sum_{j=1}^p \beta_{22,ij}(\tau)LETS_{it-j} \dots \dots 6$$

$$QLETS_{it}(\tau|LETS_{it-1}) = \beta_{01i}(\tau) + \sum_{j=1}^p \beta_{11,ij}(\tau)LETS_{it-j} + \sum_{j=1}^p \beta_{12,ij}(\tau)LENEF_{it-j} \dots \dots 7$$

$$QLENEF_{it}(\tau|LENEF_{it-1}) = \beta_{02i}(\tau) + \sum_{j=1}^p \beta_{21,ij}(\tau)LENEF_{it-j} + \sum_{j=1}^p \beta_{22,ij}(\tau)LETS_{it-j} \dots \dots 8$$

$$QLETS_{it}(\tau|LETS_{it-1}) = \beta_{01i}(\tau) + \sum_{j=1}^p \beta_{11,ij}(\tau)LETS_{it-j} + \sum_{j=1}^p \beta_{12,ij}(\tau)LCINF_{it-j} \dots \dots 9$$

$$QLCINF_{it}(\tau|LCINF_{it-1}) = \beta_{02i}(\tau) + \sum_{j=1}^p \beta_{21,ij}(\tau)LCINF_{it-j} + \sum_{j=1}^p \beta_{22,ij}(\tau)LETS_{it-j} \dots \dots 10$$

$$QLETS_{it}(\tau|LETS_{it-1}) = \beta_{01i}(\tau) + \sum_{j=1}^p \beta_{11,ij}(\tau)LETS_{it-j} + \sum_{j=1}^p \beta_{12,ij}(\tau)LHINF_{it-j} \dots \dots 11$$

$$QLHINF_{it}(\tau|LHINF_{it-1}) = \beta_{02i}(\tau) + \sum_{j=1}^p \beta_{21,ij}(\tau)LHINF_{it-j} + \sum_{j=1}^p \beta_{22,ij}(\tau)LETS_{it-j} \dots \dots 12$$

$$QLETS_{it}(\tau|LETS_{it-1}) = \beta_{01i}(\tau) + \sum_{j=1}^p \beta_{11,ij}(\tau)LETS_{it-j} + \sum_{j=1}^p \beta_{12,ij}(\tau)LPPI_{it-j} \dots \dots 13$$

$$QLPPI_{it}(\tau|LPPI_{it-1}) = \beta_{02i}(\tau) + \sum_{j=1}^p \beta_{21,ij}(\tau)LPPI_{it-j} + \sum_{j=1}^p \beta_{22,ij}(\tau)LETS_{it-j} \dots \dots 14$$

Where the null hypothesis of no Granger causality at the  $\tau \in (0,1)$  quantile is given as:  $H_0: \beta(\tau)=0$ .

### 3.2. Data

The study uses annual panel data covering 20 EU nations from 2005 to 2020. The 20 EU countries and the time frame are selected based on the availability of sufficient historical data on both the EU-ETS and inflation. These countries actively participated in the EU Emissions Trading System during the study period, which reinforced the consistency and reliability of the dataset with respect to those countries. Countries with partial or no participation in the EU-ETS were excluded, since they lacked sufficient historical data required for proper empirical analysis. Countries in the final selection are Austria, Belgium, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece,

Hungary, Ireland, Italy, Latvia, Luxembourg, the Netherlands, Poland, Portugal, Slovakia, Slovenia, and Spain.

### **3.2.1 Measures of Inflation**

The study investigates various inflation indicators each of which captures various aspects of price changes in the economy. Food Inflation (FINF) Catches commodity volatility over time and its value is derived from a weighted index based on the percentage with which consumers spend on such commodities. Food inflation is of utmost significance in countries where food constitutes a considerable percentage of household expenditure. Energy Inflation (ENEF) Comprises movements in goods and services in the energy sector, such as electricity, gas, and fuel. Extremely volatile, inflation in energy is bound to find its way into the overall inflation rate, particularly in economies that are based on fossil fuels. Core Inflation (CINF), on the other hand, excludes these volatile food and energy products and thus appropriately qualifies as an indicator of long-run inflationary pressures. Core inflation always offers central banks monetary policy-making in a predictable way. Headline inflation (HINF) is an aggregate measure of inflation that covers changes in prices of all goods and services. Producer Price Index (PPI) is a measure of change in received prices by domestic producers for the sale of their products and therefore a leading indicator of consumer price trends. The data for these measures of inflation are obtained from the World Bank Global Database of Inflation.

### **3.2.2 Construction of the EU-ETS Variable**

The EU-ETS variable is constructed based on the Table 3.2 descriptive variable, which has been uptrained from the European Energy Exchange (EEX), ICE EUA Futures Index, which represents the anticipated price of EUAs in the expectation of market participants on future carbon costs. When measured in Euros per ton of CO<sub>2</sub> equivalent, any change in the futures price indicated an alteration in perception regarding carbon costs which affects investment and production decisions across the board. Founded by the EU in 2005, the EU Emissions Trading System is one of the largest international systems for trading greenhouse gas emissions and thus provides a key forward-looking perspective on developing carbon pricing upon the ICE EUA Futures Index.

**Table 1. Descriptions of the Variables**

Variable	Nature	Source	Units of Measurement
EU-ETS	Dependent	European Energy Exchange (EEX)	Index Value
Food Inflation (FINF)	Dependent	World Bank Global Database of Inflation	Annual % Change
Energy Inflation (ENEF)	Dependent	World Bank Global Database of Inflation	Annual % Change
Core Inflation (CINF)	Dependent	World Bank Global Database of Inflation	Annual % Change
Headline Inflation (HINF)	Dependent	World Bank Global Database of Inflation	Annual % Change
Producer Price Index (PPI)	Dependent	World Bank Global Database of Inflation	Annual % Change

### 3.2.3 Summary Descriptive Statistics

Table 3.1 presents the descriptive summary statistics of the principal macroeconomic variables involved in this study, namely the EU-ETS, Food Inflation (FINF), Energy Inflation (ENEF), Core Inflation (CINF), Headline Inflation (HINF), and the Producer Price Index (PPI). The mean values convey an initial view of central tendency across the sample period, the EU-ETS averaging 13.16 to reflect relatively small carbon pricing over the period, whereas inflation proxies such as FINF, ENEF, CINF, and HINF have subdued means (ranging from approximately 1.85 and 2.96), reflecting an underlying low inflationary environment except for energy inflation, which stands highest. All of the series are proximate to the corresponding mean for their median values, which is broadly symmetrical to their mean, except that CINF and ENEF do have differences indicative of a skewed distribution potentially due to outliers. Standard deviation does have something to say about volatility, and core inflation and energy indicate the highest (6.05 and 4.51, respectively) spreads, and possibly as a result of external shocks or changes in policy. The minimum values are indicative of severe deflation, with core and energy inflation drops to -28.62 and -21.94, respectively suggesting instances of severe downside risks at some point. The maximum levels, conversely, reflect the points of peak inflationary

pressures, specifically in PPI (reaching 56.14), and CINF (44.43), and this may suggest exceptional supply-side shocks or demand booms. Collectively, these numbers not only illustrate the underlying dynamics and distribution of each of the variables individually but also serve to emphasize the necessity of studying their interdependence in the light of the broader macroeconomic and policy environment, particularly in light of energy market uncertainty and environmental policy stringency variability.

