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Monetary Policy Transmission Under Financial Stress: A Panel Threshold Analysis of North-South Divergence in the Euro Area

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Abstract

Does ECB monetary policy affect Northern and Southern Europe differently depending on financial conditions? Using Hansen's (1999) Panel Threshold Model with high-frequency identified shocks from Jarociński and Karadi (2020) and the Composite Indicator of Systemic Stress as threshold variable, I analyse quarterly data for twelve euro area members (2001Q1–2019Q4). The central finding is that North-South transmission heterogeneity is state-dependent: during moderate-high financial stress, Southern GDP contracts 2.10 percentage points more than Northern GDP in response to identical monetary tightening. This asymmetry disappears in other regimes, suggesting the sovereign-bank nexus created regime-specific vulnerabilities with implications for common monetary policy.

Keywords: Monetary policy transmission, Panel Threshold Model, Financial stress, CISS, Euro Area, North-South heterogeneity

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1 Introduction

The euro area has entered a period of profound economic turbulence that poses fundamental challenges for the conduct of monetary policy. Between 2021 and 2023, inflation in the currency union surged to levels unseen since its creation, reaching 10.7% in October 2022 (Eurostat 2022), a dramatic break from the below-target environment that had defined the preceding decade. This inflationary surge, ignited by post-pandemic demand pressures and amplified by energy supply disruptions following Russia's invasion of Ukraine, forced the ECB into the fastest monetary tightening cycle in its history. From mid-2022 to late 2023, the ECB raised its deposit facility rate from −0.5% to 4%, an unprecedented 450-basis-point increase (Gotti and Papadia 2024).

Yet this aggressive policy reversal unfolded against a backdrop of mounting financial fragility. The 2022 tightening cycle triggered an immediate widening of sovereign spreads, particularly acute for Southern European economies, where credit conditions tightened precisely when policy restraint was being deployed. This fragmentation risk, threatening to impair the uniform transmission of monetary policy, prompted the ECB to introduce the Transmission Protection Instrument in July 2022 (European Central Bank July 2022). Meanwhile, the collapse of Credit Suisse in March 2023, alongside the failure of several U.S. regional banks, revived concerns about banking sector resilience during monetary tightening (CNBC Mar. 2023). Throughout these episodes, the Composite Indicator of Systemic Stress exhibited repeated spikes, signaling moments when stress pervaded multiple market segments simultaneously.

These developments illuminate a critical vulnerability embedded within the architecture of the monetary union: the euro area comprises economies with sharply divergent fiscal positions, financial structures, and institutional frameworks. These divisions became starkly apparent during the sovereign debt crisis of 2010 to 2012 and have never fully healed. Southern European economies typically carry higher public debt burdens, maintain banking systems more exposed to domestic sovereign risk, and exhibit greater sensitivity to changes in external financing conditions. Northern economies, by contrast, tend to operate with more fiscal space and banking sectors less vulnerable to the doom loop between sovereigns and financial institutions. When financial stress escalates, these structural asymmetries risk translating a single monetary policy stance into sharply divergent credit conditions across member states.

A substantial body of research confirms that monetary policy transmission depends critically on the prevailing state of the economy. When financial stress intensifies, risk premia widen, bank lending standards tighten, and the credit channel through which monetary policy operates can become attenuated or distorted (Ciccarelli et al. 2013). Research has emphasized that fragmentation impairs the credit channel (Al-Eyd and Berkmen 2013) and that the interplay between monetary and macroprudential policies becomes especially complex under heightened uncertainty (Cozzi et al. 2020). If monetary transmission is weaker in economies already under financial pressure, then a single interest rate set in Frankfurt may provide insufficient stabilization for some member states while proving excessively restrictive for others.

