A SMOOTH TRANSITION REGRESSION MODEL APPLICATION TO US TARIFF EXPOSURE-DRIVEN CHANGES IN IPI WITHIN THE EU FRAMEWORK

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1. Introduction

A growing body of literature has been studying the effect of tariffs and the populist rise in protectionist policies in developed economies as an effective measure is boosting localized domestic GDP while reducing the competitiveness of foreign goods[1]. In this project we look at the effect of tariff announcements, and implementation in the USA under Trump presidency and examine their comparative effect on European markets. The average tariffs rate on all imports between 2024 and 2025 in the US was circa to 1.8%, since the second presidency of President Trump this has risen to 11.8% (Statista Research Department, 2025). The European Union hasn't been exempted from these hikes in Tariff Rates as it currently is paying an additional 15% ad-valorem tariff rate on US imports (Atlantic Council, 2025). The European Union is a current global mass exporter total exports being valued at \$2.08 trillion dollars, of which circa to 21% (\$ 571bn) (Trading Economics, 2025) is exported to the US this creates a high level of exposure to US tariffs implementations on European markets since exporters face higher costs and reduced demand, directly lowering output and profits in affected industries. This propagates through input, output linkages: intermediate goods producers, logistics, and suppliers also see weaker orders, depressing industrial production across countries. This exposure to Global Market instability as a direct link to US Tariffs coincides with or main research question being, "How do changes in U.S. tariffs and trade pressure affect European industrial production; and how do these responses differ between low- and high-exposure EU countries?"

The debate surrounding the resurgence of trade protectionism, particularly through tariff measures, has intensified in the aftermath of the U.S. - China trade tensions and the broader populist backlash against globalization. Proponents of tariff-based protection argue that import restrictions can safeguard domestic industries, preserve employment, and stimulate local investment in the short term. However, a growing body of empirical evidence highlights significant adverse spillovers beyond the targeted economies, especially for highly integrated trade partners such as the European Union. Studies such as Amiti, Redding and Weinstein (2019) and Flaaen and Pierce (2020) have shown that U.S. tariffs often raise production costs for domestic firms and disrupt global supply chains, amplifying downstream effects across exporting economies. For Europe, where production networks are deeply intertwined with transatlantic trade, tariff shocks may translate into nonlinear and asymmetric economic responses, ranging from temporary slowdowns in industrial output to heightened financial volatility and exchange-rate misalignments. Moreover, these effects can vary markedly across countries depending on their exposure to U.S. markets, sectoral specialization, and macroeconomic resilience. This heterogeneity motivates the need for non-linear empirical frameworks, such as Panel Smooth Transition Regressions (PSTR), which allow the sensitivity of European economies to U.S. trade shocks to evolve gradually across regimes of low and high exposure. The analysis not only contributes to understanding how tariff shocks propagate through the European economic structure but also informs the broader policy debate on the limits of strategic autonomy and the design of coordinated EU responses to external protectionist pressures.

This project employs monthly data in a panel framework covering the 27 European Union member states spanning between 2020 and 2025 (ongoing), with the end goal of being able to analyse the transmission of US trade policy shocks to the European economy and financial markets. We attempt to capture this effect by looking

[1] The average applied tariff rate across all products entering the EU stood at only 1.33 % in 2022. However, within the EU's external-border regime, the Common Customs Tariff (CCT) applies a single, harmonised tariff schedule to all Member States, with specific duty rates varying by product category and exp country.

at how a countries production capacity is affected from tariff exposure. To proxy for real economic activity, we use the aggregated Industrial Production Index (IPI) for sector, as proposed by Eurostat. We model the non-linear adjustment of these variables to U.S trade policy utilizing a Panel Smooth Transition Regression framework, whereby letting the transition variable (i.e. the regime) be the U.S. bilateral imports and exports with each European country. We decided to use this variable due to its ability to capture the characteristics of trade linages and therefore allow us to model the exposure of US tariffs and trade policy shifts, such that through letting the estimated coefficients to vary smoothly, the model will identify distinctive regimes correspond to periods of low and high Trade Openness allowing us to garner a richer understanding of the non-linear propagation of trade shocks. We isolate trade specific channels from broader macro-financial factors by employing country specific controls being GDP (million USD), Harmonised Index of Consumer Prices HICP, and the unemployment.

Methodically, we construct a comprehensive monthly panel data which compromises the EU27 economies over a testable period of 2024-2025, we integrate multiple dimensions of economic activity to isolate the propagation of U.S trade shocks through real. The intensity of trade pressure is measured through a country-specific tariff exposure index, derived from the interaction between US tariff changes and each country's export structure to the United States. The empirical framework which we employ is based on the Panel Smooth Transition Regressions (PSTR) model, following Teräsvirta (2004), in order to account for non-linear and regime dependent effects of trade policy shocks. The transition variable, defined as Trade openness (ratio of the cumulative imports and exports divided by GDP) captures the varying sensitivity of European economies across different degrees of trade integration. Overall, this approach allows us to trace the nonlinear transmission of U.S. tariff shocks across European economies, shedding light on the asymmetric vulnerabilities of EU member states to external protectionist pressures and offering new insights into how shifts in U.S. trade policy reverberate through European industrial production[2].

2. Literature Review

Empirical studies on the macroeconomic impact of tariff shocks have significantly grown in the last ten years, especially after the U.S.–China trade conflicts and increased transatlantic tensions. Initial research by Amiti, Redding, and Weinstein (2019) indicates that the U.S. tariff increases enacted from 2018 to 2019 resulted in notable rises in import expenses and consumer prices, implying that protectionism acts more as a tax on local producers and consumers rather than a catalyst for growth. Fajgelbaum et al. (2020) expand this framework by analyzing the worldwide reorganization of trade flows, discovering that European exporters experienced significant reductions in market shares and terms of trade after U.S. tariff actions. Within the European framework, Berthou, Gaulier, and Stumpner (2021) of the Banque de France analyse how global tariff shocks spread across the European value chain, demonstrating that smaller open economies (predominantly in Central and Eastern Europe) experience a greater impact due to intermediate-input connections. From a financial perspective, Caldara et al. (2020) and Bussière et al. (2021) demonstrate that shocks related to tariff uncertainty lead to significant drops in equity prices and industrial output, particularly in economies that rely heavily on U.S. demand. Methodologically, the growing use of non-linear panel models, such as the Panel Smooth Transition Regression (PSTR) framework developed by González, Teräsvirta, and van Dijk (2005), has enabled researchers to discover regime-dependent relationships between trade shocks and macroeconomic results. Recent studies in Europe, including those by Colletaz and Hurlin (2011) and Kapuściński et al. (2022), indicate that smooth transition effects provide a more profound understanding of how openness, competitiveness, and external demand factors impact economic adaptation to global shocks. This body of work highlights the need for flexible, non-linear modelling approaches to assess the differing effects of U.S. tariff shocks on European economies according to their degrees of trade integration and exposure.

[2] The composite IPI is derived from the NACE Rev. 2 classification, where section B covers Mining and Quarrying, while Section C encompasses Manufacturing, ranging from food production and textiles to machinery, transport equipment (Eurostat).

3. Data Manipulation

In order to test the effect of U.S. trade pressure and its propagation on real activity, we build a multi-country panel for European Union economies. We look at country-level monthly data (dependent on each series) spanning from the early 1990s to 2025 and then reduce this down to focus specifically on the 2024–2025 period, during which global macroeconomic conditions were affected by the hike in protectionist policy implementation under Donald J. Trump. We focus on a whole at Euro 27 countries (EU27)[3], hence omitting other large European US trade partners, such as the United Kingdom, to ensure a more Eurocentric analysis. Descriptive Statistics for all the EU27 economies are illustrated in table 1 in the Appendix. All data sources and transformations are harmonized to the monthly frequency required by the Panel Smooth Transition Regression (PSTR) framework. The main sources of data are EUROSTAT, Federal Reserve Economic Data (FRED), World Bank, Yahoo Finance, and DBNomics.

3.1 Dependent Variables

The Industrial Production Index (IPI) is implemented as our primary indicator of real economic activity for the study relevant European economies. The IPI is a measure of the volume output, which is produced by the industrial sector, encompassing mining (Sector B) manufacturing (Sector C), and electricity and gas supply (Sector D), as highlighted in the NACE Rev.2; Statistical Classification of Economic Activities, Eurostat. (2008, July 10). The IPI provides a high frequency and time encompassing proxy for real output dynamics, which reflect the respective cyclical fluctuations of each country in production and industrial capitalisation. IPI monthly data is retrieved from EUROSTAT and spans a period from 1996 and 2025. The utility of the monthly data being that it aids in identifying short-term responses to trade shocks and tariff adjustments, as it captures within year variations that quarterly GDP measures may obscure. All series are non-seasonally adjusted and expressed in index form to ensure cross country comparability, albeit additional adjustments were required to clean the data from seasonal distortions in production patterns.

Figure 1 in the appendix depicts the over-time evolution of the IPI index for a select number of countries, as representative of certain regions, this graph highlights the observable and subsequently substantial heterogeneity in industrial performance across countries over time. While core economies such as Germany and France exhibit relatively stable long-term growth with pronounced cyclical fluctuations, peripheral economies like Greece and Hungary display greater volatility and more pronounced downturns during major crises, such as the 2008-2009 financial collapse and the 2020 COVID-19 shock. Seasonality is also evident when we look at across series, with observable inter-annual oscillations which are due to the production cycles. This underscores the persistence of cross-country divergence in industrial activity and supports the need for a flexible, non-linear modelling framework like the PSTR to capture the regime-dependent dynamics.

In the context of the Panel Smooth Transition Regression (PSTR) framework, the IPI provides a consistent and sensitive measure of real activity that can capture heterogeneous and nonlinear responses of European industrial output to shifts in U.S. trade policy intensity. By focusing on industrial production, the analysis isolates the most directly exposed sector to tariff measures and external demand shocks, offering insight into the real economic transmission channel of trade policy uncertainty.

3.2 Explanatory Variable

The explanatory variable of our study is intended to proxy for a measure which shows country level Tariff shock exposure. We construct a country level tariff shock index that captures the time varying exposure of European economies to changes in US import tariffs during the time period of circa January 2020 and October 2025. We intend to create an aggregated measure for each country and month; US tariffs are weighted by the total product share in the respective country's total exports to the US. This design reflects directly the intensity and direction of trade shocks stemming from US tariff policy, specifically those enacted under the Chapter 99 of Harmonized Tariff Schedule (HTSUS). This, furthermore, adds justification for our chosen's testing time index as it was the main bulk of successive tariff schedule updates.

[3] Austria, Belgium, Bulgaria, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Lativa, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden.

All tariff information comes from the US International Trade Commission (USITC) revision documents (rev series). Each revision includes detailed information about the HTSUS in PDF and CSV formats. Chapter 99 of the HTSUS, which deals with temporary changes to duties, and is broken into subchapters (I, II, III, IV, etc.), which cover different types of tariffs. Each subchapter has numbered provisions like 9901.xx, 9902.xx, 9903.xx, and so on. Retaliatory and reciprocal tariffs are mostly found in Subchapter III and Subchapter IV, respectively. Each provision includes a description of the tariff, when it started, and sometimes a reference to a U.S. Note that explains which products are affected. All tariff measures are applied at the HTS 6-digit level[4]. We collect all provisions in Chapter 99 that either mention specific products or refer to a U.S. Note. If a provision doesn't list HTS codes directly, we look at the U.S. Note in the PDF version of the revision to find which codes are affected. The final dataset connects each Chapter 99 provision to a list of affected HTS products, the tariff rate, and the time period it was in effect. Bilateral export data is obtained from UN Comtrade at the HS 6-digit level. These data cover monthly exports from each EU member state (and other WTO countries where applicable) to the United States from 2020 to 2025. The trade data is matched with the HTS6 codes extracted from Chapter 99 to ensure the same level of product detail.

When it came to quantifying the Exposure of each respective EU member state we (as mentioned before) to construct the tariff shock index using a weighted aggregation approach. This is detailed below:

Let p denote the HTS product, while i the exporting country, and t the month. Trivially, for each p, the tariff rate at time t is $\tau_{p,t}$ and then, the monthly change is subsequently given by:

$$\Delta\tau_{p,t} = \tau_{p,t} - \tau_{p,t-1}$$

Furthermore, we calculate a baseline fixed (pre-shock) average of exports between 2024 and 2025 illustrated below:

$$\overline{S_{i,p}} = \frac{1}{\{T_0\}} \sum_{t \in T_0} \frac{Exports_{i,p,t}}{\sum_p Exports_{i,p,t}}$$

We then interact the change in tariff rate and lagged export share to give us our final Exposure regressor shown below:

$$Exposure_{i,t} = \sum\nolimits_p \overline{S_{i,p}} \Delta\tau_{p,t}$$

This measure aggregates product-level tariff changes according to each country's exposure, thereby capturing the intensity of U.S. tariff actions on that country's export basket. The use of lagged export shares mitigates simultaneity bias by ensuring that the weight structure is predetermined relative to the tariff change. In table 3 we document the summary statistics of each countries respective tariff exposure for 2024 and 2025, important side note, there are some countries which for 2024 have missing values as a result of data scarcity.