**Table 2.** Descriptive statistics

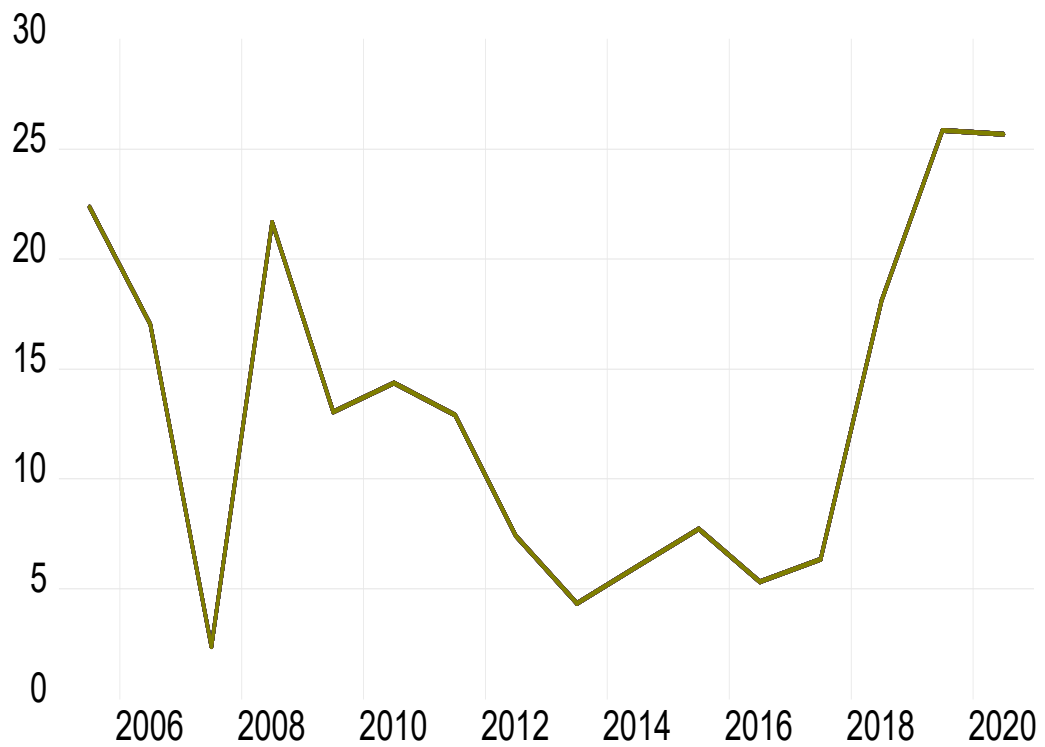
<b>Variable</b>	<b>Mean</b>	<b>Median</b>	<b>Std. dev</b>	<b>Min</b>	<b>max</b>
EU-ETS	13.15688	12.97250	7.643071	2.360000	25.85000
Food Inflation (FINF)	2.213987	1.910202	2.870565	-4.513776	18.26286
Energy Inflation (ENEF)	2.963020	2.374266	4.513776	-21.93741	29.36986
Core Inflation (CINF)	1.946637	1.409964	6.054870	-28.61942	44.42579
Headline Inflation (HINF)	1.857842	1.694741	1.874536	-4.478102	15.40232
Producer Price index (PPI)	1.785928	1.942676	4.862480	-11.55638	56.13898

### 3.3. Graphical Analysis

#### 3.3.1 EU-ETS Graph

Between 2005 and 2012, Figure 3.1 I shows that the EU Emissions Trading System (EU ETS) was highly volatile and relatively low-priced permits, reflecting its initial years and original design flaws, such as Phase I over-allocation of allowances (2005–2007). Throughout this period, there is a sharp decline in 2007–2008, during the time of the financial crisis, when lower industrial production lowered emissions and demand for permits. Between 2012 and 2017, prices were maintained low by residual surplus allowances and market lack of confidence. But from 2018, there was a huge structural shift. That was largely due to the Market Stability Reserve (MSR) reform launched in 2015 but not implemented until 2019, which effectively reduced the surplus and facilitated scarcity to return. Consequently, the trend in the carbon price between 2018

and 2020 records a strong and steady upward trend, which represents increasing investor confidence and increasing anticipation of future climate action. By the end of 2020, the EU ETS had transformed from being a notoriously ineffective compliance measure to becoming a more credible, market-based policy tool.



**Figure 1.** EU-ETS Graph

### 3.3.2 Food Inflation Graphs

Figure 3.2 the chart of the food inflation trend from 2005 to 2020 reflects different cyclical patterns based on global commodity dynamics. From 2007 to 2008, the graph reflects a sharp rise in food inflation, primarily due to global agricultural commodity spikes and biofuel demand pressures, which reached a peak during the 2008 food crisis. This peak was abruptly followed by a decline in 2009 due to the financial crisis-led reduction in demand. Between 2010 and 2013, food inflation also rose although more slowly, driven by rising global food prices, droughts in key production areas, and rising input costs. Between 2014 and 2016, the line indicates a general phase of disinflation, characterized by falling global commodity prices and relatively subdued demand. Food inflation was low and stable in 2017-2019, a sign of both macroeconomic stability and improved supply chains. Although, there is a slight rise in the latter half of 2020, which captures the beginning of the impact of pandemic-driven supply shocks and shipping delays that would gain momentum into the post-2020 inflation wave.