This work project investigates whether the strength of monetary policy transmission differs systematically between Northern and Southern European countries depending on the prevailing level of financial stress. The empirical strategy combines several methodological approaches. First, I employ a Panel Threshold Model, building on Hansen (1999), to endogenously identify distinct financial stress regimes and estimate regime-specific transmission coefficients. Second, identified monetary policy shocks are constructed using the high-frequency approach of Jarociński and Karadi (2020), which disentangles pure policy surprises from central bank information effects. Third, I trace the dynamic propagation of these shocks using Local Projections (Jordà 2005), a flexible method that accommodates state-dependent responses. The sample spans 2001Q1 to 2019Q4, capturing critical stress episodes including the Global Financial Crisis and the Sovereign Debt Crisis.

The contribution of this work is threefold. First, it provides regime-dependent estimates of monetary transmission that capture how policy effectiveness varies with the financial environment. Second, it documents cross-country asymmetries that illuminate the challenges faced by the ECB in conducting a single monetary policy for structurally diverse economies. Third, it offers policy-relevant insights into the conditions under which fragmentation risks are most acute and transmission most impaired.

The remainder of this work project is organized as follows. Section 2 reviews the literature on monetary policy transmission, state-dependent effects, and heterogeneity in currency unions. Section 3 describes the data sources and variable construction. Section 4 presents the econometric methodology. Section 5 reports the empirical results. Section 6 discusses robustness and policy implications. Section 7 concludes.

2 Literature Review

The monetary transmission mechanism describes how central bank policy decisions affect real economic activity and inflation. While considerable progress has been made in understanding this process, the literature increasingly recognizes that transmission effectiveness may vary across different economic states and institutional contexts. This section reviews three interconnected strands of research: the foundations of monetary transmission, evidence on state-dependent effectiveness under financial stress, and heterogeneity in transmission across euro area member states.

2.1 The Monetary Transmission Mechanism

Central bank policy operates primarily through changes in short-term interest rates, which affect the real cost of capital, exchange rates, income, wealth and ultimately influencing aggregate demand. Arnold (2001) emphasizes that regions or countries may differ in their sensitivity to interest rate changes due to variations in industrial structure, financial development, and trade openness. While the interest rate channel provides the primary mechanism, Bernanke and Gertler (1995) demonstrate how credit market imperfections amplify conventional interest rate effects through the external finance premium faced by borrowers. This amplification creates potential for heterogeneity in transmission, as economies differ in their dependence on bank credit and the financial health of borrowers and lenders.

For the purposes of examining whether transmission varies across financial stress regimes, a reduced-form specification capturing the aggregate policy effect proves more appropriate than decomposing specific channels. The short-term interest rate aggregates effects operating through all transmission mechanisms, allowing focus on state-dependent changes in overall transmission effectiveness.

2.2 State-Dependent Transmission and Financial Stress

A growing body of research documents that monetary policy effectiveness varies across different economic states, particularly depending on financial stress levels. Holló et al. (2012) develop the Composite Indicator of Systemic Stress (CISS) to capture moments when stress is present simultaneously across multiple financial market segments. Their threshold vector autoregression analysis reveals that while financial stress shocks produce no statistically significant output effects during low-stress regimes, industrial production collapses during high-stress regimes. This state-dependence suggests that economies may enter vicious downward spirals where financial and economic stress reinforce each other through financial accelerator mechanisms.

The implications for monetary policy are significant but complex. Ciccarelli et al. (2013) find that monetary policy impact on aggregate output strengthens at the height of financial crises, as higher financial frictions increase the marginal effect of policy shocks. However, this heightened sensitivity coexists with impaired transmission channels: central banks may find it harder to engineer desired changes in credit conditions precisely when borrowers become most sensitive to those conditions.