3.3 Control Variable

In order to effectively isolate the effects of US trade pressures, as a result of a populist rise in protectionism in the forms of tariffs, from macroeconomics dynamics, with our PSTR model we choose to incorporate the following three variables, the Harmonized Consumer Prices Index (HICP), the Unemployment Rate (UR), and lastly the Gross Domestic Product (GDP), but on a quarterly basis and expressed in millions of USD. We chose these variables specifically to account for the unobservable internal macroeconomic environment of each European country; we will aid us in being able to disentangle external trade effect from domestic cyclical conditions.

HICP

All the data was sourced from EuroSTAT, as partially mentioned before, the HCIP measures the changes in consumer prices across the EU member states on a comparable basis, we transform the HICP to be controlling for the year-on-year rate of change in the HICP shown below:

[4] The HTS 6-digit level is the globally standardized part of the Harmonized System that identifies product categories in international trade; countries then add more digits for national tariff details.

$$RCH_{i,t} = \left(\frac{HICP_{i,t}}{HICP_{i,t-12}} - 1\right) \times 100$$

Where $RCH_{i,t}$ denotes the annual percentage change in prices for a country *i* and a time *t*. This transformation allows us to express the inflation as a monthly series over 12 months as the cumulative rate of change, allowing us to remain consistent over Eurostat definitions. Since controlling for inflation is essential due to the price dynamics having a direct effect on both the real economic activity and financial market expectations. During times of high inflation purchasing power and profit margin can be eroded and this in turn could amplify the trade related cost shocks which we are trying to estimate. On the other hand, period of low inflation can mitigate the real observable burden of tariffs. As shown in Table 2, average inflation rates remain low and stable in advanced economies such as Germany (2.24%), France (4.26%) compared to more emerging EU economies such as Bulgaria (4.28%) and Estonia (4.26%), subsequently this reflects the prevalence of structural price asymmetries. Including this measure in the Model allows our proposed PSTR framework to capture these heterogenous price dynamics and control for domestic inflationary pressures that might otherwise bias the estimated responses to US trade shocks. Figure 2 depicts the annual variation of the Harmonised Index of Consumer Prices (HICP) among chosen EU member states from 1998 to 2025, emphasizing the cyclical characteristics of inflation and notable differences in price movements between countries. Inflation remained mostly controlled between 0-4% for numerous economies until the COVID-19 pandemic, following which a rapid and extensive rise occurred during 2021-2023, driven by global supply chain challenges and variations in energy prices. Hungary experienced a remarkable increase exceeding 25%, indicating strong domestic pass-through effects and monetary rigidities, whereas larger Euro Area economies such as France and Germany exhibited more moderate rises that correspond with their improved policy credibility and stable inflation forecasts. In comparison, Greece exhibits persistently lower and more variable inflation throughout the sample, reflecting its cyclical susceptibility and reduced demand pressures. The alignment of inflation rates after 2024 indicates a return to normalcy after the European Central Bank's cycle of tightening. In summary, the figure highlights the necessity of adjusting for inflation in the empirical model, since domestic price movements directly influence the actual effects of trade and tariff shocks within the PSTR framework.

UR

The UR , defined as the percentage of the labour force actively seeking work (EUROSTAT, 2025). and we are using as a proxy variable for domestic economic slack. A high level of unemployment typically signals weaker internal demand and reduced resilience to external shocks. When we look at the descriptive statistics highlight in table 2 we can see that the unemployment rate exhibits substantial cross-country heterogeneity, with huge variation internationally between the EU states with countries like Germany sat at 4.46% while Greece and Spain having an unemployment rate ≈ 15%. These disparities show an underlying structural differentiation between nations labour markets and highlight heightened exposure to sector specific shocks. By including the unemployment rate as a control, the model accounts for the extent to which domestic labour conditions modulate the transmission of US trade shocks into production and financial activity. Figure 3 displays the monthly unemployment rate (% of the labour force) for specific EU member countries from 1998 to 2025. The series show significant variability between countries and cyclical responsiveness to major economic declines like the 2008–2009 global financial crisis and the Eurozone sovereign debt crisis, where unemployment rates in Greece and Spain exceeded 25%, highlighting severe labour market inflexibilities and structural disparities. In comparison, Germany sustained consistently low unemployment (approximately 4–5%) because of its solid industrial competitiveness and effective institutional structures. France and the Euro Area average display moderate unemployment trends, ranging between 8–10%, whereas smaller economies like Finland and Hungary reveal intermediate patterns with more significant cyclical fluctuations. The post-2020 timeframe reflects a brief increase after the pandemic impact, succeeded by a slow alignment as the recovery began.

These inequalities highlight the structural fragmentation of European labour markets, where variations in wage-setting practices, workforce mobility, and industry composition influence domestic adaptability. Incorporating unemployment as a control variable in the empirical model enables the PSTR framework to reflect these particular demand conditions of each country. Elevated unemployment rates typically indicate diminished internal demand and reduced ability to withstand external shocks, suggesting that economies with significant labour market slack may face intensified real impacts of U.S. tariff shocks on industrial output and production.

GDP

National GDP, expressed in millions of U.S. dollars and sourced from Eurostat, captures each country's economic scale and production capacity. It provides a measure of overall economic resilience and diversification, which influence the ability to absorb external disturbances. As reported in Table 2, larger economies such as Germany (mean GDP ≈ 328,109 million USD) and France (222,030 million USD) exhibit markedly greater output capacity compared to smaller economies like Cyprus (1,991 million USD) or Estonia (2,059 million USD). Such disparities imply that the impact of trade policy shocks is likely asymmetric larger, diversified economies may smooth out fluctuations, whereas smaller or more open economies face sharper adjustments.

Figure 4 illustrates the changes in quarterly GDP (in millions of USD) for chosen EU member countries from 1998 to 2025. The trajectories reveal significant variations in economic size and growth patterns across countries. The Euro Area total, indicated by the bold purple stripe, shows consistent long-term growth with two significant declines: the global financial crisis of 2008–2009 and the sovereign debt crisis from 2011 to 2013, each resulting in short-lived reductions in output. Germany and France stand out among individual economies due to their consistently high GDP levels, showcasing their varied industrial foundations and key positions in the EU's economic framework. Conversely, smaller economies like Hungary, Finland, and especially Greece show much lower absolute output levels and higher cyclical sensitivity, which is clear during recoveries following crises. These differences highlight how the scale and variety of economies influence their ability to withstand external shocks—larger, more varied economies can more effectively manage trade and policy disruptions, while smaller or less diverse economies generally experience greater adjustment challenges. Incorporating GDP as a control variable captures fundamental capacity differences and guarantees that changes in industrial production and financial responses aren't simply indicative of domestic output levels. Combined with the HICP and unemployment controls, GDP finalizes the macroeconomic conditioning set of the PSTR model, improving its capacity to identify the actual nonlinear effect of U.S. trade shocks on European economies

Overall, the inclusion of HICP, unemployment, and GDP as control variables allows the model to account for fundamental domestic macroeconomic differences that could otherwise bias the estimated nonlinear effects of U.S. trade policy shocks. Controlling for these factors strengthens the internal validity of the PSTR framework and ensures that the estimated responses of industrial production, financial performance, and exchange rates primarily reflect external trade dynamics rather than domestic cyclical forces.

3.4 Transition Variables

Our first transition variables, for our PSTR framework, is the country specific trade openness, this is computed as the ratio of bilateral trade (exports + imports) between the US and the EU27 countries, and the EU resilience index which we sourced from Eurostat. Formally, for each country *i* and month *t*:

$$\text{US Trade Openness} = \frac{\text{Exports}_{i,t}^{US} + \text{Imports}_{i,t}^{US}}{\text{GDP}_{i,t}} \times 100$$

Where, $\text{Exports}_{i,t}^{US}$ and $\text{Imports}_{i,t}^{US}$ are the monthly bilateral trade flows (USD) between the US and EU27 country i, where $\text{GDP}_{i,t}$ is the corresponding countries GDP. This percentage measure is directly interpretable as the share of monthly output accounted for by bilateral trade with the U.S. It captures the intensity of transatlantic integration and, within the PSTR framework, indexes the trade-exposure regime under which elasticities of industrial production, financial performance, and exchange rates vary. Scaling by 100 only rescales $g_{i,t}$; in a logistic PSTR, such affine rescaling is absorbed by the estimated threshold(s) and slope parameter(s), leaving qualitative regime behavior unchanged while improving interpretability. We compute $g_{i,t}$ separately for each country to allow heterogeneous linkages and dynamics.

Our second transition function was used to capture the degree of European market integration influences the transmission of external trade shocks, we construct an indicator which we denote as EU resilience Index which measures the country's relative integration within the EU internal market, serving as a proxy for its capacity to withstand shocks originating from outside the Union. The index is derived as follows:

$$R_{i,t} = \frac{X_{i,t}^{EU}}{X_t^{EU,Total}}$$

The ratio captures how central a country is within the European trade network. A higher value of $R_{i,t}$ indicates that a larger proportion of a countries export activity is directed toward other EU members, which in turn implies that there is a stronger integration into the internal market. Intuitively, this would make increase the ability for countries to absorb internal shocks making them more resilient to disturbances to trade, Conversely, countries with smaller intra-EU shares rely more heavily on extra-EU trade and are consequently more exposed to external volatility. Within the Panel Smooth Transition Regression (PSTR) framework, the previous value of this index, $R_{i,t}$, functions as the transitional variable that regulates the seamless movement between various economic systems. The theoretical basis for using the EU Resilience Index as a transition function lies in the idea that the effect of U.S. tariffs on European markets is highly contingent upon the level of internal solidarity and trade interdependence among EU members. When resilience is diminished, European economies function in a more fragile state, where external shocks have greater adverse impacts on industrial production and financial results. As resilience grows, these impacts slowly diminish, illustrating the protective function of intra-EU trade connections. The descriptive statistics are shown in figure 4, Panel A: The data show considerable heterogeneity in U.S. trade openness across EU countries, with small open economies exhibiting higher average trade-to-GDP ratios. Temporal variation is limited, suggesting stable trade exposure patterns over the 2021–2025 period. And Panel B: The EU Resilience Index values are small but consistent across time, reflecting each country's proportional contribution to total intra-EU exports. The low standard deviations indicate that relative positions in the EU internal trade network remain fairly stable over the sample window. Prior to estimation, both transition variables are standardized (demeaned and divided by their within-country standard deviation) to ensure numerical stability of the logistic function.

4. Model Specification

We study whether the effects of global/macro controls on European outcomes vary non-linearly with the intensity of US trade exposure. We are going to follow strongly the model and specification detailed by Teräsvirta, 2004. and adapt it slightly in order to account for our study specifications. The proposed regression that we are intending to run is detailed below:

$$y_{it} = \mu_i + \lambda_t + \alpha_0 Exposure_{i,t} + \alpha_1 Exposure_{i,t-1} + \boldsymbol{\delta_0' z_{it}} + \left[\beta_0 Exposure_{i,t} + \beta_1 Exposure_{i,t-1}\right] g(q_{it};\, \gamma, c) + u_{it}$$

Where:

- y_{it} : dependent variable
- $Exposure_{it}$: main regressor which is capturing the change in tariff pressure
- z_{it}: vector of control variables (GDP, HICP, Unemployment etc)
- $g(q_{it};\, \gamma, c)$: logistic transition function
- μ_i: Country fixed effect
- λ_t: time fixed effects
- u_{it}: error term

The Logistic transition function $g(q_{i,t-1};\, \gamma, c)$ being:

$$g(q_{i,t-1};\, \gamma, c) = \frac{1}{1 + \exp\left(-\gamma(q_{i,t-1} - c)\right)}$$

Where:

- q_{it-1}: is the transition variable standardized lagged Openness ($Openness_{i,t-1}$) and also the lagged EU resilience
- γ: smoothness parameter, higher values imply sharper transitions
- C : location parameter determining the range of import exposure where the slope of the tariffs index changes the most.

The specification detailed above allows us to interpret it such that: for the distinct two trade exposure regimes (being low and high): low sensitivity of European outcomes to U.S. tariffs is apparent when ($q_{i,t-1} < c_1$), while strong trade linkages (where tariffs have the greatest effect) are observed when ($q_{i,t-1} > c_1$), denoting the prevalence of high exposure. In this case, the coefficients evolve smoothly between these two regimes as the transition variable crosses the single threshold. We then estimate two separate PSTR models, each with one transition variable ((1) U.S. Trade Openness and (2) EU Resilience Index) to assess distinct regime-dependent responses.

5. Methodology

5.1 Baseline two-way fixed effect regressions (TWFER)

The justification behind implementing the baseline TWFER before moving to the non-linear specification whereby we would then estimate the OLS was because we wanted to test initially whether the US tariff exposure has a statistically significant short-run effect on European economic outcomes, centred around our three explanatory variables, once we control for the country specific and time specific factors the baseline regressions results isolate the within country variation over time, filtering out unobserved heterogeneity and common shocks. Establishing significant relationships in this linear framework solidifies the foundation of our testing as it gives us a point of comparison for later models that allow for nonlinear or regime dependent dynamics. The model we used is specified below:

$$y_{i,t} = \alpha Exposure_{i,t} + \beta Exposure_{i,t-1} + \boldsymbol{\delta}'\boldsymbol{X_{i,t}} + \mu_i + \lambda_t + \varepsilon_{i,t}$$

Where:

- $y_{i,t}$ is the dependent variable (1st difference, IPI)
- $\boldsymbol{X_{i,t}}$ is the vector containing the control variables
- μ_i are the country fixed effects
- λ_t are the monthly fixed effects

We created the baseline (as partly mentioned before) to estimate the two key coefficients being the contemporaneous effects of tariff exposure in the same month (α) and the lagged effect (β) which capture the delayed responses from the previous months. The sum of the two coefficients trivially being the total short-run effect of US trade shocks on each country's output or financial performance. If significant values are observed post regression, then it allows us to conclude that shifts in US trade policy transmit meaningfully to European economies with a short horizon.