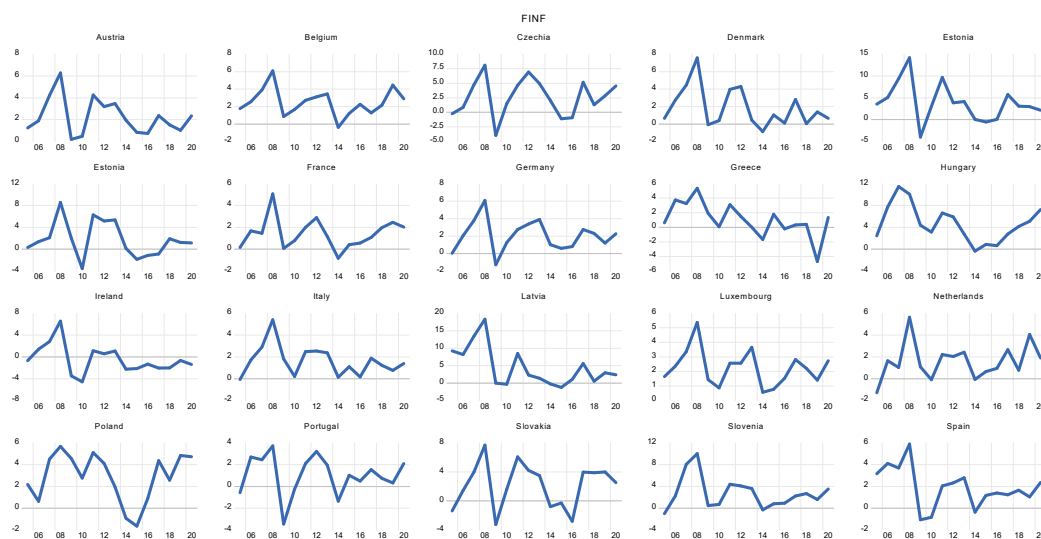
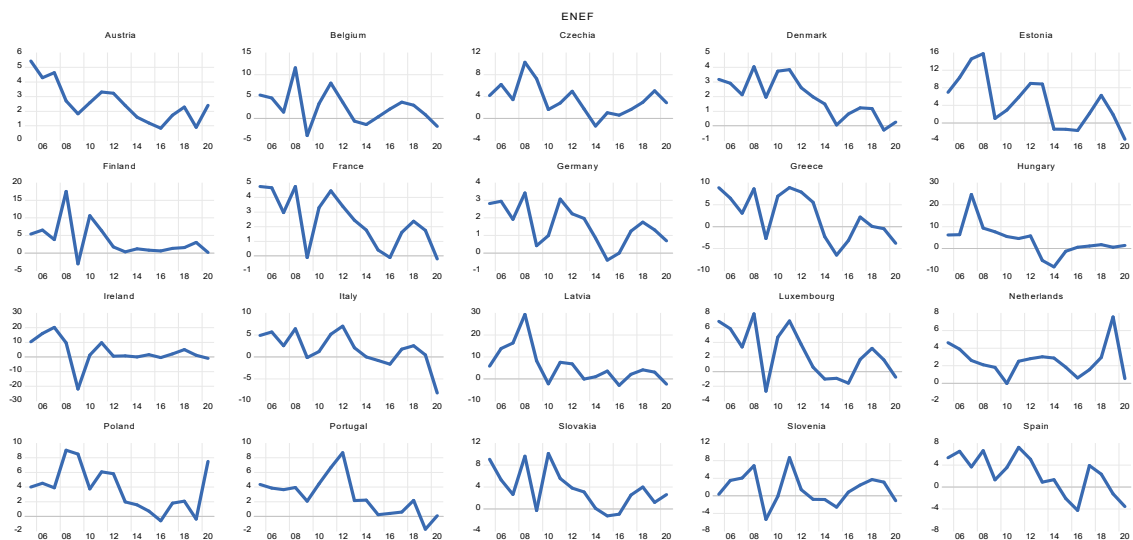


Figure 2. Food Inflation Graphs

### 3.3.3 Energy Inflation

Figure 3.3 of the energy inflation trend from 2005 to 2020 is one of high volatility and strong correlation with world oil price movements. The 2005–2008 trend shows a steep rising path, coincident with sharply increasing crude oil prices that peaked just before the 2008 global financial crisis. Energy inflation collapse during 2008–2009 reflects collapsing oil prices and an abrupt fall in economic activity. There is a recovery from 2010 to 2012, followed by a flat or slightly downward trend through 2014, consistent with moderate rebounds in oil prices and world economic recovery. There is a second sharp decline from 2014 through 2016, resulting from the world oil glut produced by the US shale boom and the refusal of OPEC initially to cut back production. Between 2017 and 2019, the chart shows moderate energy inflation, supported by relative stability in oil prices. Energy inflation implodes in 2020, this time due to the implosion in global energy demand caused by COVID-19 lockdowns, oil price wars, and record-low oil futures going briefly negative temporarily. The overall trend from 2005 to 2020 indicates the volatility of energy inflation to global shocks and commodity cycles.



**Figure 3.** Energy Graphs

### 3.3.4 Core Inflation

Referring to Figure 3.4, in contrast to headline indices, the 2005 to 2020 core inflation trend is exceedingly stable and subdued. Over the 15-year period, core inflation remained anchored to the European Central Bank reference point, moving modestly in the range of 0.8% to 1.5%. The graph illustrates how core inflation was insulated by comparison to the high volatility of food and energy items. During the 2008–2009 financial crisis, core inflation declined somewhat but then came back to its mean. Between 2013 and 2019, core inflation was consistently low despite ultra-accommodative monetary policy during quantitative easing, which is an indication of structural issues such as low wage growth, an ageing population, and slack in labor markets in most euro area economies. There is a slight uptick in 2019, which can be felt, possibly showing tight labor markets in the core economies, but this was instantly undone in 2020 due to the pandemic. This movement proves the stickiness and inertia of core inflation as well as the structural disinflationary forces which were a hallmark of the pre-pandemic era in the Eurozone.