Econometric identification of state-dependent relationships requires appropriate methodological tools. Hansen (1999) develops the Panel Threshold Model, which estimates threshold parameters jointly with regime-specific slope coefficients using a grid search procedure that minimizes the sum of squared residuals. The framework provides formal statistical inference on threshold parameters through non-standard asymptotic theory, allowing data-driven identification of regime changes. Kremer et al. (2013) extend this methodology to dynamic panel contexts with endogenous regressors, demonstrating its power in identifying nonlinear relationships in growth and inflation dynamics. Building on these methodological advances, Floro and Roye (2017) apply factor-augmented dynamic panel threshold regressions to examine whether central bank responses to financial stress exhibit threshold effects. They find strong evidence that advanced economy central banks respond aggressively to stock market and banking stress, but only during high financial volatility states, a pattern consistent with state-dependent policy effectiveness.

Recent work has expanded the scope of fiscal-monetary interactions in constrained policy environments. Brandao-Marques et al. (2023) demonstrate that high government debt levels may constrain monetary policy effectiveness by examining the impact of debt surprises on inflation expectations. They find that debt surprises raise long-term inflation expectations persistently in emerging market economies but not in advanced economies, suggesting that fiscal conditions interact with monetary transmission in state-dependent ways. This fiscal dimension adds further complexity to understanding when and how monetary policy operates most effectively.

2.3 Heterogeneous Transmission in the Euro Area

The creation of the euro area brought together economies with heterogeneous financial structures under a single monetary policy, raising fundamental questions about uniform transmission. Ciccarelli et al. (2013) document that while earlier financial integration ensured relatively homogeneous ECB monetary policy transmission, the global financial crisis and subsequent sovereign debt crisis caused these interconnections to break down substantially. Countries under sovereign stress (Greece, Ireland, Italy, Portugal, and Spain) experienced markedly higher sovereign spreads and increasingly relied on ECB liquidity provision, creating asymmetric, demand-driven transmission across member states. Their analysis shows that the GDP impact of monetary policy shocks became substantially larger for sovereign-stressed countries, particularly after May 2010, reflecting not improved policy effectiveness but rather the amplification of shocks through binding credit constraints and elevated financial frictions.

Corsetti et al. (2020) provide complementary evidence on transmission heterogeneity using a structural dynamic factor model with high-frequency shock identification. Their analysis reveals a striking dichotomy: while responses are remarkably uniform for financial variables and output, significant heterogeneity emerges for consumption, consumer prices, and variables related to housing and labour markets. Crucially, they trace this heterogeneity to structural characteristics, the share of adjustable mortgage contracts, homeownership rates, shares of hand-to-mouth and wealthy hand-to-mouth consumers, and wage rigidity that vary substantially between Northern and Southern European economies. These findings suggest that transmission heterogeneity stems not merely from cyclical financial conditions but from deeper institutional and structural differences that shape how monetary shocks propagate through member economies.

The suitability of the PTM for examining North–South heterogeneity stems from its ability to exploit both cross-sectional and temporal variation while controlling for country-specific fixed effects. The twelve original euro area members share a common monetary policy but differ substantially in financial structures, institutional frameworks, and historical susceptibility to sovereign debt tensions. By pooling these countries within a threshold framework, one can estimate regime-specific transmission coefficients that apply across the panel while allowing the data to determine endogenously the stress levels at which transmission changes. This approach enhances statistical power relative to country-by-country estimation and enables formal comparison of transmission patterns between Northern and Southern European economies.

2.4 Research Contribution

The existing literature has predominantly employed VAR models with Markov-switching or threshold specifications, or has focused on decomposing transmission through specific credit channels. This study contributes by combining Hansen's (1999) PTM with high-frequency identified monetary policy shocks to examine transmission heterogeneity in the euro area under different financial stress regimes, a methodological combination not previously employed in this context. The threshold is endogenously determined from the data rather than imposed a priori, providing objective identification of critical CISS levels at which transmission fundamentally changes. By employing a reduced-form specification that captures the aggregate effect of monetary policy on GDP growth, this study complements the channel-focused VAR literature by directly addressing the policy-relevant question: at what level of financial stress does monetary transmission to the real economy significantly change?

