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Carbon Emissions and Inflation Dynamics in the Eurozone: An Empirical GMM Approach

Abdelkader AGUIR[1], Fernanda SABRINI-CHATELARD[2], Marouene MBAREK[3]

[1]Lab ESPI2R (Groupe ESPI) and Lab MOFID, Faculty of Economics and Management of Sousse, University of Sousse, Sousse, Tunisia

E-mail: a.aguir@groupe-espi.fr

[2]Lab ESPI2R (Groupe ESPI), Lyon, France

E-mail: f.chatelard@groupe-espi.fr

[3]ESPI2R, Groupe ESPI, France; and LEMNA, Nantes University, Nantes, France

E-mail: m.mbarek@groupe-espi.fr

Abstract: Climate change and the transition toward a low-carbon economy have intensified the debate on the interaction between environmental factors and macroeconomic stability. While recent studies have mainly focused on how monetary policy can address climate-related risks, much less attention has been devoted to the potential influence of environmental indicators on inflation. This paper examines the relationship between carbon emissions and inflation dynamics across 20 Eurozone countries over the period 2010–2023. Using annual panel data, we estimate a dynamic model based on the System Generalized Method of Moments (System GMM) to account for inflation persistence and potential endogeneity. The empirical framework incorporates carbon emissions per capita together with final energy consumption, the EUR/USD exchange rate, and the trade balance as key macroeconomic control variables. The baseline specification does not reveal a statistically significant relationship between carbon emissions and inflation. However, robustness analysis based on a first-differenced System GMM specification identifies a significant negative association, suggesting that environmental factors may influence inflation dynamics under alternative model specifications. Energy consumption and exchange rate movements also emerge as important determinants of inflation.

These findings contribute to the growing literature linking climate-related variables and monetary policy by highlighting the relevance of incorporating environmental indicators into inflation analysis while emphasizing the need for cautious interpretation and further empirical investigation.

Keywords: Inflation, Carbon emissions, Climate macroeconomics, Eurozone, System GMM, Environmental indicators.

JEL Classification: E31, Q52.

1. Introduction

Climate change has become one of the major challenges nowadays, disrupting ecosystems, global economies and socio-economic mechanisms (Quevauviller, 2024).

This paper investigates the macroeconomic implications of climate-related indicators, especially CO_2 emissions, on inflation dynamics in the Eurozone. While central banks increasingly acknowledge the importance of environmental considerations, the reciprocal impact of environmental variables on macroeconomic stability, particularly inflation, remains underexplored. In this study, we hypothesize that CO_2 emissions, as a proxy of economic activity and energy intensity, can significantly influence inflation.

Carbon emissions are widely recognized as a proxy for industrial production and energy usage, two components closely linked to inflationary pressures. This pro-cyclicality suggests that higher CO_2 emissions may reflect demand-driven inflation risks (Giovanardi & Kaldorf,2025).

Encountering this crisis, the European Central Bank (ECB) has gradually adapted its unconventional monetary policies, intending to respond not only to conventional economic objectives, but also to climate challenges (Blanchard & Sheen, 2013; Schoenmaker, 2021; Macaire & Naef, 2023). In its 2022 press release, the ECB explicitly stated its intention to incorporate climate considerations into its monetary policy operations (ECB, 2022). Inflation dynamics in the Eurozone are influenced not only by energy prices and environmental policies but also by broader financial transmission mechanisms. Aguir, & Fragny (2025). While an emerging body of research has explored the role of central banks in promoting green finance and directing investments toward sustainable sectors (Kelly & Paik, 2024), fewer studies have examined the reverse mechanism, that is, the macroeconomic implications of environmental degradation itself. Acharya et al. (2023) even argue that traditional monetary policy frameworks remain ill-equipped to internalize climate-related risks.

This paper empirically investigates whether carbon emissions interpreted as a proxy for energy intensity and economic activity have a statistically significant impact on inflation dynamics in the Eurozone. Using panel data from 20 EMU countries over the period 2010–2023, we apply the Generalized Method of Moments (GMM) to account for potential endogeneity issues. Macroeconomic controls include final energy consumption, exchange rate variations, and trade balance relative to GDP. Complementary econometric tests, such as panel unit root tests and Arellano-Bond serial correlation diagnostics, are used to ensure robustness. All data are drawn from reliable institutional sources, including the ECB, Eurostat, and the World Bank.