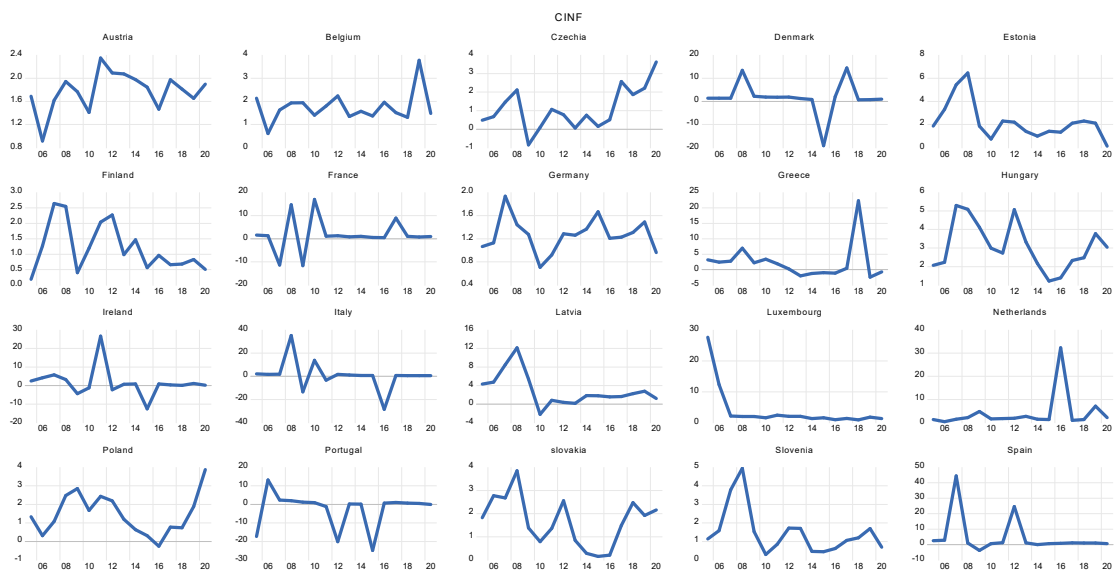


Figure 4. Core Inflation Graphs

### 3.3.5 Headline inflation

As depicted in Figure 3.5 Headline inflation for the period from 2005 to 2020 is more erratic and cyclical in trend, influenced by the impact of food and energy prices. From 2007 to 2008, it presents a precipitous rise, culminating before the global financial crisis, prompted by oil and food price spikes. The fall in 2009 represents a deflationary shock, indicating the depth of the recession. There is a gradual recovery from 2010 to 2012, followed by a disinflationary trend at a consistent rate up to 2015. There is weak global demand and the decline in oil prices during this period. Headline inflation is low and below target from 2016 to 2019, and monetary policy is highly expansionary. The drop in 2020 is deep and consistent with the deflationary effect of the pandemic since both demand and supply were impacted. Overall, headline inflation over this period emphasizes the challenge the ECB faces in maintaining price stability under the influence of external shocks and low inflation that continues.

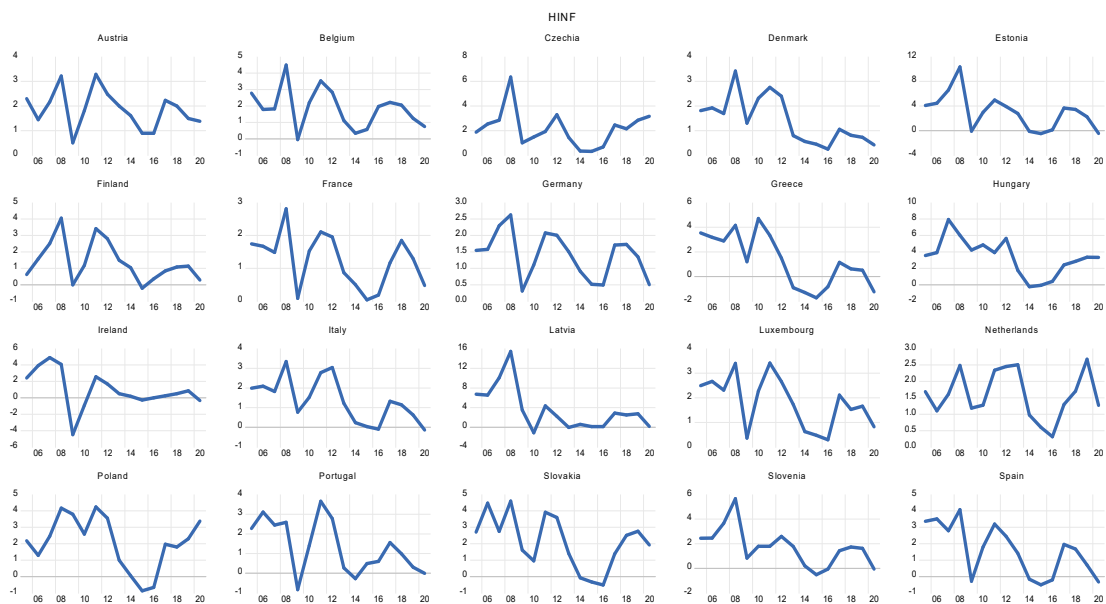
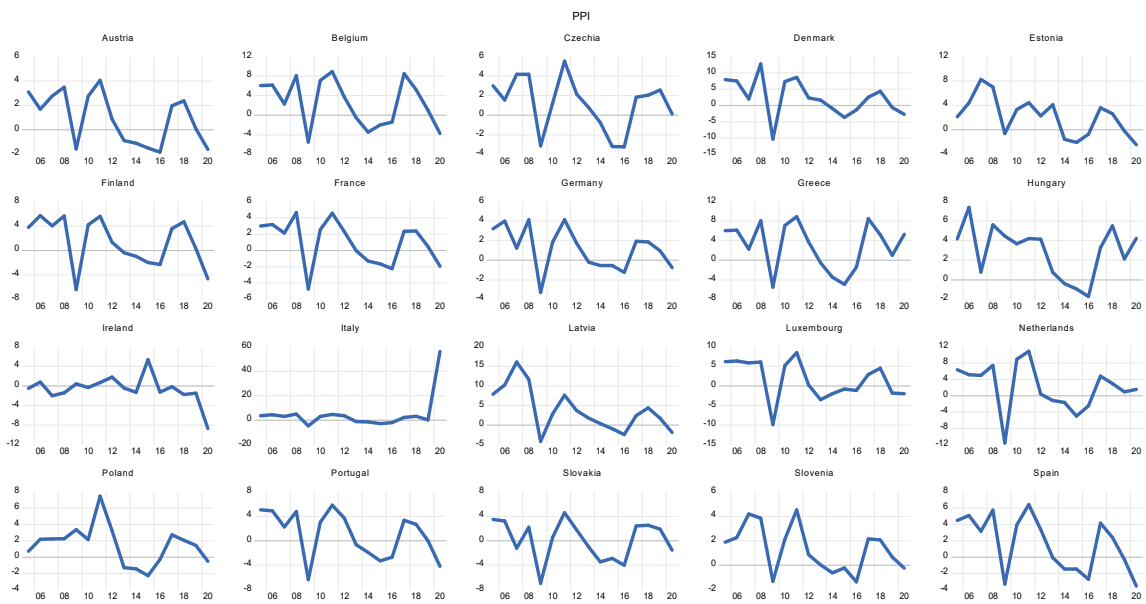


Figure 5. Headline Inflation Graphs

### 3.3.6 Producer Price Index

In Figure 3.6, the trend in the Producer Price Index (PPI) from 2005 to 2020 exhibits wide cyclical fluctuations, with a tendency to lead movements in consumer prices. The PPI rose vigorously from 2005 to mid-2008, driven by global commodity price rises and robust industrial activity. Between 2010 and 2012, the index rebounded modestly, but price expansion was still curbed by slack demand and enhanced competition. From 2013 to 2016, the PPI fell again, in tandem with declining input prices and weak industrial demand. One can see a modest rising trend from 2017 to 2019, mirroring a synchronized global upturn and modest increases in raw material prices. In 2020, the PPI dropped sharply, reflecting the effect of pandemic-related lockdowns on industrial output and input demand. The volatility of the PPI over this period underscores its leading indicator status as an indicator of upstream cost pressures and supply-chain developments.