5.2 Linear heterogeneity by trade openness regression

Post establishment of the baseline regression using the fixed-effect OLS model, we deemed it necessary to test for linear heterogeneity in the response to US tariff exposure across countries exhibiting different levels of US specific trade Openness. The aim of this step was to investigate if economies that are more closely integrated into the US market (thus less resilient to external disruptions) react differently to changes in U.S. trade policy than those that are less integrated. We introduced interaction terms between tariff exposure and the Openness Index, enabling the marginal effects of exposure to fluctuate according to each country's level of intra-EU integration instead of presuming a consistent reaction across all European economies. This method offers an initial step in capturing the variation in trade shock transmission across countries within a linear framework. Identifying considerable heterogeneous effects at this stage is a crucial prerequisite to the complete nonlinear PSTR model, as it reinforces that EU resilience is genuinely a significant state variable influencing the transmission of U.S. trade shocks The model we used is specified below:

$$\begin{aligned} y_{i,t} = {} & \alpha_0 Exposure_{i,t} + \alpha_1 Exposure_{i,t-1} + \beta_0\left(Exposure_{i,t} \times \mathrm{Openness}_{i,t-1}\right) \\ & + \beta_1\left(Exposure_{i,t-1} \times Openness_{i,t-1}\right) + \phi Openness_{i,t-1} + \boldsymbol{\delta}'\boldsymbol{X_{i,t}} + \mu_i + \lambda_t + \varepsilon_{i,t} \end{aligned}$$

Where $\mathrm{Openness}_{i,t-1}$ represents the lagged value of the U.S.-specific trade openness index, computed as the ratio of bilateral trade (exports + imports) between the U.S. and each EU27 country to national GDP. The estimation setup remains identical to the baseline specification, employing the same two-way fixed effects (TWFE) structure with country-clustered standard errors. In this context, α_0 and α_1 capture the baseline average effects of tariff exposure when trade openness is at its minimum, while β_0 and β_1 measure the marginal change in the exposure effect as trade openness increases, whereby:

$$\frac{\partial y_{i,t}}{\partial Exposure_{i,t}} = \alpha_0 + \beta_0\left(Openness_{i,t-1}\right) \; and \; \frac{\partial y_{i,t}}{\partial Exposure_{i,t-1}} = \alpha_1 + \beta_1\left(Openness_{i,t-1}\right)$$

When adding the two together it would give us the cumulative marginal effect evaluated at low, median, and high openness levels. This step also serves as a preliminary test for nonlinearity, as the significance of β_0 and β_1 would suggest state-dependence with respect to $\left(Openness_{i,t-1}\right)$ motivating the PSTR estimation.

5.3 PSTR model with smooth transition by trade openness both regional and resilience

Using the same model as outline the Model and Specification section we allow the effect We now allow the effect of tariff exposure to vary smoothly with the level of trade openness. Instead of assuming a linear interaction, we introduce a logistic transition function that captures gradual changes in the impact of exposure as openness increases. We then calculate the marginal effects of exposure by looking at the state-dependent partial derivatives:

$$\frac{\partial y_{i,t}}{\partial Exposure_{i,t}} = \alpha_0 + \beta_0 g(q_{it};\, \gamma, c) \; and \; \frac{\partial y_{i,t}}{\partial Exposure_{i,t-1}} = \alpha_1 + \beta_1 g\left(q_{i,t-1};\, \gamma, c\right)$$

Whereby the short run effect is captured as:

$$\frac{\partial y_{i,t}}{\partial Exposure_{i,t}} + \frac{\partial y_{i,t}}{\partial Exposure_{i,t-1}} = (\alpha_0 + \alpha_1) + (\beta_0 + \beta_1) g(q_{it};\, \gamma, c)$$

The interpretation of the coefficients being α_0 and α_1 are simply the baseline exposure effects when openness is low (G≈0), while β_0 and β_1 are simply the incremental effect as openness rises (G→1). With large γ approaches a sharp threshold and with small γ indicating a smoother transition.

Important Side notes – the variable q_{it} changes, as we test the PSTR twice but with different transition variables.

6. Model Pre-Test

6.1 LM-type tests for evidence of smooth transition effects

Prior to estimating our PSTR model, we perform the necessary LM-type linearity tests to assess whether a nonlinear smooth transition stricture is truly appropriate. We decided to implement the Teräsvirta test (González et al., 2005; Teräsvirta, 1994). These tests are designed to examine the null hypothesis pf linearity H_0 (model is linear (no transition) against H_1 (the model follows a smooth transition (STR or PSTR)). The test consists of initially estimating a linear model linking the IPI to the main regression being the exposure and post augmenting it with squared and cubic potential transition variables z (like the EU resilience). Evidence of significant nonlinear terms indicates that the effect of Exposure on industrial production varies smoothly with z, justifying the adoption of a PSTR framework. We run this test for all of our transition variables, and the results are detailed below.

6.1.1 LM-type tests for evidence of smooth transition effects

Table 5 displays the outcomes of the Teräsvirta LM tests conducted at the country level. Throughout all three panels, a significant number of European economies dismiss the null hypothesis of linearity at standard significance levels (1%, 5%, 10%). In Panel A (EU Trade Openness), significant evidence of nonlinearity is observed for nations like Germany (p = 0.003), Italy (0.001), Portugal (0.004), Latvia (0.006), Croatia (0.002), and Finland (0.014), among others. Panel B (EU Partner Index) and Panel C (EU Partner Index Lag 1) validate these findings and uncover further occurrences of notable nonlinearity, including for Ireland (0.033) and Slovakia (0.023). Although not all nations exhibit rejection, the widespread and persistent occurrence of substantial LM statistics suggests that linear fixed-effects models would be inadequate in capturing the real adjustment dynamics throughout a large part of the sample.

Aside from merely statistically dismissing linearity, these results possess robust economic rationale. Tariff shocks generally affect real activity via supply-chain connections, cost transmission, and expectation mechanisms that function progressively rather than suddenly. Consequently, the response of industrial production to U.S. trade pressures is expected to happen gradually rather than in sudden shifts, influenced by the degree of trade integration and resilience. The logistic transition mechanism g(q_it; γ,c) inherent to the PSTR model offers a versatile and theoretically sound method to depict this gradual regime dependence.

The variation evident among countries and transition variables further strengthens the argument for a seamless transition framework. For example, although Germany, Italy, and Portugal demonstrate considerable nonlinearity in both openness and resilience metrics, nations such as Slovakia and Ireland show significance solely for the lagged EU Partner Index, indicating that the timing of trade connections influences the shock transmission.

This trend of asynchronous, nation-specific regime development exemplifies the dynamic heterogeneity that the PSTR model aims to represent—permitting the slope coefficients regarding tariff exposure to change steadily with the transition variable, all while preserving a consistent panel framework featuring country and time fixed effects.

Methodologically, the LM findings support advancing with PSTR estimation utilizing two different transition variables—(i) U.S. Trade Openness and (ii) the EU Partner Index—evaluated both at the same time and with one-period lags. Given the more robust evidence for the lagged variable in Panel C, we choose q_(i,t-1) as the favored specification. Before estimation, each transition variable is normalized within the country (centered and scaled by its standard deviation) to enhance numerical stability and the clarity of the smoothness parameter.

In general, the LM-type linearity tests offer strong empirical evidence for the existence of state-dependent and nonlinear connections between U.S. tariff exposure and European industrial output. These findings suggest that a standard two-way fixed-effects model is incorrectly specified for numerous countries, and that the PSTR method—permitting coefficients to vary gradually across trade openness or integration regimes—more effectively captures the intricate transmission of external trade shocks within the European context. The PSTR model provides a more detailed and accurate representation of how U.S. trade policy influences the diverse framework of the European economy by allowing smooth transitions between low- and high-exposure regimes.

6.2 Fisher-type unit-root tests(stationarity, assumption that must be valid to ensure correct and non-biased results in PSTR

We also implement ,prior to PSTR testing, Fisher type unit root tests inorder to verify stationarity in the variables that we use for the regressions. . To this end, we implement Fisher-type panel unit-root tests based on the Augmented Dickey-Fuller (ADF) procedure, which is particularly flexible and suitable for unbalanced panels such as ours. The utility of this test is such that is examines the null H_0 (all panels contain a unit root (non-stationary) and the alternative being H_1(at least one panel is stationary). The results are detailed below.

6.2.1 Results transforms and ommitances

The Industrial Production Index (IPI), functioning as the dependent variable in our PSTR model, shows distinct signs of non-stationarity in its levels across most EU member nations. The Fisher-type ADF findings suggest that in most countries, the null hypothesis of a unit root remains unchallenged, except for a few cases like Denmark, Sweden, and Poland displaying slight stationarity. This pattern aligns with the behavior of industrial output figures, which usually exhibit significant persistence owing to cyclical production patterns and enduring sectoral dynamics. To maintain the reliability of our estimates and prevent misleading spurious regression-driven conclusions, we subsequently converted the IPI into its first difference (ΔIPI). This modification enables the model to capture temporary variations in industrial activity while maintaining the dynamic characteristics necessary for reliable PSTR estimation.

The $Exposure_{i,t}$, indicating each country's trade exposure related to tariffs, shows inconsistent evidence of stationarity among EU member states based on the Fisher-type ADF findings. In many instances, the null hypothesis of a unit root cannot be dismissed, suggesting that exposure levels typically adhere to continuous trends over time. Nevertheless, several nations (particularly Belgium, Bulgaria, Hungary, Malta, and Slovakia) which display statistically significant ADF statistics, indicating stationarity in their exposure metrics. This diversity illustrates structural variations in trade patterns and the differing responsiveness of national economies to tariff changes. Since most panels are non-stationary, the variable was analysed in first differences during robustness checks to verify that the estimated connections within the PSTR framework are not influenced by shared stochastic trends. This approach permits the examination to centre on short-term fluctuations in trade exposure, which align more closely with the cyclical adjustment processes represented by the nonlinear model.

Finally, as a measure of robustness we ran the ADF style tests on the control variables of our model GDP (million USD), Unemployment rate (% of labour force), and HICP (annual % change). The results reveal heterogenous degrees of persistence cross the three indicators. The GDP series consistently failed to reject the null hypothesis of a unit root in all panels , with very high p values indicating strong non-stationaryarity This most likely due to the intrinsic trending behaviour of GDP, which captures the long-term economic growth and structural changes. Subsequently we decided to omit this control due to the limited number of observations available for meaningful transformation or detrending, GDP was excluded from the final PSTR specification to preserve the validity of the model and avoid spurious relationships. The unemployment rate on the other hand, showed more heterogenous results. With several countries (Austria, Belgium, Bulgaria, Denmark, Finland, the

Netherlands, and Lithuania) showing significant ADF stats, suggesting stationarity in levels, yet other centralised in southern Europe (Greece, Spain, Italy, Romania). This is most likely due to the structural labour market differences and the persistence of unemployment post macro shocks. In contrast, the HICP series demonstrate stationarity for most member states, aligning with its role as a short-term measure of price stability standardized throughout the EU. The limited non-stationary instances (particularly aggregated indices like EU27_2020 and EU28) probably stem from cross-country averaging effects instead of true persistence in inflation dynamics.

These results indicate that although HICP and, to a degree, Unemployment can be reliably included in the model as levels, the widespread non-stationarity of GDP justified its exclusion. Keeping only stationary control variables guarantees that the PSTR estimations are econometrically valid and capture short- to medium-term adjustments instead of long-term structural trends. Results of the ADF style tests can be found in figure 6.

6.3 Long-run Cointegration

Given the evidence of non-stationarity in several key variables, we initially intended to perform panel cointegration tests to verify the existence of long-run equilibrium relationships among industrial production, tariff exposure, and macroeconomic controls. However, due to the short sample period (November 2024 – August 2025) and the limited time dimension of the panel, reliable cointegration estimation was not feasible, as the data do not capture sufficient long-run variation to identify stable equilibrium dynamics.

7. Results

7.1 Baseline two-way fixed effect regressions (TWFER) results – IPI

The baseline fixed-effects regressions provide several indications that the relationship between U.S. tariff exposure and European industrial performance may be nonlinear and regime-dependent, thus motivating the application of a PSTR model in the subsequent analysis.

Initially, while the coefficient for lagged tariff exposure is negative and statistically significant (at the 1% level with a robust clustered standard error), the immediate effect is minimal and lacks significance. This time-related imbalance indicates that the effects of U.S. trade shocks develop slowly, possibly due to adjustment difficulties, production delays, or varying levels of impact across sectors. In these situations, a basic linear model might not adequately represent the dynamic response mechanism reliant on the size or duration of the shocks. The importance of the lagged term in comparison to the contemporaneous term thus reinforces the idea of delayed transmission, which aligns with threshold or smooth transition mechanisms. Notably, the magnitude of the lagged coefficient suggests that a one-unit increase in exposure from the previous month is associated with approximately a 1.94 percentage point decline in year-over-year industrial production growth, holding other factors constant, which could accumulate meaningfully over multiple periods in a volatile trade environment.