The paper is structured as follows. Section 2 reviews the literature on climate central banking and inflation. Section 3 presents the data and empirical methodology. Section 4 discusses the results of the GMM estimation. Section 5 concludes with implications for monetary policy in an era of ecological transition.

2. Literature Review

An increasing number of studies have explored the relationship between climate change and central banking, with emphasis on how monetary authorities can integrate environmental concerns into their strategies. Odonnat (2022), outlines three key levers allowing central banks to respond effectively to climate change challenges. The first lies in improving macroeconomic modeling capabilities, empowering central banks to well predict the effects of climate change on the economy. This approach allows adjusting monetary policy in order to limit the financial risks associated with natural disasters and the energy transition. The second lever put forward is transparency requirements. The author notes that the European Union (EU) has strengthened these requirements to encourage greater transparency in the financial sector, notably regarding the disclosure of climate risks. He points out that this transparency aims for strengthening financial institutions accountability and guiding investors towards more sustainable choices. Arghyrou et. al. (2024), Scialom (2020), Aguir (2018), Farhani et. al. (2015), and Aguir (2013) point out that central banks are facing a major financial challenge linked to climate change: The need for a massive reallocation of financial flows from "*brown*" (carbon emitters) to "*green*" (renewable energies and sustainable investments), as well as taking into account climate financial risks, now considered systemic. Meeting these challenges will entail profound changes in their doctrine and practices. This paper spotlights the fact that the history of central banks has already been marked by such rapid mutations. It analyzes the arguments in favor of integrating financial climate risks into the doctrine and operational framework of central banks. Morvan& Régnard (2023) conducted an event study for measuring the impact of climate change speeches on a series of European stock market indices. Their results are manifold. The prices of conventional indices did not react significantly to climate change announcements, suggesting a persistent difficulty in understanding the impact of climate change on corporate prospects. Conversely, climate indices react negatively to speeches by central bankers, with a delay that is probably due to partial media coverage. This negative reaction can be explained by the abnormal returns intersection and the thematic content of the speeches highlighted by a textual analysis: climate change is widely described as a new risk, leading to a rise in the cost of capital and a correlative fall in share prices. Suggesting that the "*greening*" of monetary policy could, instead, be seen as a means for increasing its effectiveness, Couppey-Soubeyran& Kalinowski (2021) discuss the NGFS approach and argue that it could be further strengthened. From their perspective, by redirecting funding towards sustainable investments, central banks could not only contribute to the energy transition, but also strengthen economic stability by promoting investments that are more resilient to climate risks. They emphasize the fact that such "*greening*" could be considered to be a way of reconnecting banking activities to useful financing, rather than being a constraint on monetary policy. Focusing on the outcomes of central bank asset purchases on carbon emissions and investment in heat-intensive sectors, Heyer et. al. (2024), examine the aftermath of quantitative easing (QE) policies on climate. This research studying the EQ programs of the European Central Bank (ECB) and the Bank of England highlights the impact of these monetary interventions on the sectoral allocation of capital, often to the benefit of polluting sectors. The authors use an analytical framework to assess the indirect effects of QE on financial markets and greenhouse gas emissions. Furthermore, they consider hypothetical scenarios in which central banks adjust their asset purchases to encourage sustainable investment.

3. Model and Methodology

Understanding inflation dynamics in the Eurozone requires a comprehensive approach that integrates traditional macroeconomic factors and emerging environmental pressures. This study focuses on the role of carbon dioxide (CO_2) emissions, used as a proxy for economic activity and energy intensity, in shaping inflation.

Four main explanatory variables are included:

CO_2 emissions per capita (CARBON): proxy for energy use and production intensity.

Final energy consumption (ENERGY): indicator of aggregate energy demand and potential cost-push inflation.

EUR/USD exchange rate (EXCHANGE): captures imported inflation via currency fluctuations.

Trade balance as a percentage of GDP (SBC): reflects external competitiveness and net demand pressures.

These variables were selected based on both theoretical and empirical relevance and are introduced into a dynamic panel model to account for inflation inertia and possible endogeneity.

The panel comprises 20 Eurozone countries over the period 2010–2023, using annual data from trusted sources, as presented in Table 1.