**Figure 6.** Producer Price Index Graphs

## CHAPTER 4

### 4. RESULTS AND DISCUSSION

#### 4.1. Geary's LM test

To provide a rationale for adopting a quantile regression method, Geary tests for the normality assumption in panel data is first conducted. As seen in the Table 4.1 below, there is sufficient evidence to reject the assumption of normality at a 5 percent level of significance in all the five cases examined as all the probability values are below the threshold of 0.05 required to establish significance at 5 percent. This finding implies that the data has some non-normal features that need to be addressed in the analysis. The non-normality of the data implies that rather than there being a single uniform relationship, different groups of individuals within the data may exhibit different types of relationships with the outcome variable. Quantile regression is used in this regard as it makes it possible to investigate the distribution of the endogenous variable as it relates to the predictors rather than just the mean of that distribution. Quantile regression, by its nature, can provide important findings that are lost in the typical regression approach that ignores the effect of any variable except at its mean. This is especially true in this study, where warp data distributions are present.

**Table 3.** Geary's LM test

Model	Geary LM T-Statistics	P-Value
EU-ETS $\neq$ FINF	-8,059 <sup>b</sup>	0.0178
EU-ETS $\neq$ ENEF	-8,048 <sup>b</sup>	0.0179
EU-ETS $\neq$ HINF	-8,721 <sup>b</sup>	0.0128
EU-ETS $\neq$ CINF	-5,742 <sup>c</sup>	0.0566
EU-ETS $\neq$ PPI	-8,272 <sup>b</sup>	0.0160

*Note: <sup>a</sup>, <sup>b</sup>, and <sup>c</sup> denote statistical significance at 1%, 5%, and 10 % respectively*

## 4.2. Correlation Analysis

The following table presents a Pearson correlation matrix between the EU-ETS and the disaggregated inflation indicators: Food Inflation (FINF), Energy Inflation (ENEF), Core Inflation (CINF), Headline Inflation (HINF), and the Producer Price Index (PPI). Each correlation coefficient is followed by its corresponding p-value, quantifying the statistical significance. The footnotes to the table indicate the application of standard significance levels: 1%, 5%, and 10%, marked respectively as (a), (b), and (c), although not distinctly marked on the values in the table.

The main reason for presenting this table is to look at the power and direction of linear associations between the EU ETS (carbon price proxy) and various inflation measures within the framework of an empirical macroeconomic investigation of the way in which environmental policy can pass through price mechanisms. The correlation coefficients ranging from -1 to +1 are all positive, showing a positive association, and p-values allowing us to make a conclusion about the statistical significance of these estimates.

### 4.2.1. Correlation between EU-ETS and Food Inflation (FINF)

The correlation coefficient of the EU-ETS and food inflation is 0.100 with a related p-value of 0.073. It reflects a weak positive relationship between carbon prices and food inflation. Even though the coefficient is small in magnitude, the p-value suggests marginal significance at the 10% level. Macro-economically, this outcome can be interpreted as potentially reflecting that the carbon price element integrated into the EU-ETS may exert upward pressures on food prices, albeit constrained. The channel of transmission is possible through more expensive energy inputs for agricultural and food processing sectors, which are energy-intensive and therefore vulnerable to carbon cost instability. But the low magnitude of the coefficient implies that the direct pass-through from carbon prices to food inflation is constrained, maybe due to the buffering mechanisms such as government subsidies, supply chain flexibility, or food industry price controls.

#### **4.2.2 Correlation between EU-ETS and Energy Inflation (ENEF)**

The EU-ETS and energy inflation nexus is also significantly positive, with a coefficient of 0.117 and a significant p-value of 0.035. This evidence is in line with a statistically significant and positive carbon price-energy inflation nexus in agreement with theoretical expectation and the available empirical literature. The EU-ETS targets emissions-intensive industries, of which energy production is one where carbon pricing instruments are intended to encourage cleaner manufacturing but, in the short term, may have the effect of increased input costs. These might be passed through consumers in elevated energy prices. The strong correlation verifies the role of carbon pricing as an energy price behavior determinant, consistent with environmental tax incidence theory and supportive of the hypothesis that market-based environmental regulation exerts quantifiable inflationary pressures, particularly on energy markets.

#### **4.2.3 Correlation between EU-ETS and Core Inflation (CINF)**

The correlation coefficient between core inflation and EU ETS is 0.069 with a p-value of 0.212. The relationship is statistically insignificant and very weak in size. Core inflation excludes volatile energy and food prices and in general is regarded as a more accurate gauge of underlying inflationary tendencies. The absence of such strong correlation means that the EU ETS, even as impacting particular price bands (e.g., energy), fails to impact aggregate inflation content when these sensitive factors are adjusted away. Such an outcome complements the theory that the system of carbon pricing does not yield localized and no systemic or widespread inflation effects. From a policy point of view, it is reassuring that environmental regulation by means of emissions trading is not threatening macroeconomic price stability in a generalized way.

#### **4.2.4 Correlation between EU-ETS and Headline Inflation (HINF)**

The EU-ETS and headline inflation are correlated at 0.163, with a p-value of 0.000, showing a statistically significant and moderate positive correlation. Headline inflation, with all items included in the consumer basket, reacts to changes in food and energy prices. While with the strong associations observed earlier to both food as well as energy inflation (though especially energy), the result in this case corresponds to the notion that the EU ETS will increase headline inflation through these very channels. Such a finding

holds economic significance, as it represents the implication that even if not affecting core inflation, the EU ETS affects consumers' overall cost of living. The result is particularly relevant in times of high carbon prices or supply-side shocks, where the inflationary impact of environmental regulation is most likely to be more pronounced.

#### **4.2.5. Correlation between EU-ETS and Producer Price Index (PPI)**

The EU-ETS and producer price index correlation is 0.183 with a p-value of 0.001, suggesting a statistically significant and moderately positive correlation. PPI portrays input and wholesale prices at the producer level and is generally a leading indicator for consumer price inflation. The close relationship here suggests that carbon pricing mechanisms embedded in the EU-ETS create extra costs for firms, particularly in energy- and emissions-intensive sectors. To the extent that these costs can be transmitted down supply chains and, ultimately, to consumer prices, this has important implications. From a policy analysis perspective, this result highlights a fundamental trade-off between environmental policy aspirations and cost-push inflationary pressures at the production stage. It also emphasizes the necessity of complementary policies, i.e., subsidies to green investments or compensatory schemes in transition, to mitigate the inflationary effect on producers.