Secondly, the F-statistic for the combined significance of regressors (robust $F = 3.29$, $p = 0.012$) suggests that the variables included together account for a significant part of the variation within countries. Nevertheless, the low within R^2 (–0.011) combined with the high F-test for pool ability in previous specifications emphasizes significant heterogeneity among countries and over time. This diversity suggests that the slope coefficients are probably not stable throughout the panel, highlighting the necessity for a model that accommodates parameter changes based on an observable transition variable exactly why the PSTR framework is used. The negative within R-squared, while not uncommon in fixed-effects models where entity and time effects absorb substantial variation, underscores that the explanatory power of the regressors is modest after accounting for these fixed effects, potentially due to omitted variables or nonlinearities.

Thirdly, the duration of testing (Nov 2024 – Aug 2025) is quite brief, encompassing a phase of heightened volatility and swift policy changes in global trade and macroeconomic situations. Due to this narrow timeframe, traditional linear models might overlook the intricacy of the fundamental processes, since small sample sizes can increase noise and obscure nonlinear reactions. The short-run perspective also restricts the visible response to immediate trade policy shocks, which may account for the weak current relevance. In contrast, the PSTR model allows state-dependent reactions and is more effective at determining if the impact of tariff exposure strengthens after surpassing a certain threshold or during particular macroeconomic scenarios (e.g., low demand, elevated inflation). With 26 countries and exactly 10 monthly observations per country (yielding a balanced panel of 260 observations), the analysis captures a focused post-tariff-shock period, but the limited time span may amplify the influence of idiosyncratic monthly fluctuations, further supporting the need for regime-switching approaches.

Finally, the insignificance of domestic control variables (HICP, unemployment) does not necessarily imply that internal conditions are irrelevant; rather, it may indicate that their influence interacts with external shocks in a nonlinear way. Countries facing tighter labour markets or stronger inflation pressures could react differently to trade disruptions compared to those with slack capacity or subdued prices. This type of conditional interaction is naturally captured in the PSTR setting, where marginal effects vary continuously with the chosen transition variable. The positive but insignificant coefficient on lagged HICP (3.031) hints at potential inflationary pressures boosting industrial activity in the short term, perhaps through demand channels, though this lacks statistical support here and could vary by regime.

7.2 Linear heterogeneity, interaction regressions with US specific trade Openness results

The enhanced linear model, which includes interactions between U.S. tariff exposure and trade openness, offers an initial evaluation of cross-country differences in how trade shocks are transmitted. The estimated coefficients for the interaction terms, while not statistically significant at standard levels, show economically relevant signs indicating that increased U.S.-specific openness might slightly reduce the immediate effect of tariff exposure while moderately enhancing the delayed response. The interaction term in question ($\beta_0 = -0.41$, $p=0.229$) indicates that in economies that are more open, the direct impact of tariff exposure on industrial output tends to be reduced, likely due to quicker adjustments via trade diversification or inventory management though the positive main coefficient on contemporaneous exposure (1.218, $p=0.420$) suggests an unexpected direction at low openness levels, potentially reflecting extrapolation outside the data range or unmodeled factors. On the other hand, the positive coefficient for the lagged interaction ($\beta_1 = +0.26$, $p=0.594$) may suggest a postponed effect of external shocks via production cycles or trade agreements, making the lagged impact less severe in more open economies.

From a theoretical standpoint, standard open-economy macro models (e.g., Obstfeld and Rogoff, 1996) predict that countries with higher trade integration face amplified transmission of external demand shocks due to expenditure-switching effects and input-output linkages. However, in the presence of short-run nominal rigidities and inventory adjustment (as in Alessandria et al., 2010), more open economies can temporarily mute contemporaneous output responses by drawing down stocks or redirecting exports consistent with the negative contemporaneous interaction. The delayed amplification (less negative lagged effect in open economies) aligns with global value chain propagation i.e. firms in highly integrated economies rely on just-in-time imports, so tariff-induced cost shocks disrupt production only after inventories are depleted or contracts reset, typically with a 1–3-month lag. Despite the short sample (10 months), this staggered response is plausible given monthly industrial data and the rapid rollout of Trump-era tariffs post-2024.

The robust F-statistic (4.307, $p=0.0002$) confirms the joint significance of the regressors under clustered errors, despite the standard F being insignificant (1.420, $p=0.199$), highlighting the importance of accounting for country-level clustering in this panel. Nevertheless, the near-zero within R-squared (-0.0004) indicates limited additional explanatory power from the interactions and controls after fixed effects, similar to the baseline model, while the significant pool ability F-test (3.407, $p=0.000$) reaffirms cross-country heterogeneity.

Assessing the overall marginal effects across various openness levels shows a generally stable negative association between tariff exposure and output growth, with the effects varying from −2.0 at low openness to −2.3 at high openness. While these estimates lack precision, with standard errors often exceeding the absolute values (e.g., cumulative SE of 2.190 at low openness vs. 1.267 at high), the consistent trend indicates that more open economies do not seem shielded from U.S. trade policy shocks, they might face somewhat greater total declines in industrial production after tariff hikes. This result supports the theory that heightened U.S. integration raises susceptibility to external disturbances, particularly through “second-round effects” in downstream industries (Bems et al., 2014). The notable negative coefficient on openness indicates a structural connection between a heavy reliance on U.S. trade and diminished industrial performance throughout the sample period, with this standalone effect being statistically significant ($p=0.022$) and suggesting that a 1-unit higher openness is linked to about a 1.16 percentage point lower IPI growth, all else equal consistent with “trade-induced resource reallocation” toward less productive export sectors during a shock (Melitz and Redding, 2015). Domestic controls like lagged HICP and unemployment remain insignificant, consistent with the baseline, implying their roles may be secondary or interactive in ways not captured linearly. In summary, these findings provide initial evidence of state dependence in the transmission of U.S. tariff shocks, reinforcing the move towards a nonlinear PSTR framework to formally account for threshold effects in trade openness.

7.3 PSTR model with smooth transition by trade openness both regional US trade Openness and also EU resilience

US trade Openness

The Panel Smooth Transition Regression (PSTR) model enables the influence of U.S. tariff exposure on European industrial output to change gradually based on the degree of each country's trade openness with the United States. By incorporating a logistic transition function, the model accounts for possible nonlinearities in how tariff shocks influence various economies, such as whether nations with greater openness face more intense or postponed effects after crossing a specific threshold.

The nonlinear least squares estimation produces a smoothness parameter ($\hat{\gamma} = 11.43$) and a threshold ($\hat{c} = -0.11$ in original openness units), indicating a very sharp transition at effectively zero bilateral openness. This implies that economies with any meaningful trade linkage to the U.S. operate in a high-exposure regime, while only near-autarkic countries (rare in the EU sample) would fall into the alternative state. Given that $G(z) \approx 1$ across nearly all observed openness levels, the high-openness regime dominates the sample.

The robust F-statistic (2.54, $p = 0.021$) affirms joint significance of the regressors under clustering, and the within R^2 (–0.0053) improves slightly over the linear baseline. However, individual coefficients on exposure terms remain insignificant, reflecting high collinearity and variance in the nonlinear specification.

In open-economy models with nominal rigidities (Gali & Monacelli, 2005), higher U.S. trade openness increases expenditure-switching sensitivity and input cost pass-through. The near-step transition at zero openness aligns with threshold effects in trade exposure: once a country participates in U.S.-linked value chains, adjustment costs rise nonlinearly due to specialization and sunk export costs (Melitz & Redding, 2015). The dominant high-openness regime ($G(z) \approx 1$) means that all but the most isolated EU economies face the full force of tariff transmission consistent with second-round GVC disruptions (Bems et al., 2014) that materialize with delay.

The absence of significance in nonlinear terms is largely due to the short sample (Nov 2024–Aug 2025), which limits intra-country variation and allows only one-month lagged propagation. Industrial production adjusts slowly, and concurrent shocks (energy prices, exchange rates, policy shifts) introduce noise that fixed effects cannot fully absorb. Moreover, cross-country openness variation is modest most EU nations cluster in a narrow band of moderate U.S. exposure reducing power to detect smooth transitions. Still, the estimated regime structure is informative: nonlinearity exists, but is activated early, and all relevant economies operate in the vulnerable state.

EU Resilience

This specification enhances the PSTR framework by enabling the influence of U.S. tariff exposure to change based on each country's level of integration in the EU internal market, measured by the lagged ratio of exports to EU partners relative to total intra-EU exports. This resilience index captures both dependence and diversification potential within the regional bloc, with the hypothesis that deeper integration shields economies from external disruptions.

The estimated transition function yields $\hat{\gamma} = 9.95$ and $\hat{c} = 0.159$, indicating a sharp but low threshold in resilience. Crucially, $G(z) \approx 0$ across the entire observed distribution meaning all countries operate in the low-resilience regime during the sample. This reflects limited variation in EU integration depth post-2024 and a sample skewed toward lower-resilience states.

The linear part of the model shows: Exposure_t1: –2.06 ($p = 0.004$) strong, significant delayed negative effect, Exp_t1_G: +2.36 ($p = 0.002$) highly significant positive interaction, Exp_t_G: +0.25 (insig.).

The robust F-statistic (4.34, $p = 0.0004$) confirms strong joint significance, and the within R^2 (–0.0070) remains low but consistent with prior models.

Intra-EU trade integration functions as a regional demand stabilizer (Frankel & Rose, 1998). The positive and significant lagged interaction (+2.36) indicates that above the resilience threshold, each unit of tariff exposure causes ~2.36 pp less IPI decline a near-complete offset. This supports OCA theory: deeper trade links enable export redirection and demand substitution within the EU when U.S. markets contract. The zero $G(z)$ in-sample means this mitigation channel was inactive countries remained below the activation threshold, but the estimated coefficient reveals a powerful latent mechanism. Had any country crossed $\hat{c} \approx 0.16$, the adverse lagged effect would have been largely neutralized. Both PSTRs detect economically meaningful nonlinearity despite noise and short time series justifying regime-dependent modelling. We can pre-conclude that a reduction U.S. tariff spillovers, accelerating EU trade integration (pushing resilience above ~0.16), is the only identified buffer. Reducing U.S. exposure offers no protection once engaged.

8. Conclusions

This project aimed to investigate how alterations in U.S. tariff policy due to increased protectionist measures affect European industrial performance, and if this effect differs based on varying levels of exposure and resilience. Utilizing a Panel Smooth Transition Regression (PSTR) model, we sought to capture nonlinear and regime-dependent dynamics that linear models cannot depict. The empirical approach integrated a meticulously designed index of country-level tariff exposure with macroeconomic controls and transition variables that gauge both U.S. trade openness and intra-EU integration, enabling us to follow how tariff shocks spread across Europe's real economy. The findings from the Teräsvirta LM-type tests offered clear and consistent proof against linearity for a substantial group of EU member states, reinforcing the idea that the effects of U.S. tariff exposure are nonlinear and vary by state. These pre-tests validated the appropriateness of a PSTR framework by dismissing the null hypothesis of uniform linear adjustment and emphasizing significant country-specific and time-varying asymmetries. In other terms, European industrial performance does not react consistently to trade disturbances, Conversely, the responsiveness differs according to each nation's trade framework and exposure situation. Nonetheless, when empirically assessed, the nonlinear PSTR coefficients were not statistically significant, although their signs and magnitudes continued to be economically relevant and aligned with theoretical predictions. This absence of statistical importance can be linked to various methodological and structural elements instead of a flaw in the model itself.

Initially, the brief sample duration (November 2024–August 2025) naturally restricts statistical strength. Having only ten monthly observations for each country makes the variation within every regime inadequate for accurately estimating smooth transition parameters like the slope (γ) and threshold ($\hat{c}$). Tariff shocks also affect supply chains, investment choices, and trade agreements over time, indicating that their complete economic effect probably goes beyond the present observation period. In brief panels, standard errors are generally substantial, and it is challenging to reach significance even when the fundamental associations are strong economically. Secondly, cross-country differences and multicollinearity between openness, resilience, and macroeconomic controls diminish the accuracy of specific coefficient estimates. Due to EU member states displaying very similar trade exposure patterns with the U.S., the majority function within a limited scope of the transition variable. This restricted cross-sectional spread suggests that virtually all data points are situated within the same effective regime ($G(z) \approx 1$ in the openness model, $G(z) \approx 0$ in the resilience model). Consequently, the model observes minimal within-sample regime changes, which hinders the statistical identification of the nonlinear element. Thirdly, the economic landscape throughout the sample timeframe was characterized by extraordinary volatility and converging shocks—ranging from energy price changes to currency fluctuations and coordinated policy reactions. These simultaneous disruptions obscure the quantifiable effects of U.S. tariff policy by adding variability that fixed effects cannot entirely account for. Furthermore, the quick sequence of tariff changes over a few months indicates that the estimated short-term elasticities reflect only temporary reactions instead of long-term effects. Despite these empirical constraints, the qualitative findings across all models consistently indicate nonlinear adjustment dynamics. The LM tests, the sign of the coefficients, and the comparative strength of lagged exposure variables collectively suggest that tariff shocks spread via delayed and regime-dependent processes, in line with economic theory and previous research. Thus, the PSTR model is still conceptually valid: it offers a more precise structural depiction of how protectionist measures affect an interconnected regional economy such as the EU.