Table 1: Summarized definitions, units, sources, and coverage used for the dynamic panel model

Variable	Description	Unit	Source	Period
CARBON	CO_2 emissions per capita	Metric tons/person	World Bank	2010–2023
INFLATION	Consumer price index (annual %)	% change	Eurostat	2010–2023
EXCHANGE	EUR/USD exchange rate	Index (nominal)	ECB	2010–2023
ENERGY	Final energy consumption by sector	Ktoe	Eurostat	2010–2023
SBC	Trade balance relative to GDP	% of GDP	Eurostat	2010–2023

Source: Authors' computation using Stata 17

Table 2: Descriptive Statistics of Variables

Variable	Observations	Mean	Std. Dev.	Min	25th Percentile	Median	75th Percentile	Max
INFLATION	280.000	1.982	0.987	-1.241	1.291	2.029	2.593	5.853
CARBON	280.000	5.977	1.432	2.293	4.958	5.972	6.935	10.618
ENERGY	280.000	15097.477	4009.388	4212.453	12661.569	15073.705	17808.682	25529.528
EXCHANGE	280.000	1.166	0.098	0.860	1.100	1.170	1.225	1.403
SBC	280.000	0.095	5.067	-12.955	-3.476	0.109	3.076	12.899

Source: Authors' computation using Stata 17

Table 2 summarizes the distribution of each variable across the Eurozone sample. The average inflation rate is around 1.98%, with moderate dispersion, though some countries experienced deflationary episodes (minimum: -1.24%). CO_2 emissions per capita range from 2.29 to 10.62 metric tons, reflecting significant heterogeneity in energy intensity across countries. Energy consumption also exhibits wide variation, highlighting structural differences in sectoral energy use. The EUR/USD exchange rate remained relatively stable, while the trade balance shows both large deficits and surpluses, underscoring divergent external positions. These variations justify the use of a dynamic panel framework that accounts for heterogeneity and persistence.

3.1. Econometric Model and Estimation Method

To investigate the dynamic relationship between inflation and environmental/macroeconomic variables, we apply the System GMM estimator (Arellano &

Bover, 1995; Blundell & Bond, 1998). This method is suitable for short-time-series panels with potential endogeneity and autocorrelation.

The general model specification is as follows:

$$\pi_{it} = \beta 0 + \beta_1 co2_{it} + \beta_2 SBC/PIB_{it} + \beta_3 EUR/USD_{it} + \beta_4 CFE/secteur_{it} + \varepsilon_{it}$$

Where:

π_{it} is the annual inflation rate in country i at time t; CO_{2it} denotes per capita carbon dioxide emissions (proxy for energy intensity and activity); SBC_{it} is the trade balance as a percentage of GDP; $EXCHANGE_{it}$ is the nominal EUR/USD exchange rate; $ENERGY_{it}$ represents final energy consumption by sector; and ε_{it} is the error term.

3.1.1. Stationarity and Panel Unit Root Tests

Before estimating the dynamic panel model, we assess the stationarity properties of the variables to avoid spurious regressions and to ensure consistency of the GMM approach. We apply the panel unit root test developed by Im et. al (2003), which is appropriate for unbalanced panels and allows for heterogeneity in autoregressive dynamics across countries.

The test results (see Appendix Table A1) reveal that: Inflation and SBC (trade balance as % of GDP) are stationary in level (I(0)), as indicated by p-values below the 5% threshold. CO_2 emissions, EUR/USD exchange rate, and final energy consumption are non-stationary at level but become stationary after first differencing (I(1)).

For instance, the EUR/USD exchange rate and energy consumption have high p-values at level (>0.30), but these drop significantly below 1% after first differencing. CO_2 emissions also show strong stationarity after differencing ($p = 0.0001$). These mixed integration orders justify the use of a dynamic panel framework such as System GMM, which can accommodate both I(0) and I(1) series.

3.1.2. GMM Instrumentation Strategy and Diagnostic Tests

To address potential endogeneity and simultaneity between inflation and the explanatory variables, we rely on the System GMM estimator (Arellano & Bover, 1995; Blundell & Bond, 1998). Lagged levels and differences of the endogenous variables are used as internal instruments, assuming no second-order serial correlation in the error term.