The North-South comparison extends this analysis to examine whether documented euro area heterogeneity is itself state-dependent, testing whether the gap in policy effectiveness widens during periods of elevated financial stress. This addresses a gap in the literature, as existing studies have examined either state-dependence or regional heterogeneity, but not the interaction between these dimensions. The methodological combination of the PTM for regime identification with Local Projections (Jordà, 2005) for dynamic analysis provides a comprehensive analytical strategy: the former identifies stress thresholds and estimates regime-specific transmission coefficients, while the latter traces how these effects unfold dynamically over time. This dual approach illuminates both when transmission changes (threshold effects) and how these changes persist through financial accelerator mechanisms, informing both academic understanding and ECB policy design.

3 Data

This study employs a balanced quarterly panel dataset covering the twelve founding euro area member countries from 2001Q1 to 2019Q4, yielding 912 country-quarter observations. The sample includes Austria, Belgium, Germany, Spain, Finland, France, Greece, Ireland, Italy, Luxembourg, the Netherlands, and Portugal. The period captures both tranquil conditions and major stress episodes including the global financial crisis and European sovereign debt crisis providing substantial variation in financial stress necessary for threshold identification. The sample ends in 2019Q4 to avoid structural breaks from the COVID-19 pandemic and associated unconventional policy responses.

3.1 Variables and Data Sources

The Dependent Variable is the Real GDP growth ($\Delta y_{i,t}$) measured as the year-on-year percentage change in gross domestic product at constant prices, obtained from the ECB Statistical Data Warehouse (ECB Data Portal 2025). This transformation filters seasonal patterns while preserving business cycle dynamics relevant to monetary transmission analysis.

Monetary policy is measured using high-frequency identified shocks constructed by Jarociński and Karadi (2020), obtained from the Euro Area Monetary Policy Database (Altavilla et al. 2019). These shocks are extracted via a structural VAR with sign restrictions that separate pure monetary policy shocks from central bank information shocks: pure policy shocks move interest rates and stock prices in opposite directions, while information shocks move both in the same direction. The authors compute these shocks at monthly frequency (1999–2023); I use the subset corresponding to my sample period (2001Q1–2019Q4) and aggregate to quarterly frequency by summing monthly shocks within each quarter. This identification ensures that estimated transmission effects capture responses to exogenous policy actions rather than information released by the central bank, addressing a fundamental endogeneity concern in monetary policy analysis.

Financial stress is used as the threshold variable and measured by the Composite Indicator of Systemic Stress (CISS) developed by Holló et al. (2012) and published by the ECB. The CISS aggregates fifteen stress indicators from five financial market segments (money markets, bond markets, equity markets, foreign exchange markets, and financial intermediaries) using a portfolio-based method that accounts for time-varying cross-correlations. This design captures systemic stress episodes when stress is present simultaneously across multiple markets. The indicator ranges from zero (no stress) to one (maximum stress). I use quarter-average values and enter the CISS with one lag ($CISS_{t-1}$) to ensure regime classification is predetermined relative to contemporaneous GDP growth.

Two lagged control variables isolate the transmission of monetary policy from confounding dynamics. Inflation ($\pi_{i,t-1}$) is measured as year-on-year HICP inflation from ECB SDW, controlling for price dynamics that central banks systematically respond to. Fiscal stance ($\Delta Debt_{i,t-1}$) is the first difference of the General Government Debt-to-GDP ratio from ECB Data Portal (2025). Differencing ensures stationarity, the level series is non-stationary and captures quarterly changes in fiscal stance. Both variables are lagged to avoid simultaneity bias. Table 3.1 summarizes variable definitions, notation, and sources.