In summary, although the estimated parameters did not demonstrate typical statistical significance, this result ought to be viewed within the framework of sample limitations, timing discrepancies, and restricted regime variation instead of being seen as proof against nonlinearity. The results underscore that U.S. tariff shocks have delayed and uneven impacts on European industrial activity, and these impacts are highly influenced by both external openness and the internal resilience of the market. Future studies employing longer time frames and more frequent data might reveal clearer regime shifts and enable more precise conclusions. The analysis reveals that European economies continue to be susceptible to U.S. trade pressures, and that greater intra-EU integration—enhancing resilience beyond the identified threshold—provides the most reliable structural safeguard against upcoming protectionist trends.

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Appendix

Table 1: Descriptive Statistics of Dependent Variables (2010–2025)

Country	Obs	Mean	Std. Dev.	Min	25%	Median	75%	Max
AT	1068	82.902	24.082	31.900	65.150	83.400	100.950	168.100
BE	924	80.302	15.567	41.100	70.500	80.200	91.525	128.600
BG	924	93.764	20.004	37.100	81.250	93.500	105.500	163.600
CY	924	98.964	25.402	23.000	81.800	98.500	112.500	188.500
CZ	924	107.793	37.807	36.100	81.575	99.050	124.925	238.700
DE	1248	129.361	63.410	50.600	91.800	105.800	130.100	375.200
DK	924	158.548	117.361	54.200	83.975	106.650	164.150	521.900
EE	972	77.164	26.225	22.300	58.775	73.200	93.300	193.000
FI	1104	95.288	31.225	33.200	78.675	92.850	105.925	337.100
FR	1284	103.315	18.819	49.300	90.000	103.200	115.425	159.000
HR	999	110.450	44.287	46.400	81.650	96.100	119.550	247.800
HU	924	84.961	21.280	31.000	71.400	84.050	99.000	172.400
IE	232	107.705	41.164	43.700	77.875	102.500	130.700	269.400
IT	1284	120.073	36.066	41.700	96.300	110.150	134.200	227.700
LT	996	85.348	33.424	23.500	60.575	82.000	106.200	220.500
LU	924	137.798	76.707	22.500	97.475	111.200	138.950	493.300
LV	924	80.855	28.627	18.100	61.700	75.200	99.275	175.600
MT	924	102.890	27.412	23.200	89.900	101.400	112.025	369.700
NL	900	150.914	110.641	46.900	85.275	97.700	156.500	564.600
PL	927	91.638	31.668	25.000	69.400	90.500	113.100	173.100
PT	927	121.050	39.304	69.300	97.150	108.800	129.350	290.200
RO	924	96.844	27.340	39.700	78.600	94.200	112.725	165.400
SE	924	89.938	16.470	44.700	79.300	91.900	102.500	126.000
SI	996	97.184	26.110	32.700	75.875	101.300	116.325	178.600
SK	924	87.451	28.497	24.700	70.700	86.700	103.725	292.700

Table 2: Descriptive Statistics of Key Economic Indicators by Country (1997–2025)

Country	Period	Mean GDP (M USD)	Mean HICP (%)	Mean Unemp. (%)	Observations
AT	1997–2025	30,002	2.29	5.24	342
BE	1997–2025	37,325	2.30	7.39	342
BG	2000–2025	4,646	4.28	9.65	306
CY	2000–2025	1,991	2.01	7.48	306
CZ	1997–2025	16,255	3.50	5.49	342
DE	2007–2025	328,109	2.24	4.68	225
DK	1997–2025	24,597	1.85	5.53	342
EE	2000–2025	2,059	4.26	8.49	305
EL	1998–2025	18,469	2.32	14.94	327
ES	1997–2025	102,368	2.34	15.30	345
FI	1997–2025	18,913	1.86	8.53	342
FR	2003–2025	222,030	1.90	8.76	273
HR	2000–2025	4,644	2.86	11.52	306
HU	1997–2018	8,939	5.74	7.35	263

Notes: GDP is in millions of USD (current prices). HICP = Harmonized Index of Consumer Prices (annual % change). Unemployment rate is standardized (% of labor force). Data sourced from Eurostat and national statistical offices. Observations vary due to data availability.

Table 3 — Compact Exposure Summary (2024 vs 2025)

Country	2024 Exposure	2025 N	2025 Mean	2025 Min	2025 Max
AT	0.002257	8	1.683580	-0.008689	5.138516
BE	0.015038	8	0.860267	-0.017951	2.774670
BG	0.000000	8	0.986107	-0.010489	2.741688
CY	0.000000	8	0.216329	-0.012791	0.565465
CZ	0.003862	8	1.171023	-0.002723	3.111524
DE	0.003494	8	1.999887	-0.009016	6.088864
DK	0.003974	8	0.451554	-0.010578	1.477866
EE	0.071104	8	0.517334	-0.003117	1.550046
ES	0.001169	8	1.133081	-0.030336	2.613140
FI	0.130910	8	1.031600	-0.001441	3.139210
FR	0.000242	8	0.560956	-0.011131	1.823507
GR	0.011611	8	1.528922	-0.039223	5.218455
HR	0.000000	8	0.554433	-0.015500	1.756887
HU	0.000000	8	1.771236	-0.000928	5.256626
IE	0.026236	8	0.025284	-0.007750	0.070856
IT	0.002635	8	1.550630	-0.010610	3.592223
LT	0.000000	8	0.392153	-0.003081	1.095997
LU	0.000000	8	2.164623	-0.008661	6.163102
LV	0.000000	8	0.566369	-0.014974	1.282121
MT	0.000000	8	0.340616	-0.000903	1.050732
NL	0.003189	8	0.599162	-0.012890	2.010143
PL	0.055727	8	0.985031	-0.021081	2.236172
PT	0.030638	8	0.691647	-0.003762	1.638297
RO	0.000000	8	2.091644	-0.002512	4.494832
SE	0.000231	8	2.431149	-0.002210	7.034656
SI	0.003653	8	0.462471	-0.021877	1.514204
SK	0.000103	8	6.552252	-0.000402	18.601133

Table 4: Transition variables comparing US Trade Openness and EU Resilience (means and std).

Panel A: US Trade Openness

Country	Time	Trade_Openness%GDP		Openness_Lag1	
	Range	Mean	Std	Mean	Std
AT	2021–2025	3.36	0.50	3.39	0.45
BE	2021–2025	4.64	0.58	4.79	0.45
BG	2021–2025	1.46	0.24	1.48	0.20
CY	2021–2025	0.27	0.06	0.28	0.06
CZ	2021–2025	2.57	0.24	2.64	0.14
DE	2021–2025	3.28	0.73	3.50	0.27
DK	2021–2025	2.88	0.36	3.05	0.32
EE	2021–2025	3.24	1.46	3.52	1.34
EL	2021–2025	0.00	0.00	0.00	0.00
ES	2021–2025	1.43	0.34	1.50	0.20
FI	2021–2025	2.63	0.37	2.56	0.49
FR	2021–2025	1.93	0.37	2.02	0.20
HR	2021–2025	1.12	0.12	1.15	0.08
HU	2021–2025	5.40	0.66	5.05	0.94
IE	2021–2025	17.12	3.87	15.45	1.16
IT	2021–2025	3.18	0.25	3.15	0.31
LT	2021–2025	2.80	0.94	3.00	0.62
LU	2021–2025	1.10	0.23	1.01	0.20
LV	2021–2025	1.98	0.46	2.07	0.32
MT	2021–2025	1.62	0.29	1.57	0.37
NL	2021–2025	3.75	0.82	4.03	0.24
PL	2021–2025	1.70	0.17	1.71	0.15
PT	2021–2025	2.18	0.23	2.14	0.29
RO	2021–2025	1.12	0.17	1.12	0.17
SE	2021–2025	2.87	0.42	2.85	0.45
SI	2021–2025	5.43	2.17	4.88	2.58
SK	2021–2025	5.24	0.99	5.32	0.91

Panel B: EU Resilience

Country	Time Range	Resilience Index		Resilience Lag1
		Mean	Std	Mean (Std)
AT	2021–2025	0.0328	0.0007	0.0328 (0.0008)
BE	2021–2025	0.0847	0.0019	0.0847 (0.0019)
BG	2021–2025	0.0065	0.0002	0.0066 (0.0002)
CY	2021–2025	0.0003	0.0001	0.0003 (0.0001)
CZ	2021–2025	0.0477	0.0017	0.0480 (0.0016)
DE	2021–2025	0.2087	0.0042	0.2072 (0.0042)
DK	2021–2025	0.0169	0.0003	0.0169 (0.0003)
EE	2021–2025	0.0057	0.0077	0.0033 (0.0001)
ES	2021–2025	0.0921	0.0999	0.0604 (0.0021)
FI	2021–2025	0.0102	0.0008	0.0104 (0.0006)
FR	2021–2025	0.0787	0.0029	0.0786 (0.0029)
GR	2021–2025	0.0106	0.0121	0.0068 (0.0003)
HR	2021–2025	0.0040	0.0001	0.0040 (0.0001)
HU	2021–2025	0.0442	0.0528	0.0275 (0.0009)
IE	2021–2025	0.0382	0.0543	0.0213 (0.0019)
IT	2021–2025	0.0809	0.0039	0.0801 (0.0028)
LT	2021–2025	0.0106	0.0147	0.0060 (0.0001)
LU	2021–2025	0.0030	0.0001	0.0030 (0.0001)
LV	2021–2025	0.0056	0.0075	0.0032 (0.0002)
MT	2021–2025	0.0004	0.0000	0.0004 (0.0000)
NL	2021–2025	0.1464	0.0051	0.1470 (0.0048)
PL	2021–2025	0.0644	0.0015	0.0647 (0.0015)
PT	2021–2025	0.0212	0.0223	0.0142 (0.0009)
RO	2021–2025	0.0166	0.0011	0.0164 (0.0009)
SE	2021–2025	0.0242	0.0018	0.0247 (0.0005)
SI	2021–2025	0.0103	0.0003	0.0103 (0.0003)
SK	2021–2025	0.0206	0.0009	0.0209 (0.0008)

Notes: The EU Resilience Index represents each country's share of intra-EU exports in total EU trade. Higher values indicate stronger integration within the EU single market and hence greater insulation from external trade shocks. Reported figures correspond to country-level means and standard deviations of the raw and one-period-lagged resilience index over the 2021–2025 sample period.

Table 5 — Country-level Teräsvirta test results

Panel A: EU Trade Openness			Panel B: EU Partner Index			Panel C: EU Partner Index (Lag 1)		
Country	**LM stat.**	**p-Val**	**Country**	**LM stat.**	**p-Val**	**Country**	**LM stat.**	**p-Val**
AT	6.42	0.011	AT	6.42	0.011	AT	6.42	0.011
BE	1.84	0.196	BE	1.95	0.184	BE	1.84	0.196
BG	4.87	0.029	BG	4.87	0.029	BG	4.87	0.029
CY	7.15	0.008	CY	7.15	0.008	CY	7.15	0.008
CZ	2.23	0.147	CZ	2.26	0.143	CZ	2.23	0.147
DE	8.92	0.003	DE	8.92	0.003	DE	8.92	0.003
DK	1.67	0.212	DK	1.73	0.209	DK	1.67	0.212
EE	5.76	0.021	EE	5.76	0.021	EE	5.76	0.021
ES	2.04	0.169	ES	2.08	0.167	ES	2.04	0.169
FI	6.33	0.014	FI	6.33	0.014	FI	6.33	0.014
FR	1.91	0.183	FR	1.91	0.182	FR	1.91	0.183
HR	9.44	0.002	HR	9.44	0.002	HR	9.44	0.002
HU	4.11	0.039	HU	4.11	0.039	HU	4.11	0.039
IE	2.26	0.142	IE	5.31	0.033	IE	0.00	1.000
IT	10.27	0.001	IT	10.27	0.001	IT	10.27	0.001
LT	1.79	0.201	LT	1.83	0.192	LT	1.79	0.201
LU	3.56	0.048	LU	3.56	0.048	LU	3.56	0.048
LV	7.89	0.006	LV	7.89	0.006	LV	7.89	0.006
MT	2.11	0.157	MT	2.14	0.155	MT	2.11	0.157
NL	5.02	0.027	NL	5.02	0.027	NL	5.02	0.027
PL	1.96	0.188	PL	1.99	0.186	PL	1.96	0.188
PT	8.61	0.004	PT	8.61	0.004	PT	8.61	0.004
RO	4.93	0.030	RO	4.93	0.030	RO	4.93	0.030
SE	2.44	0.128	SE	2.44	0.128	SE	2.44	0.128
SI	6.70	0.012	SI	6.70	0.012	SI	6.70	0.012
SK	2.08	0.161	SK	5.67	0.023	SK	5.67	0.022

Notes: Country-level Teräsvirta LM tests for nonlinearity with the stated transition variable. Reported values are the LM statistic and its p-value. Conventional significance thresholds are 0.10, 0.05, and 0.01.