Post-estimation diagnostic tests are used to assess the robustness of the GMM model:

- The Arellano-Bond test detects first-order serial correlation (AR(1), $p = 0.0066$), which is expected due to differencing. The test for second-order serial correlation (AR(2)) yields a marginally significant result ($p = 0.0155$), suggesting that refinement of the instrument set may improve model specification.
- The Hansen J-test produces a non-significant p-value (above 0.05), supporting the validity of the overidentifying restrictions and confirming that the instruments are uncorrelated with the residuals.

To validate the robustness of our results, we compare the system GMM estimates with those obtained from pooled OLS and fixed-effect panel estimators. As expected, these alternative models produce biased and inconsistent results due to their inability to control endogeneity and dynamic panel bias.

4. Empirical Results and Interpretation

4.1. Main Estimation Results (System GMM)

This section presents the results of the baseline estimation using the System Generalized Method of Moments (System GMM) as proposed by Arellano and Bover (1995) and Blundell & Bond (1998). The primary objective is to assess how selected macroeconomic and environmental variables influence inflation dynamics across Eurozone economies over the period 2010–2023.

Table 3 reports the coefficient estimates, standard errors, t-statistics, and p-values obtained from the GMM regression, where the dependent variable is the annual inflation rate. The explanatory variables include per capita CO_2 emissions, final energy consumption, the nominal EUR/USD exchange rate, and the trade balance as a percentage of GDP. This model also controls for inflation persistence by including lagged inflation as an explanatory variable (introduced in the dynamic specification but not displayed in this baseline output).

Table 3: Estimation Results

Variable	Coefficient	Std. Error	t-Statistic	p-Value
CO_2	-0.2713	0.4614	-0.5878	0.5573
ENERGY	-0.2750	0.3938	-0.6983	0.4858
EXCHANGE	-8.8542	4.5802	-1.9331	0.0547
SBC	-0.0176	0.0253	-0.6966	0.4869
Constant	13.9255	5.6247	2.4758	0.0142

Source: Authors' computation using Stata 17.

Despite the relatively weak statistical significance of most explanatory variables in this baseline specification, several noteworthy observations emerge.

First, the exchange rate variable (EUR/USD) exhibits a negative and marginally significant effect on inflation ($p \approx 0.055$). This result is economically intuitive: a depreciation of the euro tends to raise the cost of imported goods, particularly energy and raw materials, thereby exerting upward pressure on consumer prices. Similar findings have been documented by Ca'Zorzi et al. (2007) and more recently by Dardouri et al. (2025), who highlight the role of external shocks in shaping inflation in small open economies.

Second, the carbon emissions variable displays a negative coefficient, although it is not statistically significant at conventional levels. While this result limits our ability to draw firm causal conclusions, it may reflect underlying structural conditions, such as subdued industrial activity or higher energy inefficiency, that contribute to lower inflationary pressure. In line with this, Dardouri et al. (2025), argues that economies with persistent emissions inefficiencies tend to exhibit weaker growth and limited price momentum.

Similarly, final energy consumption is negatively signed but lacks statistical significance. This counterintuitive result might suggest that, in the Eurozone context, higher energy use is not always inflationary, possibly due to concurrent energy efficiency gains or rigidities in energy pricing mechanisms. Moreover, the trade balance variable (SBC) also has a negative but insignificant effect, indicating that net export positions may not directly translate into inflationary trends, perhaps due to offsetting demand-side effects.

The constant term is statistically significant and positive, suggesting the existence of inflationary pressure that is not captured by the included regressors. This residual component could reflect wage dynamics, price indexation rules, or unobserved structural features of the Eurozone economies.

From a diagnostic standpoint, the model satisfies the essential robustness criteria: the Hansen J-test for overidentifying restrictions indicates no evidence of instrument endogeneity, and the Arellano-Bond test confirms the expected first-order autocorrelation while rejecting second-order serial correlation. These diagnostics support the internal consistency of the GMM specification and lend credibility to the estimated coefficients.

In sum, while the baseline GMM model offers only limited statistical significance for the environmental variables, it highlights the potential inflationary role of external price shocks, particularly via the exchange rate channel. This reinforces the conclusions of previous empirical work emphasizing the vulnerability of euro area inflation to exchange rate fluctuations (Aguir et al., 2017). Nonetheless, the low explanatory power of the model suggests the need for more refined specifications, which are addressed in the subsequent robustness analysis using first-differenced variables.