Taken together, the correlation analysis reveals that the EU-ETS is associated statistically with energy inflation, headline inflation, and the producer price index but has weak and statistically insignificant correlation with core inflation. The results concur with theoretical expectations that environmental pricing mechanisms exert sector-specific inflationary effects, particularly in energy- and carbon price-sensitive sectors. The findings endorse the view that while the EU-ETS will contribute to some inflationary pressures, particularly in the short term, its broader impact on underlying inflation trends is minimal. Policymakers must therefore weigh cautiously environmental stringency gains against its distributional and inflationary effects, especially for poor sectors and households.

**Table 4.** Correlation matrix table

<b>Correlation matrix</b>	<b>EU-ETS</b>	<b>FINF</b>	<b>ENEF</b>	<b>CINF</b>	<b>HINF</b>	<b>PPI</b>
<b>EU-ETS</b>	1.000 ----					
<b>FINF</b>	0.100 <sup>c</sup> (0.073)	1.000 -----				
<b>ENEF</b>	0.117 <sup>b</sup> (0.035)	0.545 <sup>a</sup> (0.000)	1.000 -----			
<b>CINF</b>	0.069 <sup>c</sup> (0.212)	0.227 <sup>a</sup> (0.000)	0.220 <sup>a</sup> (0.000)	1.000 ----		
<b>HINF</b>	0.163 <sup>a</sup> (0.000)	0.806 <sup>a</sup> (0.000)	0.8130 <sup>a</sup> (0.000)	0.267 <sup>a</sup> (0.000)	1.000 ----	
<b>PPI</b>	0.183 <sup>a</sup> (0.001)	0.368 <sup>a</sup> (0.000)	0.304 <sup>a</sup> (0.000)	0.148 <sup>a</sup> (0.000)	0.434 <sup>a</sup> (0.000)	1.000 ----

Note: <sup>a</sup>, <sup>b</sup>, and <sup>c</sup> denote statistical significance at 1%, 5%, and 10 % respectively

### 4.3. Quantile Panel-Type Causality Results

This study examines the causal relationships between emission trading schemes and various inflationary factors, including food inflation, energy inflation, core inflation, headline inflation, and producer price index, across different quantiles. The findings reveal significant variations in these relationships based on the inflationary quantiles under investigation. The analysis provides a nuanced understanding of how EU-ETS interacts with and influences various measures of inflation across a range of economic conditions. The study delves deeper into the complex interplay between environmental policies, such as EU-ETS, and different facets of inflation, offering valuable insights for policymakers as they navigate the intricate balance between environmental sustainability and economic stability. This research offers a comprehensive examination of the causal linkages between EU-ETS and multiple dimensions of inflation, underscoring the importance of considering the broader economic context when evaluating the impacts of

environmental policies on inflation. The findings from this study highlight the heterogeneous effects of emission trading schemes on inflation, with the relationships varying significantly across different quantiles of the inflationary spectrum. This underscores the need for policymakers to adopt a more nuanced and context-specific approach when designing and implementing environmental policies, recognizing that the impact of such policies on inflation can be highly dependent on the prevailing economic conditions.

#### **4.3.1 A Quantile Panel type causality relationship between Emission Trading Schemes and Food Inflation**

As shown in Table 4.2, the quantile panel-type causality test between EU ETS and food inflation implies a non-asymmetric and non-linear causal relationship. The lower (0.1, 0.2) and higher (0.9) quantiles only provide statistically significant ETS causality to food inflation with p-values of 0.0445, 0.0837, and 0.00225 respectively, implying responsiveness of food inflation to carbon market news primarily under conditions of rare inflation. The large and positive coefficient at the 0.9 quantile (0.103) suggests that during high inflation, ETS can exert upward pressure on food prices, possibly due to increased production costs and transmission of input prices. Whereas causality of food inflation to ETS is more transient and weaker and identified statistical only at quantiles 0.4 to 0.7 and 1–5% significance levels, therefore, variations in food inflation seemingly through economic sentiments or policy adjustment affect the price of ETS under the scenario of moderate level inflation. These results point toward a regime-dependent but bidirectional causality between ETS and food inflation in which food inflation will have greater effects on ETS in general circumstances and in which shocks to ETS will exert larger effects on food prices at high inflation levels.

**Table 5.** Quantile Panel-Type Causality Results (EU-Emission Trading Schemes and Food Inflation)

Null hypothesis	Quantile	Coefficient	P-value	Causality detected
EU-ETS $\neq$ FINF	0.1	0.047 <sup>b</sup>	0.044	Yes
	0.2	0.038 <sup>c</sup>	0.083	Yes
	0.3	0.034	0.138	No
	0.4	0.033	0.135	No
	0.5	0.027	0.242	No
	0.6	-0.007	0.734	No
	0.7	-0.007	0.731	No
	0.8	0.0149	0.561	No
	0.9	0.103 <sup>a</sup>	0.002	Yes
FINF $\neq$ EU-ETS	0.1	-0.442 <sup>b</sup>	0.048	Yes
	0.2	-0.311	0.249	No
	0.3	0.264	0.444	No
	0.4	0.635 <sup>b</sup>	0.023	Yes
	0.5	0.714 <sup>a</sup>	0.003	Yes
	0.6	0.713 <sup>a</sup>	0.002	Yes
	0.7	0.657 <sup>a</sup>	0.004	Yes
	0.8	0.201	0.355	No
	0.9	-0.093	0.730	No

Note: <sup>a</sup>, <sup>b</sup> and <sup>c</sup> denote statistical significance at 1%, 5% and 10 % respectively

### **4.3.2 A Quantile Panel type causality relationship between EU-Emission Trading Schemes and Energy Inflation**

The result in Table 4.3 shows that the EU ETS causality to energy inflation displays a unique pattern of significance for median to upper quantiles (0.5 to 0.9), with coefficients between 0.086 and 0.133 and p-values below 0.05, the majority at the 1% level. This reveals that carbon market impacts energy inflation significantly in average to high inflation months, as might be anticipated by the concept that higher ETS prices make energy production more costly, especially compared to where fossil fuels prevail. Notably, lower quantiles are not causally related, and the point lies in the strength of the message that when lower inflationary pressure exists, there is weak ETS-energy price linkage. Strong reverse causality from energy inflation to ETS exists across all mid quantiles (0.3 to 0.8), with exceptionally high statistical strength at 0.3 to 0.6 (at 1% level) that decreases in power at higher quantiles (at 10% at 0.8 and 0.9). This two-way and substantial two-way causality emphasizes a feedback mechanism by which energy price trends and carbon market indicators reinforce one another, especially in the presence of inflationary stress, having the potential to fuel volatility in both markets and to complicate the use of ETS as a one-purpose environmental instrument.