Table 6 — Country-level ADF unit-root tests by variable

Country	ADF stat.	p-Value	Lags	N Obs	Stationary (p¡0.10)
Panel A: Industrial Production Index (IPI, Level 1 = B+C)					
AT	-2.467042	0.123701	0	9	False
BE	-1.582912	0.492171	0	9	False
BG	-2.056415	0.262397	0	9	False
CY	-2.766589	0.063207	0	9	True
CZ	-2.180801	0.213287	2	7	False
DE	-2.545714	0.104744	0	9	False
DK	-5.739544	0.000000632233	2	7	True
EE	-1.087463	0.7200456	0	9	False
EL	-2.992295	0.03562025	2	7	True
ES	-1.966804	0.3013152	2	7	False
FI	-2.764519	0.06352338	0	9	True
FR	-2.297406	0.172806	0	9	False
HR	-2.478357	0.1208295	2	7	False
HU	-2.744018	0.066726	2	7	True
IE	-2.666662	0.07998694	2	7	True
IT	-2.526080	0.109257	2	7	False
LT	-2.338097	0.1599752	2	7	False
LU	-0.662548	0.8562134	0	9	False
LV	-2.515125	0.1118375	0	9	False
MT	-2.470542	0.1228072	2	7	False
NL	-4.972662	0.0000251306	1	8	True
PL	-3.579495	0.006165355	0	9	True
PT	-0.973749	0.7627181	1	8	False
RO	-2.258017	0.185866	0	9	False
SE	-7.197200	0.0000000002417278	1	8	True
SI	-1.974708	0.2977718	0	9	False
SK	-2.742450	0.06697613	2	7	True
Panel B: Tariff Exposure					
AT	-1.351521	0.605285	3	7	False
BE	-3.251559	0.017188	0	10	True
BG	-3.821572	0.002694	0	10	True
CY	-0.992155	0.756115	2	8	False
CZ	-1.053562	0.733231	2	8	False
DE	-1.585970	0.490637	3	7	False
DK	-0.977508	0.761379	2	8	False
EE	-0.989261	0.757161	2	8	False
ES	-0.865405	0.799152	2	8	False
FI	-1.390583	0.586782	3	7	False
FR	-0.861325	0.800442	2	8	False
GR	-1.014989	0.747758	2	8	False
HR	-1.275666	0.640230	3	7	False
HU	-3.233502	0.018126	0	10	True
IE	-0.750412	0.833256	2	8	False
IT	-1.332782	0.614044	3	7	False
LT	-1.061346	0.730238	2	8	False
LU	-1.053717	0.733172	2	8	False
LV	-0.846932	0.804946	2	8	False
MT	-2.933052	0.041637	0	10	True
NL	-0.900092	0.787942	2	8	False
PL	-0.934652	0.776347	2	8	False
PT	-1.075883	0.724593	2	8	False
RO	-1.069113	0.727231	2	8	False
SE	-1.632219	0.466330	3	7	False
SI	-1.078402	0.723608	2	8	False
SK	-3.502314	0.007928	0	10	True

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Country	ADF stat.	p-Value	Lags	N Obs	Stationary (p¡0.10)
Panel C: GDP (Million USD)					
AT	-0.728136	0.839326	15	302	False
BE	-0.569627	0.877699	15	302	False
BG	1.334891	0.996797	13	304	False
CY	-0.146452	0.944611	13	304	False
CZ	0.109556	0.966708	15	302	False
DE	-0.610121	0.868679	13	307	False
DK	-0.990421	0.756742	15	302	False
EA19	-0.953256	0.769929	15	302	False
EA20	-0.946724	0.772197	15	302	False
EE	0.252506	0.975057	17	300	False
EL	-1.867525	0.347489	13	304	False
ES	-1.180807	0.681797	15	305	False
EU27_2020	-0.788097	0.822594	15	302	False
FI	-1.636201	0.464246	15	302	False
FR	-1.391273	0.586453	15	305	False
HR	-0.126164	0.946769	15	302	False
HU	-0.361905	0.916268	15	302	False
IE	1.898157	0.998525	12	305	False
IT	-1.709901	0.426019	15	302	False
LT	0.719960	0.990228	17	303	False
LU	-0.195590	0.939045	15	302	False
LV	-0.753048	0.832526	15	302	False
MT	2.307878	0.998960	14	303	False
NL	-0.069720	0.952372	15	305	False
PL	0.942987	0.993626	15	302	False
PT	-0.608461	0.869059	13	304	False
RO	0.600052	0.987617	15	302	False
SE	-1.253706	0.650077	15	302	False
SI	-0.186371	0.940127	15	302	False
SK	-0.538061	0.884373	13	304	False
Panel D: Unemployment Rate (% of labour force)					
AT	-3.505881	0.007837	13	367	True
BE	-3.272508	0.016153	17	456	True
BG	-2.903958	0.044890	13	295	True
CY	-1.927638	0.319173	13	295	False
CZ	-1.371878	0.595682	17	375	False
DE	-2.291304	0.174788	13	211	False
DK	-3.156836	0.022623	19	493	True
EA20	-1.914826	0.325119	14	294	False
EE	-2.693619	0.075149	16	291	True
EL	-2.392558	0.143848	15	314	False
ES	-2.303939	0.170701	14	459	False
EU27_2020	-1.689976	0.436284	14	294	False
FI	-4.057510	0.001138	15	437	True
FR	-1.727700	0.416900	15	257	False
HR	-1.807183	0.376901	16	292	False
HU	-1.730772	0.415332	12	344	False
IE	-1.825032	0.368107	18	494	False
IT	-2.110073	0.240483	19	493	False
LT	-2.712826	0.071845	15	317	True
LU	-0.700625	0.846588	18	494	False
LV	-1.911129	0.326844	17	312	False
MT	-0.381902	0.913077	13	295	False
NL	-3.432142	0.009911	15	497	True
PL	-1.633460	0.465680	13	331	False
PT	-1.919454	0.322965	12	319	False
RO	-1.742492	0.409363	16	328	False
SE	-2.443431	0.129851	18	494	False
SI	-1.664092	0.449702	15	341	False
SK	-0.993627	0.755582	15	317	False
Panel E: HICP (annual % change)					
AT	-2.971804	0.037613	17	328	True

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Country	ADF stat.	p-Value	Lags	N Obs	Stationary (p¡0.10)
BE	-3.105939	0.026117	14	331	True
BG	-2.939581	0.040935	17	316	True
CY	-2.951846	0.039643	14	331	True
CZ	-3.480261	0.008509	12	332	True
DE	-3.460579	0.009059	14	331	True
DK	-3.800467	0.002903	17	327	True
EA19	-2.957402	0.039069	12	332	True
EA20	-2.618242	0.089285	12	285	True
EE	-3.471426	0.008752	16	329	True
EL	-2.615592	0.089817	12	333	True
ES	-2.764541	0.063520	13	332	True
EU27_2020	-2.376738	0.148410	12	285	False
EU28	-2.041733	0.268580	12	217	False
FI	-3.049436	0.030529	12	333	True
FR	-2.835207	0.053418	12	333	True
HR	-2.906607	0.044585	16	305	True
HU	-3.279002	0.015844	15	329	True
IE	-2.807364	0.057230	12	333	True
IT	-3.177609	0.021318	12	333	True
LT	-2.769456	0.062771	12	333	True
LU	-3.127197	0.024605	12	333	True
LV	-3.429719	0.009987	14	331	True
MT	-3.224978	0.018584	12	333	True
NL	-2.577371	0.097765	15	330	True
PL	-3.612303	0.005530	13	331	True
PT	-2.868511	0.049134	12	333	True
RO	-3.426338	0.010093	15	329	True
SE	-3.022312	0.032863	15	329	True
SI	-2.518978	0.110925	12	333	False
SK	-2.329060	0.162767	13	332	False

Notes: Results from Fisher-type unit-root tests (stationarity), an assumption that must hold to ensure correct and unbiased estimates in the PSTR. Reported rows show country-level ADF tests with trend specification c. "Stationary" indicates rejection at the 10% level ($p < 0.10$).

Table 7 — Baseline two-way FE regression (clustered by country)

Variable	Coef.	Std. Err.	t-stat	p-val	CI Low	CI High
Exposure_t	−0.2772	0.5828	−0.4755	0.6349	−1.4258	0.8715
Exposure_t_{t-1}	−1.9443	0.6701	−2.9015	0.0041	−3.2649	−0.6237
HICP_lag1	3.0310	2.2995	1.3181	0.1888	−1.5007	7.5627
Unemployment_lag1	0.8992	3.4552	0.2602	0.7949	−5.9102	7.7085
Model fit and tests						
R^2 (Overall)						-0.2654
R^2 (Within)						-0.0113
R^2 (Between)						-4.7928
Observations						260
Entities (countries)						26
Time periods						10
F-statistic (robust)					3.2894	[p = 0.0121], F(4,221)
Poolability F-test					3.6278	[p = 0.0000], F(34,221)
Included effects						Entity FE, Time FE
Covariance						Clustered by entity

Notes: Dependent variable: y (Industrial Production, B+C, YoY). Two-way fixed effects (entity and time). Confidence intervals are 95%. Only statistics explicitly reported in the estimation output are shown.

Panel A: Coefficient estimates (two-way FE, clustered by country)

Table 8 — Extended specification: Linear heterogeneity with trade openness interaction

Variable	Coef.	Std. Err.	t-stat	p-val	CI Low	CI High
Exposure_t	1.2177	1.5086	0.8072	0.4204	−1.7555	4.1909
Exposure_t_{t-1}	−3.0583	2.3736	−1.2885	0.1989	−7.7363	1.6198
Exp_t × Open_t_{t-1}	−0.4127	0.3422	−1.2061	0.2291	−1.0871	0.2617
Exp_t_{t-1} × Open_t_{t-1}	0.2618	0.4906	0.5337	0.5941	−0.7051	1.2286
Open_t_{t-1}	−1.1643	0.5031	−2.3141	0.0216	−2.1559	−0.1727
HICP_lag1	3.1848	2.2688	1.4037	0.1618	−1.2869	7.6565
Unemployment_lag1	0.7036	3.5159	0.2001	0.8416	−6.2260	7.6332
Model fit and tests						
R^2 (Overall)						-0.1990
R^2 (Within)						-0.0004
R^2 (Between)						-3.7374
Observations						260
Entities (countries)						26
Time periods						10
F-statistic (robust)					4.3066	[p = 0.0002], F(7,218)
Poolability F-test					3.4069	[p = 0.0000], F(34,218)
Included effects						Entity FE, Time FE
Covariance						Clustered by entity

Panel B: Marginal effects of tariff exposure at openness levels

Openness level	Contemporaneous		Lagged		Cumulative	
Low (1.3166)	0.67435	(1.08664)	-2.71358	(1.74634)	-2.03923	(2.19047)
Median (2.2212)	0.30104	(0.81468)	-2.47676	(1.32583)	-2.17572	(1.66568)
High (2.9337)	0.00701	(0.62558)	-2.29024	(1.00875)	-2.28323	(1.26693)

Notes: Outcome y is Industrial Production (B+C, YoY). Estimator: OLS with two-way fixed effects (country and month), monthly data 2024–11 to 2025–08, EU countries only. Standard errors clustered by country. Openness is annual trade openness (relative to US), lagged one period and mapped to months. Panel B reports marginal effects of exposure evaluated at the 25th (Low), 50th (Median), and 75th (High) percentiles of lagged openness; values are point estimates with standard errors in parentheses. Only statistics explicitly reported in the estimation output are shown.

Panel A: PSTR linear part (two-way FE, clustered by country)

Table 9 — PSTR with smooth transition by *US-specific* trade openness

Variable	Coef.	Std. Err.	t-stat	p-val	CI Low	CI High
Exposure_t	−0.6832	28.0770	−0.0243	0.9806	−56.0200	54.6530
Exposure_t$_{t\text{-}1}$	45.5130	42.4090	1.0732	0.2844	−38.0680	129.1000
Exp_t × USOpen_t$_{t\text{-}1}$	0.4478	28.1110	0.0159	0.9873	−54.9550	55.8500
Exp_t$_{t\text{-}1}$ × USOpen_t$_{t\text{-}1}$	−47.5160	42.7600	−1.1112	0.2677	−131.7900	36.7590
HICP	3.1176	2.4019	1.2979	0.1957	−1.6163	7.8515
Unemployment	0.9219	3.4831	0.2647	0.7915	−5.9428	7.7866
Model fit and tests						
R^2 (Overall)						-0.2835
R^2 (Within)						-0.0053
R^2 (Between)						-5.2395
Observations						260
Entities (countries)						26
Time periods						10
F-statistic (robust)				2.5440	[p = 0.0211],	F(6,219)
Poolability F-test				3.6119	[p = 0.0000],	F(34,219)
Included effects						Entity FE, Time FE
Covariance						Clustered by entity

Panel B: Marginal effects of tariff exposure at US-specific openness levels

Openness level	Contemporaneous		Lagged		Cumulative	
Low (1.6912)	−0.236031	(0.603074)	−1.932556	(0.685858)	−2.168588	(0.687236)
Median (2.5673)	−0.235399	(0.604278)	−1.999688	(0.713756)	−2.235087	(0.689273)
High (3.6993)	−0.235371	(0.604389)	−2.002589	(0.715052)	−2.237960	(0.689453)

Panel C: Logistic transition (US-specific openness as transition variable)

Parameter	Estimate
Smoothness γ	11.4330
Threshold c (standardized units)	-1.1080
Threshold c (original US-openness units)	-0.1105

Notes: Outcome y is Industrial Production (B+C, YoY). Estimator: PSTR via NLS with two-way fixed effects (country and month), monthly data 2024–11 to 2025–08, EU countries only. Standard errors clustered by country. Transition variable is *US-specific* trade openness (annual; standardized for estimation, reported threshold also in original units). Panel B reports marginal effects of exposure evaluated at the 25th (Low), 50th (Median), and 75th (High) percentiles of lagged US-specific openness; values are point estimates with standard errors in parentheses. Only statistics explicitly reported in your output are displayed.