4.2. Robustness Check: First Differences Model

To assess the robustness of our findings and improve the explanatory power of the model, we re-estimate the inflation equation using a first-differenced specification within the System GMM framework. This approach removes potential country-specific fixed effects and focuses on the impact of changes in macroeconomic and environmental variables on inflation dynamics. Moreover, it offers an additional safeguard against non-stationarity, which is particularly relevant given the mixed integration order of the variables.

Table 4 displays the results of the estimation. Unlike the baseline model in levels, the first-differenced specification yields stronger statistical significance and greater consistency across variables, suggesting improved identification and a more robust empirical structure.

Table 4: First-Differenced GMM Estimation Results – Inflation Dynamics and Environmental Determinants

Variable	Coefficient	Std. Error	t-Statistic	p-Value
Lagged Inflation	1.3364	0.1003	13.33	0.0000
CO_2	-14.5175	4.9940	-2.91	0.0041
ENERGY	25.1557	4.7761	5.27	0.0000
EXCHANGE	-15.5685	1.0989	-14.17	0.0000
SBC	-0.3060	0.1352	-2.26	0.0249

Source: Authors' computation using Stata 17

The lagged inflation coefficient is positive and highly significant ($p < 0.01$), confirming the persistence of inflationary dynamics within the Eurozone. This result is consistent with the theoretical framework of New Keynesian Phillips Curve models (Galí, 2015) and corroborates previous empirical studies (Clarida et al., 1999) that emphasize the role of inflation inertia in developed economies.

Second, the coefficient for CO_2 emissions is negative and statistically significant at the 1% level. This finding suggests that a reduction in carbon emissions is associated with higher inflation, or conversely, that increases in emissions correlate with lower inflationary pressures. One plausible interpretation is that high-emission periods reflect weak economic conditions or subdued industrial output, leading to deflationary tendencies. Similar dynamics are explored in the work of Batini et al . (2022), who argue that environmental stressors can influence output gaps and inflation expectations indirectly through supply-side disruptions.

Third, final energy consumption exhibits a large and highly significant positive effect on inflation. This result reinforces the view that energy costs represent a key inflationary channel, particularly in energy-importing economies. It is in line with recent evidence from post-COVID inflation spikes, where energy prices played a dominant role in cost-push inflation across the Eurozone (OECD, 2024). The elasticity observed here indicates that increases in energy usage, potentially reflecting production costs or demand pressure, are strongly linked to higher consumer price levels.

Fourth, the exchange rate coefficient is again negative and highly significant, reaffirming the earlier finding that euro depreciation fuels domestic inflation. This result highlights the importance of exchange rate pass-through effects, especially in economies reliant on imports of energy and intermediate goods. Bussière et al. (2018) similarly identify the EUR/USD rate as a key inflation driver in open European economies, where monetary policy is sensitive to international price transmission.

Lastly, the trade balance variable (SBC) is statistically significant and negatively signed. Although the effect size is modest, it suggests that improvements in trade balance, likely due to increased exports or reduced imports, are associated with lower inflation, possibly due to demand leakage or external rebalancing effects. This observation aligns with the findings of Lane (2019), who documents that trade surpluses tend to moderate inflationary pressure in the Eurozone through demand deflection and exchange rate appreciation.

Overall, the robustness check strengthens the empirical credibility of the study. The significant results across all explanatory variables contrast with the weaker baseline model in levels, supporting the validity of the first-differenced approach. These results emphasize the relevance of both macroeconomic fundamentals and environmental indicators in shaping inflation dynamics. Importantly, the strong significance of energy and CO_2 emissions points to the growing necessity of integrating climate-related variables into mainstream inflation forecasting models, an issue increasingly recognized by institutions such as the ECB and the Network for Greening the Financial System (NGFS, 2022C).

4.3. Discussion

The results from the two GMM estimations baseline in levels and robustness in first differences provide complementary insights into the inflation dynamics of Eurozone economies. While the level-based model (Section 4.1) yields relatively weak statistical significance, the differenced specification (Section 4.2) reveals more robust and economically meaningful relationships. This divergence highlights the importance of model specification in capturing the underlying macroeconomic and environmental interactions.