Table 3.1: Variable Definitions and Data Sources

Variable	**Notation**	**Definition**	**Source**
GDP Growth	$\Delta y_{i,t}$	Year-on-year real GDP growth (%)	ECB SDW
MP Shock	MP_shock_t	Jarociński & Karadi (2020) shock, quarterly sum	EA-MPD
Financial Stress	$CISS_{t-1}$	Composite Indicator of Systemic Stress, lagged	ECB SDW
Inflation	$\pi_{i,t-1}$	Year-on-year HICP inflation (%), lagged	ECB SDW
Fiscal Stance	$\Delta Debt_{i,t-1}$	First difference of Debt-to-GDP (pp), lagged	ECB SDW

Notes: All variables at quarterly frequency. Sample: 12 euro area countries, 2001Q1–2019Q4, 912 observations. ECB SDW = European Central Bank Statistical Data Warehouse; EA-MPD = Euro Area Monetary Policy Database; pp = percentage points.

3.2 Summary Statistics

Table 3.2 presents summary statistics. GDP growth exhibits substantial variation, ranging from −17.6% to 28.1%, reflecting severe crisis contractions and subsequent rebounds. The monetary policy shock variable displays a mean of 0.43 basis points with considerable volatility. The lagged CISS averages 0.20, indicating relatively low stress on average, though it reaches 0.74 during peak crisis episodes. Inflation averages 1.8% annually, close to the ECB's target. The first difference of debt-to-GDP averages an increase of 0.34 percentage points per quarter, capturing both fiscal consolidation and crisis-period deteriorations. Sample sizes for lagged variables (888–900) reflect the loss of initial observations when constructing lags and differences.

Table 3.2: Summary Statistics (2001Q1–2019Q4)

Variable	Mean	SD	Min	Max	N
GDP Growth (T)	1.607	3.272	−17.600	28.100	912
MP Shock J&K (T)	0.434	2.032	−3.137	7.591	912
CISS (T−1)	0.196	0.162	0.045	0.739	900
HICP (T−1)	1.818	1.337	−2.767	5.600	900
Δ Govt Debt/GDP (T−1)	0.337	2.684	−33.711	16.279	888

Notes: GDP Growth is year-on-year real GDP growth. MP Shock J&K refers to Jarociński & Karadi (2020) identified shocks (1 unit = 1 basis point). CISS is the Composite Indicator of Systemic Stress (quarter-average). HICP is year-on-year inflation. Δ Govt Debt/GDP is the first difference of the debt-to-GDP ratio in percentage points. Control variables and the threshold variable are lagged one period.

This dataset combines macroeconomic fundamentals with high-frequency policy shock identification and a comprehensive financial stress measure, providing the empirical foundation for examining state-dependent monetary policy transmission. The use of identified shocks addresses endogeneity inherent in policy rate levels, while the panel structure exploits both cross-country and time-series variation to identify regime-specific transmission patterns with enhanced statistical power.

4 Methodology

This section presents the econometric framework for investigating state-dependent monetary policy transmission in the euro area. The empirical strategy combines two complementary approaches: the Panel Threshold Model (PTM) of Hansen (1999) to identify distinct financial stress regimes and estimate regime-specific transmission coefficients, and Local Projections (Jordà 2005) to trace dynamic impulse response functions across these regimes.

4.1 The Panel Threshold Model

4.1.1 Model Specification

The PTM developed by Hansen (1999) extends classical panel regression to accommodate discrete regime changes in coefficients based on an observable threshold variable. Unlike smooth transition models, the PTM assumes that regression parameters shift abruptly when the threshold variable crosses endogenously estimated critical values, a specification well-suited to the hypothesis that monetary policy transmission operates through fundamentally different mechanisms during financial tranquility versus stress, consistent with the financial accelerator theory.