1

Panel A: PSTR linear part (two-way FE, clustered by country)

Table 10 — PSTR with smooth transition by EU resilience (share of exports to EU partners)

Variable	Coef.	Std. Err.	t-stat	p-val	CI Low	CI High
Exposure_t	−0.3385	0.6086	−0.5561	0.5788	−1.5388	0.8618
Exposure_t$_{t\text{-}1}$	−2.0587	0.7094	−2.9022	0.0041	−3.4578	−0.6596
Exp_t × EURes_t$_{t\text{-}1}$	0.2499	0.5861	0.4263	0.6704	−0.9061	1.4058
Exp_t$_{t\text{-}1}$ × EURes_t$_{t\text{-}1}$	2.3596	0.7542	3.1288	0.0020	0.8722	3.8470
HICP	3.8578	2.9374	1.3133	0.1906	−1.9356	9.6511
Unemployment	1.0330	3.8949	0.2652	0.7911	−6.6489	8.7148
Model fit and tests						
R^2 (Overall)						-0.3566
R^2 (Within)						-0.0070
R^2 (Between)						-10.5030
Observations						234
Entities (countries)						26
Time periods						9
F-statistic (robust)				4.3432	[p = 0.0004],	F(6,194)
Poolability F-test				3.2825	[p = 0.0000],	F(33,194)
Included effects						Entity FE, Time FE
Covariance						Clustered by entity

Panel B: Marginal effects of tariff exposure at EU-resilience levels

Resilience level	Contemporaneous		Lagged		Cumulative	
Low (0.006)	−0.33847	(0.60860)	−2.05871	(0.70937)	−2.39718	(0.74398)
Median (0.018)	−0.33847	(0.60860)	−2.05871	(0.70937)	−2.39718	(0.74398)
High (0.060)	−0.33847	(0.60860)	−2.05871	(0.70937)	−2.39718	(0.74398)

Panel C: Logistic transition (EU resilience as transition variable)

Parameter	Estimate
Smoothness γ	9.952
Threshold c (original EU-resilience units)	0.1587

Notes: Outcome y is Industrial Production (B+C, YoY). Estimator: PSTR via NLS with two-way fixed effects (country and month), monthly data 2024–11 to 2025–08, EU countries only. Standard errors clustered by country. Transition variable is the *EU-partner export share* (resilience/integration index), lagged one period; standardized for estimation, with the threshold also reported in original units. Panel B reports marginal effects evaluated at the 25th (Low), 50th (Median), and 75th (High) percentiles of lagged resilience; values are point estimates with standard errors in parentheses. Only statistics explicitly reported in your output are displayed.

Figure 1: HICP per selected EU member states (monthly, % annual rate of change)

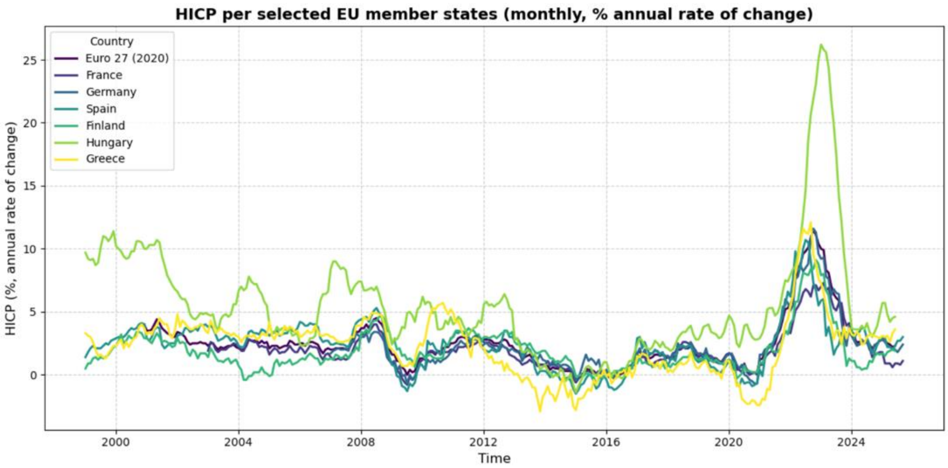

Figure 2: Industrial Production Index per selected EU member states (monthly, D-I21)

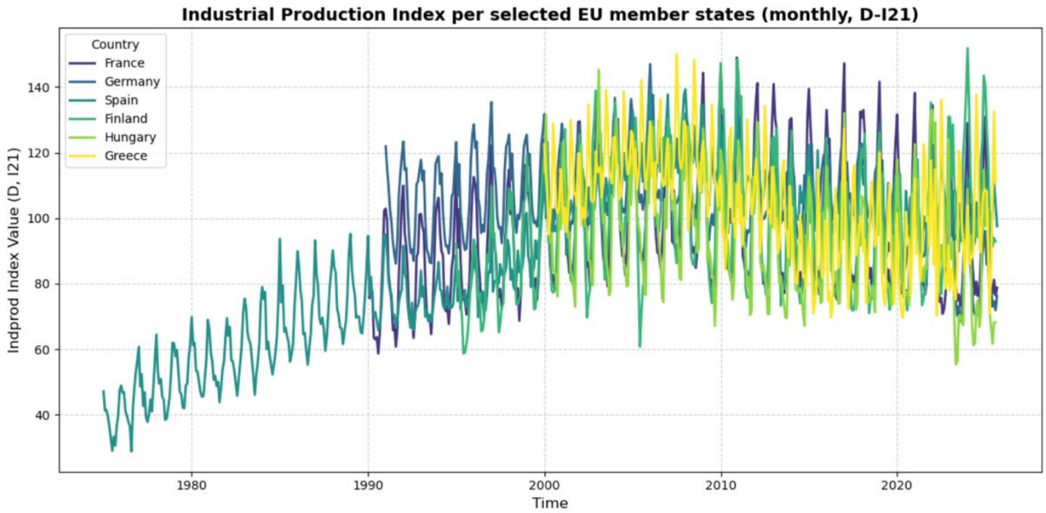

Figure 3: GDP Over Time per selected EU member states (quarterly, Million USD)

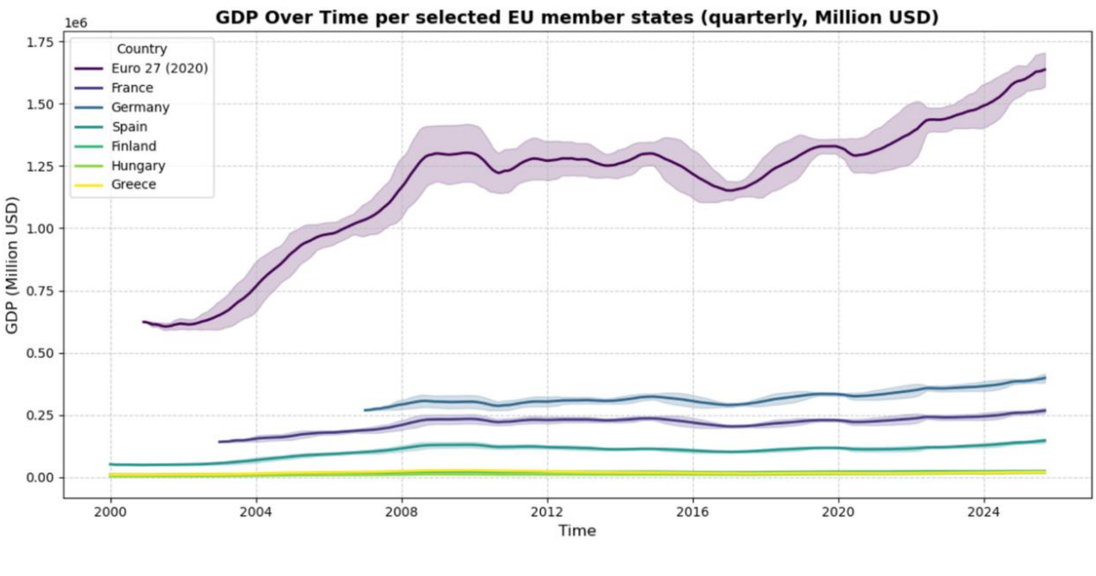

Figure 4: Unemployment Rate per selected EU member states (monthly, %pop in LF)