**Table 6.** Quantile Panel-Type Causality Results (EU-Emission Trading Schemes and Energy Inflation)

Null hypothesis	Quantile	Coefficient	P-value	Causality detected
EU-ETS $\neq$ ENEF	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 <sup>b</sup>	0.024	Yes
	0.6	0.118 <sup>a</sup>	0.003	Yes
	0.7	0.112 <sup>a</sup>	0.008	Yes
	0.8	0.109 <sup>a</sup>	0.009	Yes
	0.9	0.133 <sup>a</sup>	0.003	Yes
ENEf $\neq$ EU-ETS	0.1	-0.115	0.347	No
	0.2	0.199	0.352	No
	0.3	0.550 <sup>a</sup>	0.002	Yes
	0.4	0.677 <sup>a</sup>	0.000	Yes
	0.5	0.692 <sup>a</sup>	0.000	Yes
	0.6	0.582 <sup>a</sup>	0.000	Yes
	0.7	0.418 <sup>b</sup>	0.024	Yes
	0.8	-0.159 <sup>c</sup>	0.075	Yes
	0.9	-0.261 <sup>c</sup>	0.084	Yes

Note: <sup>a</sup>, <sup>b</sup> and <sup>c</sup> denote statistical significance at 1%, 5% and 10 % respectively

### **4.3.3 A Quantile Panel type causality relationship between EU-Emission Trading Schemes and Core Inflation**

Table 4.4 shows the results between ETS and core inflation show unidirectional causality from core inflation to ETS at mid quantiles (0.4 to 0.7) with p-values ranging from 0.092 to 0.029, reflecting moderate but pervasive influence. The connection at 5–10% significance levels suggests that broad inflationary pressures, once volatile food and energy prices are stripped off, may affect expectations or policy response in the ETS. However, causality from ETS to core inflation does not hold in all quantiles, and this shows that carbon pricing instruments have weak direct impacts on core inflationary trends. The one-way relationship may be a sign of structural insulation of core inflation components (like services and manufactures) from direct carbon cost pass-through forces. These findings imply that even while underlying trends towards inflation could possibly influence ETS adjustments or price behaviors via responsiveness of policies the opposite being false endorses the assumption that ETS impacts are primarily limited to tradable and energy-intensive industries in comparison to the broad inflation basket.

**Table 7.** Quantile Panel-Type Causality Results (EU-Emission Trading Schemes and Core Inflation)

Null hypothesis	Quantile	Coefficient	P-value	Causality detected
EU-ETS $\neq$ CINF	0.1	0.013	0.388	No
	0.2	0.009	0.391	No
	0.3	0.004	0.645	No
	0.4	0.009	0.364	No
	0.5	0.012	0.238	No
	0.6	0.014	0.192	No
	0.7	0.011	0.364	No
	0.8	0.007	0.587	No
	0.9	0.0196	0.574	No
CINF $\neq$ EU-ETS	0.1	-0.068	0.371	No
	0.2	-0.023	0.802	No
	0.3	0.023	0.804	No
	0.4	0.190 <sup>c</sup>	0.092	Yes
	0.5	0.250 <sup>b</sup>	0.036	Yes
	0.6	0.246 <sup>b</sup>	0.035	Yes
	0.7	0.307 <sup>b</sup>	0.029	Yes
	0.8	0.028	0.872	No
	0.9	-0.116	0.493	No

Note: <sup>a</sup>, <sup>b</sup> and <sup>c</sup> denote statistical significance at 1%, 5% and 10 % respectively

#### **4.3.4 A Quantile Panel type causality relationship between EU-Emission Trading Schemes and Headline Inflation**

Table 4.5 indicate that the causality of EU ETS with headline inflation is evident with strong causality from ETS at different quantiles, particularly at 0.2 ( $p = 0.033$ ), 0.3 ( $p = 0.003$ ), 0.4 and 0.5 (both at  $\sim 10\%$  level), and 0.9 ( $p = 0.011$ ). This is suggestive of a non-linear but significant carbon price transmission to overall price level, particularly under mild to severe inflation conditions. The highest coefficient at the 0.9 quantile (0.051) confirms the inflationary amplification effect of ETS under conditions of high price increase. By contrast, headline inflation is also reversed causally highly significant from quantile 0.3 to 0.7, with all p-values less than 5% and coefficients significantly large (for example, 1.30 at 0.5 and 1.61 at 0.6), indicating a considerably more robust feedback of inflation toward carbon pricing. These results suggest that since aggregate inflation is accelerating, it can impact ETS through increased demand for emission permits, regulatory tightness, or investor attitude. Overall, a strong bidirectional and regime-dependent causality seems to be the reality, which indicates headline inflation and ETS co-evolve and potentially even are mutually reinforcing during inflationary periods.

**Table 8.** Quantile Panel-Type Causality Results (EU-Emission Trading Schemes and Headline Inflation)

Null hypothesis	Quantile	Coefficient	P-value	Causality detected
EU-ETS $\neq$ HINF	0.1	0.020	0.138	No
	0.2	0.029 <sup>b</sup>	0.033	Yes
	0.3	0.043 <sup>a</sup>	0.003	Yes
	0.4	0.029 <sup>c</sup>	0.054	Yes
	0.5	0.030 <sup>c</sup>	0.059	Yes
	0.6	0.017	0.273	No
	0.7	0.021	0.223	No
	0.8	0.026	0.144	No
	0.9	0.051 <sup>b</sup>	0.011	Yes
HINF $\neq$ EU-ETS	0.1	-0.459	0.195	No
	0.2	0.504	0.261	No
	0.3	0.831 <sup>b</sup>	0.031	Yes
	0.4	1.54 <sup>a</sup>	0.000	Yes
	0.5	1.30 <sup>a</sup>	0.000	Yes
	0.6	1.61 <sup>a</sup>	0.000	Yes
	0.7	1.46 <sup>a</sup>	0.003	Yes
	0.8	0.276	0.497	No
	0.9	-0.371	0.315	No

Note: <sup>a</sup>, <sup>b</sup> and <sup>c</sup> denote statistical significance at 1%, 5% and 10 % respectively

#### **4.3.5 A Quantile Panel type causality relationship between EU-Emission Trading Schemes and Producer Price Index**

Lastly, the Table 4.6, the causality from EU ETS to producer price index is particularly robust and linear across a wide quantile range (0.2 to 0.8), with coefficients increasing from 0.065 to 0.143 and significance levels from 1% to 10%. This consistent pattern validates the theoretical link between carbon pricing and upstream cost pressures in the production sector, especially as firms internalize carbon costs and pass them down the supply chain. At higher quantiles, the magnitude of this pass-through flattens (no causality at 0.9), possibly due to pricing stickiness or inflation transmission saturation. Reverse causality from PPI to EU-ETS also exhibits high and statistically significant correlation in the range of 0.2–0.7, with especially high coefficients and p-values at the 1% and 5% levels. These findings indicate two-way influence in that higher production costs potentially reflective of aggregate economic activity or inflationary expectations are fed back into ETS prices, possibly through anticipated emission levels or compliance costs. The two-way causality indicates that the ETS is not just an instrument of policy but a market signal embedded within macroeconomic systems, and that PPI is a significant medium for transmission and feedback.