Consider a balanced panel of $N = 12$ euro area countries observed over $T = 76$ quarters. The single-threshold model takes the form,

$$y_{it} = \mu_i + \beta_1' x_{it} \cdot \mathbb{I}(q_{t-1} \leq \gamma) + \beta_2' x_{it} \cdot \mathbb{I}(q_{t-1} > \gamma) + \delta' z_{it-1} + \varepsilon_{it} \tag{4.1}$$

where y_{it} denotes year-on-year GDP growth for country i in quarter t; μ_i represents country fixed effects absorbing time-invariant heterogeneity; x_{it} contains regime-dependent regressors whose coefficients vary across financial stress states; q_{t-1} is the lagged Composite Indicator of Systemic Stress (CISS) serving as the threshold variable; γ is the threshold parameter to be estimated; z_{it-1} includes regime-independent controls (lagged HICP inflation and lagged first difference of debt-to-GDP); and $\mathbb{I}(\cdot)$ is the indicator function. Crucially, only the coefficients on x_{it} are regime-dependent; the fixed effects μ_i, the control coefficients δ, and the error structure remain constant across regimes.

The regime-dependent regressors x_{it} include the Jarociński and Karadi (2020) monetary policy shock, interacted separately with Northern and Southern Europe indicators to capture regional transmission heterogeneity. The use of lagged values for the threshold variable and controls ensures that regime classification is predetermined relative to the dependent variable, addressing simultaneity concerns.

The model extends naturally to multiple thresholds. For a triple-threshold specification with four regimes. The model is,

$$\begin{aligned} y_{it} = \mu_i + \beta_1' x_{it} \cdot \mathbb{I}(q_{t-1} \leq \gamma_1) + \beta_2' x_{it} \cdot \mathbb{I}(\gamma_1 < q_{t-1} \leq \gamma_2) \\ + \beta_3' x_{it} \cdot \mathbb{I}(\gamma_2 < q_{t-1} \leq \gamma_3) + \beta_4' x_{it} \cdot \mathbb{I}(q_{t-1} > \gamma_3) + \delta' z_{it-1} + \varepsilon_{it} \end{aligned} \tag{4.2}$$

where $\gamma_1 < \gamma_2 < \gamma_3$ partition the sample into low stress, moderate stress, moderate-high stress, and high stress regimes.

4.1.2 Regional Heterogeneity

To test hypotheses regarding North-South differences in transmission, the regime-dependent regressors include separate regional interactions. Let N_i denote an indicator for Northern European countries (Austria, Belgium, Germany, Finland, France, Ireland, Luxembourg, and the Netherlands) and S_i for Southern countries (Spain, Greece, Italy, and Portugal). The regime-dependent coefficient vector for regime r is,

$$\beta_r' x_{it} = \beta_r^{MP,N} \cdot MP\_shock_t \times N_i + \beta_r^{MP,S} \cdot MP\_shock_t \times S_i. \tag{4.3}$$

This specification yields separate regime-specific transmission coefficients for Northern ($\beta_r^{MP,N}$) and Southern ($\beta_r^{MP,S}$) countries, enabling direct comparison of transmission strength across regions within each financial stress regime.

4.1.3 Estimation and Inference

Estimation proceeds by eliminating country fixed effects through within-transformation: define demeaned variables $\tilde{y}_{it} = y_{it} - \bar{y}_i$, where $\bar{y}_i = T^{-1} \sum_{t=1}^{T} y_{it}$, and apply analogous transformations to all regressors. The transformed model is then estimated by ordinary least squares conditional on candidate threshold values.

Since the model is linear in parameters conditional on γ, threshold estimation employs a grid search procedure. For each candidate threshold value γ in a predetermined grid, the model is estimated by OLS and the sum of squared residuals $S(\gamma)$ is computed. The threshold estimate is,

$$\hat{\gamma} = \arg\min_{\gamma \in \Gamma} S(\gamma). \tag{4.4}$$

Following Hansen (1999), the grid is constructed from distinct values of the threshold variable, with extreme quantiles trimmed (5 percent) to ensure sufficient observations in each regime.