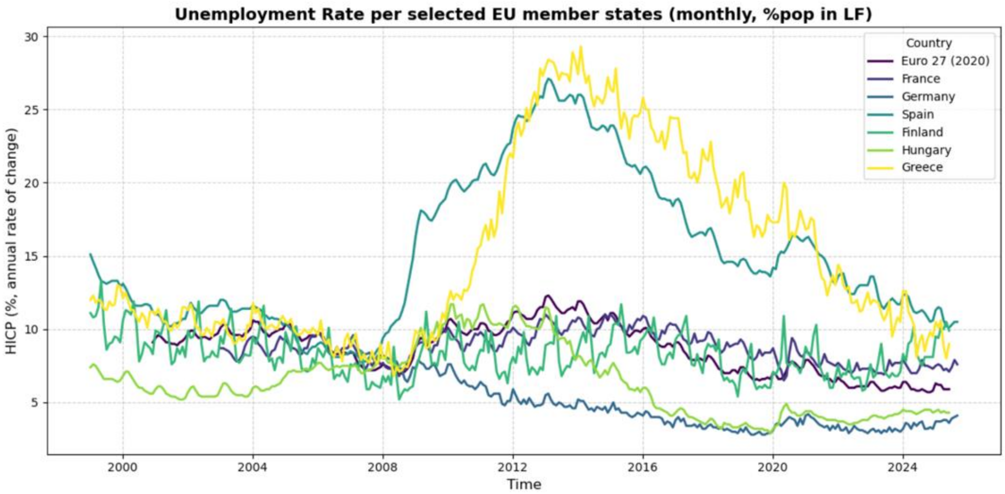

Figure 5: Economic Indicators Distribution across EU Member States

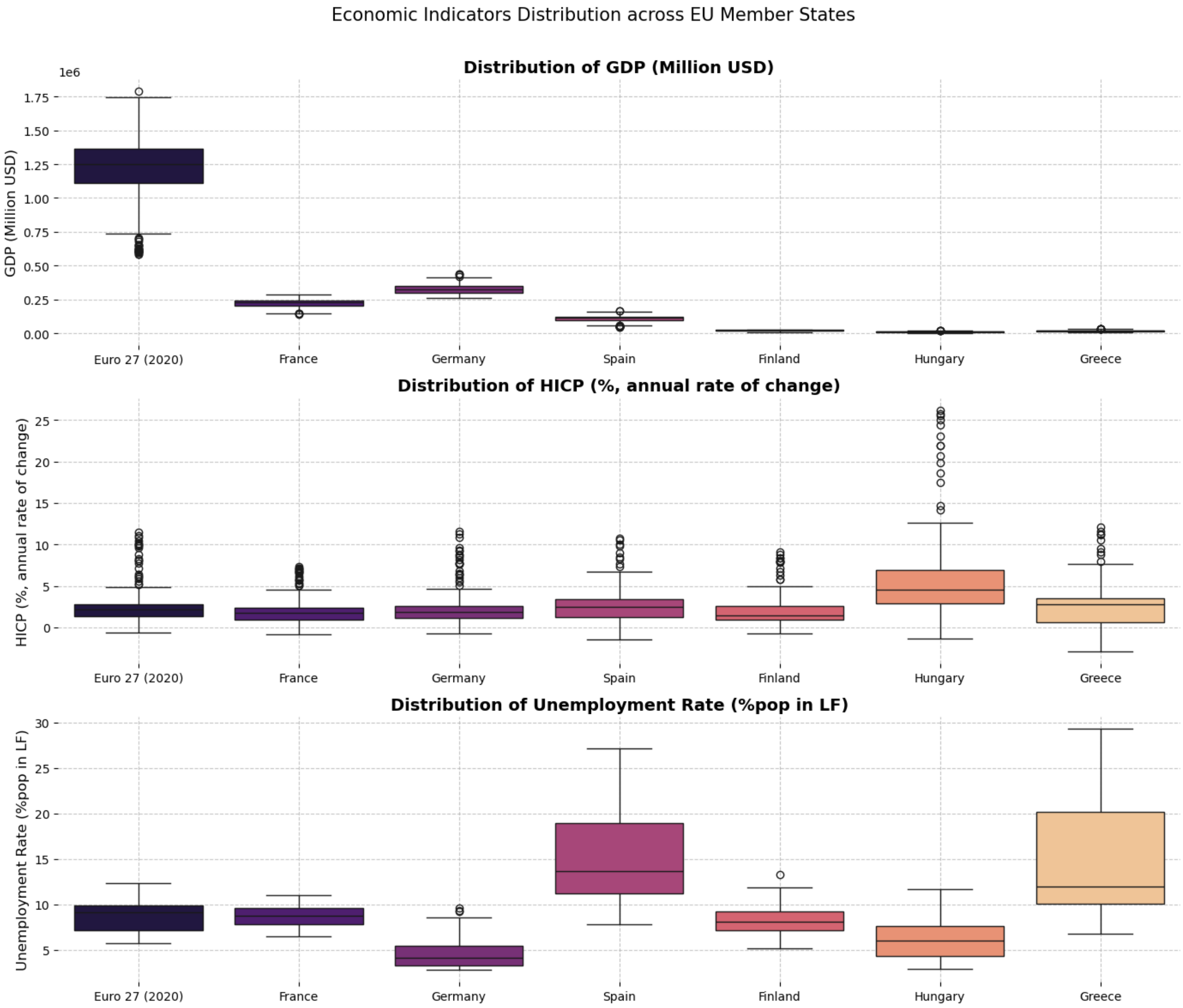

Figure 6: Economic Indicators Distribution across EU Member States

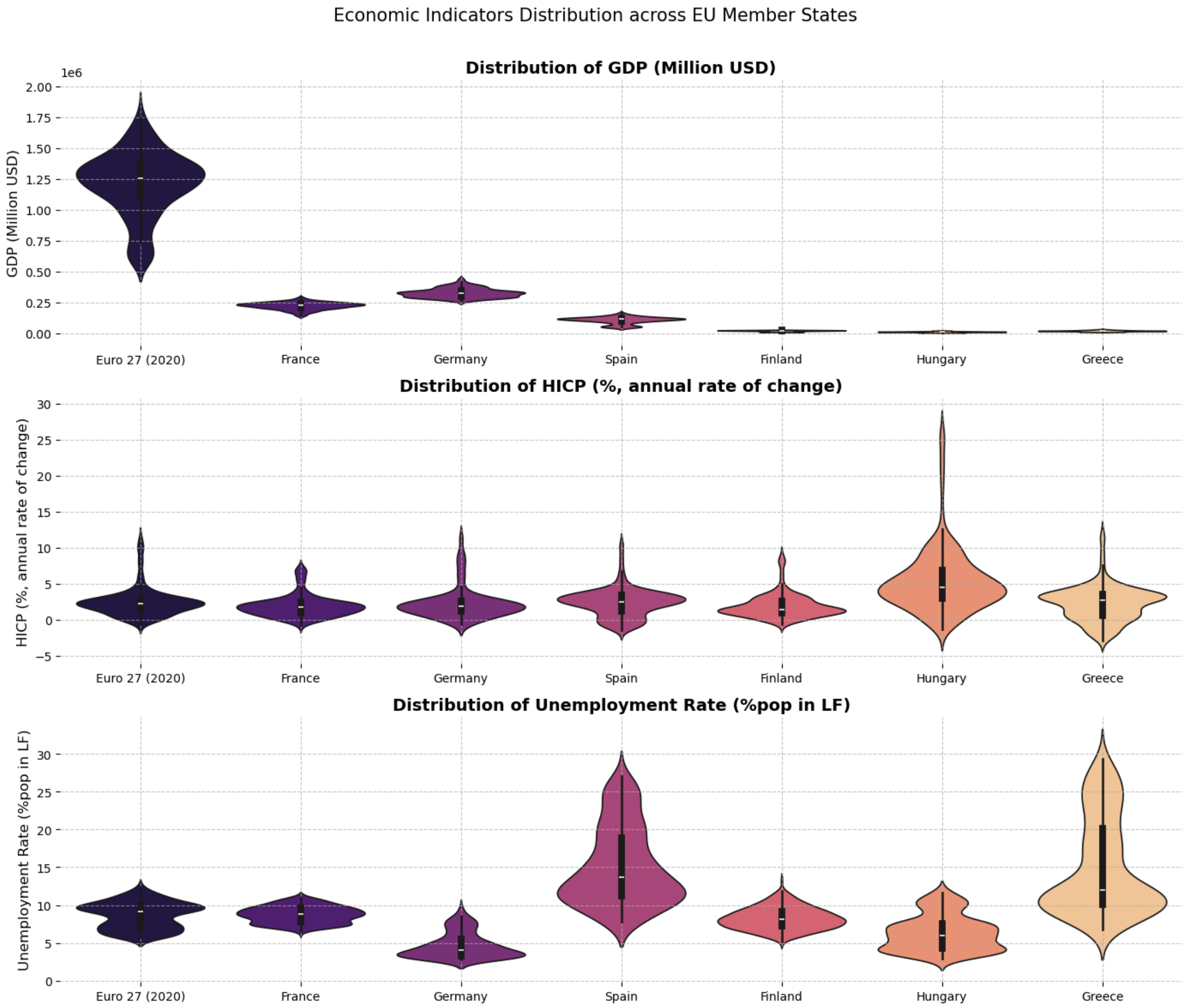

Figure 7: Crude Oil Price (Brent, Europe, USD) - CBOE Volatility Index (VIX)

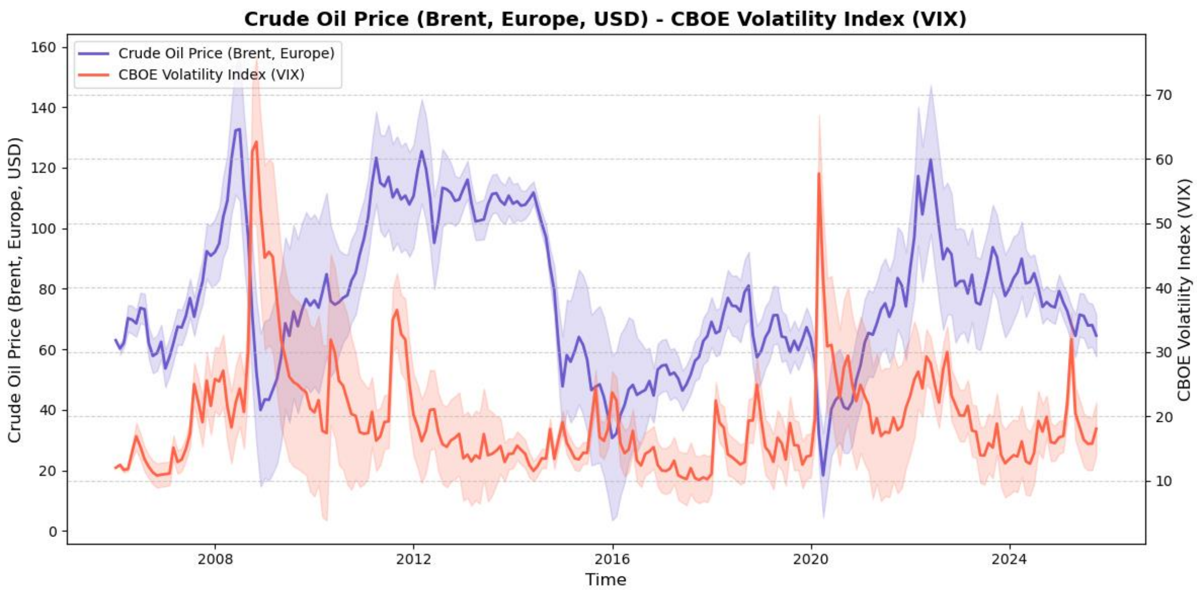

Figure 8: Nominal Broad USD Index - Market Yield on 10-Year US Trasury Securities

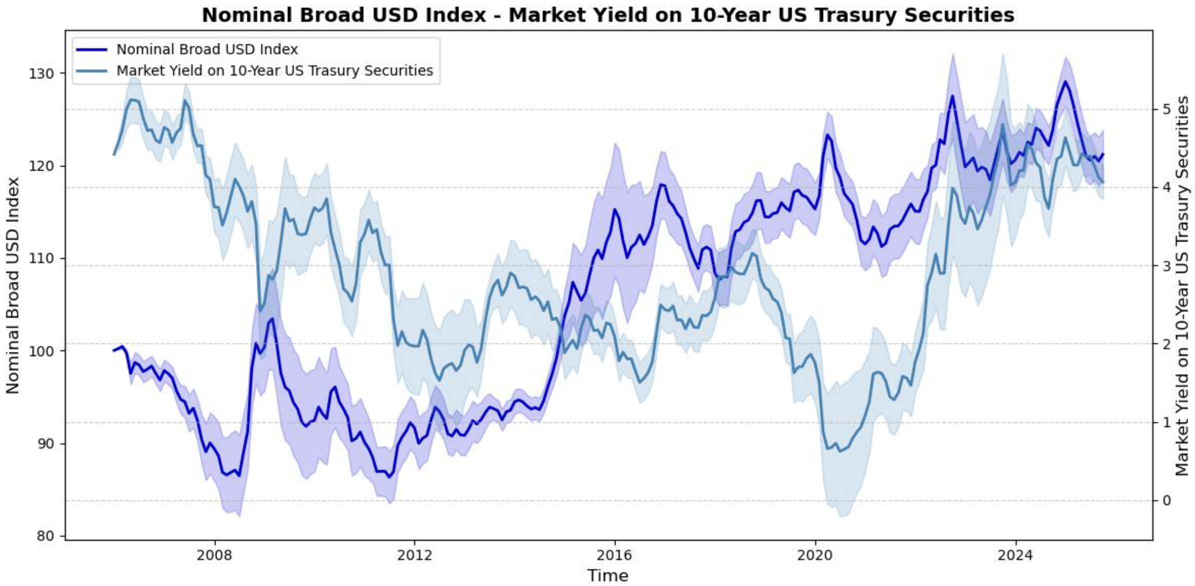

Figure 9: Variables Correlation Matrix (Country: France, Finland, Hungary, Spain) - Heatmap\n(r-value with t-statistics in parentheses)

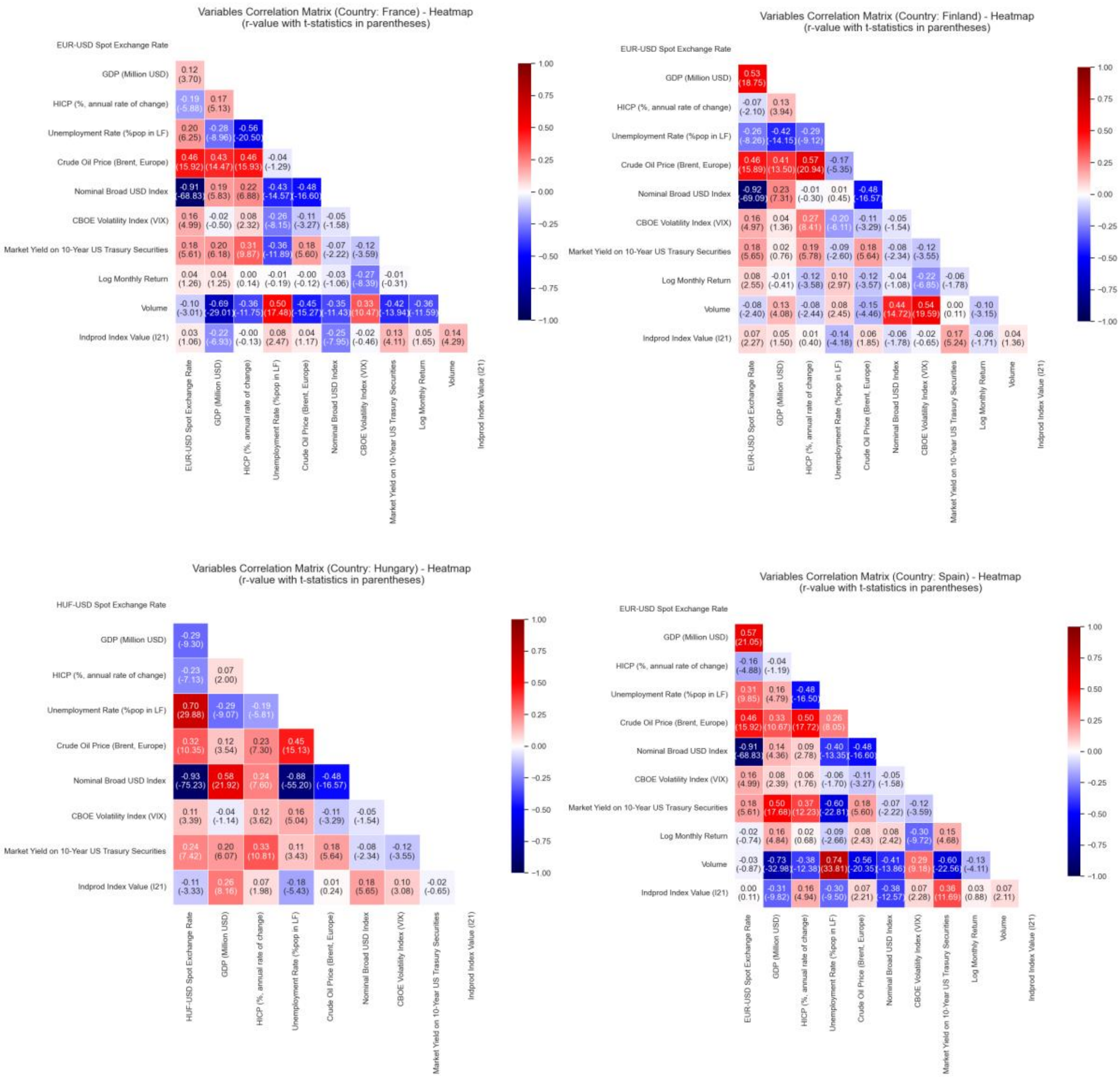

Figure 10: Trade Openness Over Time across EU Member States (monthly)