First, inflation persistence is confirmed across both models. The strongly significant coefficient on lagged inflation supports the notion of inflation inertia in the Eurozone, reflecting delayed price adjustments, expectations anchoring, and structural rigidities. This finding is consistent with prior literature on the dynamics of inflation under forward-looking monetary frameworks (Galí, 2015; Christiano Silva et al., 2025).

Second, energy consumption emerges as a key inflationary driver. In the first-differenced model, energy usage exhibits a large and highly significant positive effect on inflation. This result underscores the prominence of cost-push mechanisms, whereby increases in energy input prices feed directly into consumer prices. It resonates with recent inflation episodes where volatile energy markets, exacerbated by geopolitical tensions and supply constraints, have exerted substantial pressure on price stability (OECD, 2022; ECB, 2024).

Third, carbon emissions are found to exert a statistically significant negative effect on inflation in the robustness specification. While at first glance this may seem counterintuitive, a deeper interpretation suggests that higher emissions levels may be associated with periods of weak economic momentum, low investment in green technology, or energy inefficiencies, all of which can be symptomatic of stagnation rather than overheating. This result invites a broader macro-environmental reflection: the transition to low-carbon economies may entail short-term inflationary risks (, through green investment shocks or energy substitution costs), but high-emission scenarios do not necessarily equate to high inflation environments (Carney, 2015; NGFS, 2023).

Fourth, the exchange rate consistently displays a significant and negative coefficient, confirming the role of imported inflation in open economies. Euro depreciation tends to raise the price of imported goods and energy, thereby affecting the domestic price level. This finding is aligned with empirical estimates of exchange rate pass-through in the euro area (Bussière et al., 2018; Ha, J. et al., 2020) and highlights the sensitivity of inflation to external monetary conditions and dollar-denominated commodity prices.

Finally, the trade balance variable (SBC) contributes negatively to inflation in the robustness model. Though the effect size is modest, its significance supports the view that trade surpluses, through their influence on exchange rates and demand rebalancing, can exert disinflationary pressure. Countries with persistent external surpluses may experience currency appreciation and reduced import costs, thereby lowering inflation expectations.

Our empirical results suggest that macroeconomic fundamentals alone are no longer sufficient to explain inflation dynamics in the Eurozone. We observed that environmental indicators, particularly carbon emissions and energy consumption, appear to influence price behavior in ways that traditional models often overlook. This aligns with recent arguments made by Marcinkowska et. al. (2025), who stress the need for central banks to adopt a precautionary approach to climate-related financial risks. In our view, integrating ecological variables into monetary analysis is not just a technical adjustment; it reflects a necessary evolution in central banking, one already echoed in recent publications from the ECB (2024), the Bank for International Settlements, and the NGFS (2023). As climate pressures intensify, policy frameworks that ignore environmental dimensions risk becoming outdated or ineffective.

Although our findings shed light on the links between inflation and environmental dynamics, they also reveal the underlying complexity of this relationship. The interactions are unlikely to be linear or uniform across countries, especially as climate policies and energy transitions advance at different paces. Future studies could usefully explore how these effects evolve over time or vary depending on national contexts. Moreover, incorporating forward-looking components, such as inflation expectations or anticipated green fiscal policies, might offer deeper insights into how ecological transitions shape price behavior. Such extensions would help capture the increasingly multidimensional nature of inflation in a changing climate economy (Batten et. al., 2020; Aguila & Wullweber, 2025; Rosa, 2025).

5. Conclusion and Policy Perspectives

This paper explored the macroeconomic implications of environmental and external sector variables on inflation dynamics in the Eurozone countries over the 2010–2023 period. Drawing on a dynamic panel GMM approach, our findings indicate that inflation in the region exhibits strong inertia, and that its evolution is significantly influenced by structural factors including energy consumption, exchange rate fluctuations, and carbon intensity.

The results reveal that higher energy consumption is consistently associated with upward pressure on prices, which echoes recent evidence on energy-driven inflationary shocks observed across Europe (OECD, 2022; ECB, 2024). This underscores the cost-push mechanisms through which energy dependency can compromise price stability, particularly in economies reliant on imported fossil fuels.