**Table 9.** Quantile Panel-Type Causality Results (EU-Emission Trading Schemes and Producer Price Index)

Null hypothesis	Quantile	Coefficient	P-value	Causality detected
EU-ETS $\neq$ PPI	0.1	0.016	0.661	No
	0.2	0.065 <sup>c</sup>	0.043	Yes
	0.3	0.070 <sup>c</sup>	0.042	Yes
	0.4	0.128 <sup>a</sup>	0.001	Yes
	0.5	0.143 <sup>a</sup>	0.001	Yes
	0.6	0.123 <sup>a</sup>	0.004	Yes
	0.7	0.096 <sup>b</sup>	0.030	Yes
	0.8	0.100 <sup>b</sup>	0.015	Yes
	0.9	0.037	0.362	No
PPI $\neq$ EU-ETS	0.1	-0.160	0.504	No
	0.2	0.288 <sup>a</sup>	0.009	Yes
	0.3	0.350 <sup>a</sup>	0.001	Yes
	0.4	0.653 <sup>b</sup>	0.014	Yes
	0.5	0.695 <sup>a</sup>	0.006	Yes
	0.6	0.359 <sup>b</sup>	0.025	Yes
	0.7	0.432 <sup>b</sup>	0.049	Yes
	0.8	0.079	0.525	No
	0.9	-0.259	0.411	No

Note: <sup>a</sup>, <sup>b</sup> and <sup>c</sup> denote statistical significance at 1%, 5% and 10 % respectively

Overall, the Quantile Panel-Type Causality results exhibit intricate, quantile-dependent, and, in many cases, bidirectional causal relationships between the EU-ETS and several different measures of inflation. Energy and producer price index exhibit the highest amounts of bidirectional relationships with the EU-ETS, with policy-relevant carbon pricing-real economy cost structure feedback mechanisms. Food and headline inflation also exhibit high dynamics but more asymmetrically. Core inflation is least affected by EU-ETS movements, affirming its status as a more stable inflation measure less subject to short-term price shocks.

## CHAPTER 5

### 5. CONCLUSION

While market-based environmental measures such as carbon pricing have proven to be highly effective in reducing greenhouse gas emissions and accelerating the green transition, they do raise significant issues over their broader economic impacts (Olasehinde-Williams, 2024). From the outset, there have been theoretical and empirical debates highlighting the possible adverse impacts of these policies on key macroeconomic indicators, particularly inflation (Warwick et al., 2021). These concerns have in the past caused some prudence on the part of policymakers in fully adopting stringent carbon pricing tools such as the EU Emissions Trading System (EU ETS). This thesis contributes to this ongoing debate by empirically examining the differentiated inflationary effects of the EU ETS across sectors within the Eurozone using a quantile panel approach. By way of a systematic unraveling of the distributional impacts of carbon pricing across disaggregated inflation measures, the research offers advanced insights into the trade-offs involved and thus contributes to academic research and policy formulation.

This thesis has empirically tested the disaggregated inflationary effects of the European Union Emissions Trading System (EU-ETS) in the Eurozone through a quantile panel causality methodology. From a rigorous analysis of food, energy, core, headline, and producer price index indices of twenty Eurozone economies between 2005 to 2020, the study has shed significant light on heterogeneous and quantile-sensitive dynamics of environmental pricing mechanisms and their effects on inflationary processes. The results set that the EU-ETS, although it was designed to be a market-based climate policy instrument, has empirically observable causal relationships with many components of inflation most notably energy inflation and producer price index particularly at higher quantiles of inflation distribution. This brings out the asymmetrical inflationary pressures created by carbon pricing in periods of inflation peaks, consistent with earlier theoretical arguments over cost-push inflation in the context of environmental regulation (Kharroubi & Smets, 2024; Warwick, 2021).

One of the key contributions of this research is methodological. With a quantile panel Granger causality test, the analysis captures standard mean-based inference, catching up

on nonlinear, asymmetric, and distribution-sensitive effects more typical of economic transmission mechanisms under environmental regulation. The results indicate that carbon pricing in the EU-ETS is not inflation-neutral. Alternatively, it reveals sectoral inflationary pressures within energy-intensive production chains that are reflected in statistically significant causal links along both upstream (PPI) and downstream (HICP) dimensions. These results corroborate embryonic empirical work Nishigaki, (2023); Olasehinde-Williams, (2024c) that the inflationary effect of climate policy is conditional upon underlying macroeconomic regimes and sectoral composition.

In addition, the study presents new evidence regarding the inflation-environment nexus under the macroeconomic stability, monetary policy interaction, and income inequality contexts. Though food and core inflation appear to be less systematically impacted by the EU-ETS across the median quantiles, the distribution tails under high inflation especially register a resurgence of robust causality, suggesting periodic yet efficient transmission of regulatory costs to consumer prices. These are indications that the EU-ETS's inflationary footprint is contingent, not uniform, and therefore supportive of the need for finely tuned, context-specific climate policy interventions (Spyromitros, 2023; Warwick et al., 2021b). The thesis also confirms that environmental regulation tends to amplify distributive distortions and macroeconomic instability, particularly among low-income earners and energy-intensive firms, in the absence of viable compensatory or revenue recycling programs (Dao, 2023; Gaber Elbasheer Elhassan, 2020).

Therefore, the empirical evidence calls for a pragmatic integration of environmental and macroeconomic objectives. Policymakers must recognise the inflationary effects of carbon pricing, especially under supply-side slack and external shocks, and must come up with complementing fiscal policy measures for shielding adverse impacts. Tools such as differentiated subsidies, carbon dividends, or green investment rebates can balance short-run inflationary effects while maintaining long-run decarbonization objectives. In addition, the results highlight the significance of incorporating climate policy shocks into central banks' inflation forecast models and monetary policy instruments, particularly the European Central Bank. Finally, this research opens wide doors for future research, particularly the need to examine firm-level cost pass-through behavior, regional heterogeneity in inflation reactions, and interactions between emissions trading and other climate instruments in a multi-equilibrium framework. Macro-economic stability must

remain a co-equal objective to environmental sustainability in the steering of the green transition.

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