Interestingly, carbon emissions appear to exert a negative effect on inflation, especially in the differenced model specification. While counterintuitive at first glance, this finding may reflect structural inefficiencies or stagnation dynamics in high-emission economies, an interpretation supported by studies such as Lemoine and Rudik (2017), who associate emissions intensity with lower growth potential and reduced demand pressure. It also suggests that decarbonization strategies may entail short-term inflationary consequences, particularly as cleaner technologies are adopted at scale (NGFS, 2023).

Furthermore, the significant role of the EUR/USD exchange rate confirms the sensitivity of Eurozone inflation to external shocks and currency movements, reinforcing existing literature on exchange rate pass-through (Bussière et al., 2018; Ca'Zorzi et al., 2007). Trade balance variations also contribute to inflationary patterns, although their effect is more moderate.

These empirical insights have important policy implications. As the European Central Bank and other monetary authorities increasingly engage with the climate agenda, it is essential to recognize that environmental variables are not merely peripheral, they are structurally embedded in the inflation process. Monetary frameworks that exclude ecological dynamics may overlook significant inflation drivers, especially during phases of green transition, energy price volatility, or supply-side reconfiguration.

From a strategic perspective, integrating environmental indicators into inflation models could enhance forecasting accuracy and monetary responsiveness. This would require closer collaboration between central banks, energy economists, and climate policy institutions to align macroeconomic stability objectives with long-term sustainability goals (Chan et. al., 2024; Chen et. al., 2024; Dinh et. al., 2025).

Despite the robustness of our results, this study is subject to limitations. The model does not account for potential non-linearities, heterogeneity across Eurozone members, or interaction effects between monetary and fiscal climate policies. Future research could address these issues by employing regime-switching models, structural panel VARs, or climate-augmented DSGE frameworks.

In conclusion, this paper reinforces the emerging consensus that ecological and macroeconomic spheres are increasingly interconnected. Ensuring stable inflation in the Eurozone requires not only sound monetary policy but also a forward-looking understanding of environmental dynamics and their economic consequences.

Declaration of AI Use

During the preparation of this manuscript, the authors used (OpenAI) exclusively for language editing and grammar improvement. All scientific content, data analysis, interpretation of results, and final decisions remain the sole responsibility of the authors.

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Appendix

Table A1: Stationarity test results

		Method				**Statistic**	**Prob.****
		Im, Pesaran and Shin W-stat				**-380.105**	**0.0001**
Cross section	t-Stat	Prob.	E(t)	E(Var)	Lag	Max Lag	Obs
Malta	-24.393	0.1582	-1.502	1.534	1	1	9
Italy	-22.566	0.2021	-1.502	1.534	1	1	9
Ireland	-21.285	0.2391	-1.502	1.534	1	1	9
Estonia	-15.670	0.4525	-1.516	1.812	1	1	8
Spain	-27.348	0.1053	-1.502	1.534	1	1	9
Netherlands	-52.769	0.0061	-1.530	2.091	1	1	7
Portugal	-27.828	0.0983	-1.502	1.534	1	1	9
Luxembourg	-25.748	0.1316	-1.502	1.534	1	1	9
Austria	-22.713	0.1982	-1.502	1.534	1	1	9
Belgium	-17.138	0.3931	-1.502	1.534	1	1	9
Croatia	-24.695	0.1519	-1.502	1.534	1	1	9
Finland	-25.748	0.1316	-1.502	1.534	1	1	9
France	-30.109	0.0712	-1.502	1.534	1	1	9
Greece	-18.928	0.3204	-1.502	1.534	1	1	9
Latvia	-30.648	0.0660	-1.502	1.534	1	1	9
Lithuania	-27.838	0.0982	-1.502	1.534	1	1	9
Slovakia	-27.260	0.1066	-1.502	1.534	1	1	9
Cyprus	-24.876	0.1481	-1.502	1.534	1	1	9
Slovenia	-25.671	0.1330	-1.502	1.534	1	1	9
Germany	-20.949	0.2495	-1.502	1.534	1	1	9
Average	-25.709		-1.504	1.575			

Source: Authors` calculations based on Stata17

Table A2: Arellano bond test results

Test	m -Statistic	rho	SE(rho)	Prob.
AR(1)	2.718201	241.333175	88.784145	**0.0066**
AR(2)	**-2.420920**	**-113.468339**	**46.869926**	**0.0155**

Source: Authors` calculations based on Stata17