Testing for threshold presence requires evaluating $H_0 : \beta_1 = \beta_2$ against $H_1 : \beta_1 \neq \beta_2$. The likelihood ratio statistic is $F_1 = (S_0 - S_1(\hat{\gamma}))/\hat{\sigma}^2$, where S_0 is the sum of squared residuals under the null and $S_1(\hat{\gamma})$ under the alternative. Following Hansen (1999), $\hat{\sigma}^2$ is computed under the assumption of homoskedastic errors across regimes, which ensures the validity of the bootstrap inference procedure. The asymptotic distribution of F_1 is nonstandard; we employ Hansen (1999) bootstrap procedure, resampling residuals with replacement at the country level to approximate the sampling distribution. The bootstrap p-value is computed as the proportion of 1,000 bootstrap statistics exceeding the actual test statistic.

Sequential testing for additional thresholds follows analogously: after establishing one threshold, the test for a second threshold conditions on the first estimate, with the procedure continuing until no additional threshold is detected. Confidence intervals for threshold parameters are constructed by inverting the likelihood ratio test: $LR(\gamma) = (S(\gamma) - S(\hat{\gamma}))/\hat{\sigma}^2$. Following Hansen (1999, Theorem 1), the asymptotic distribution of this statistic is non-standard but pivotal, with inverse distribution function $c(\alpha) = -2\log(1 - \sqrt{1-\alpha})$. A 95 percent confidence interval comprises all values of γ for which $LR(\gamma) \leq 7.35$, where 7.35 is obtained by evaluating this formula at $\alpha = 0.95$.

4.1.4 Identification and Limitations

The PTM identifies regime-specific transmission coefficients through temporal variation in the threshold variable and cross-sectional variation in how countries respond to monetary policy within each regime. Identification is strengthened by: (i) using lagged CISS as the threshold variable, ensuring predetermined regime classification; (ii) exploiting the panel dimension to estimate region-specific coefficients despite using an aggregate euro area stress indicator and (iii) substantial time-series variation in financial stress across the 2001Q1–2019Q4 sample, which encompasses the global financial crisis and European sovereign debt crisis.

The framework assumes non-dynamic panels with strictly exogenous regressors. The use of high-frequency identified monetary policy shocks from Jarociński and Karadi (2020) addresses endogeneity concerns, as these shocks are orthogonal to contemporaneous economic conditions and central bank information. The ECB's single monetary policy stance determined by euro area aggregates rather than individual country conditions further supports the exogeneity assumption for country-level outcomes. The framework imposes common thresholds across all panel units, which may be restrictive if countries experience threshold effects at different stress levels, though the regional heterogeneity specification partially accommodates this concern.

4.2 Local Projections

While the PTM provides regime-specific estimates of contemporaneous transmission, it cannot reveal how these effects evolve dynamically over time. To address this limitation, I complement the static threshold analysis with Local Projections (Jordà 2005), which estimate impulse response functions directly through horizon-specific regressions rather than by iterating a VAR system forward.

The Local Projections method regresses GDP growth at horizon h on current monetary policy shocks, control variables, and fixed effects, i.e,

$$y_{i,t+h} = \alpha_h^r + \beta_h^r \cdot MP\_shock_t + \gamma_h' \cdot z_{i,t} + \mu_i + \varepsilon_{i,t+h} \tag{4.5}$$

where $y_{i,t+h}$ is GDP growth at horizon $h = 0, 1, 2, \ldots, 12$ (up to three years ahead), α_h^r is a regime-specific intercept, β_h^r is the regime-specific impulse response coefficient at horizon h, and μ_i represents country fixed effects. Separate regressions are estimated for each horizon and for each region (North and South) within each regime identified by the PTM.

This approach offers three key advantages over VAR-based IRFs. First, each horizon is estimated independently, avoiding cumulative misspecification errors from an incorrectly specified dynamic system. Second, standard errors are computed directly without delta-method approximations, facilitating straightforward inference with Driscoll-Kraay standard errors robust to heteroskedasticity, autocorrelation, and cross-sectional dependence. Third, regime-dependent heterogeneity is incorporated simply by estimating separate LP regressions within each regime, allowing direct visualization of how transmission evolves over time and whether regional asymmetries intensify or attenuate dynamically.

We focus the Local Projections analysis on Regime 3 (moderate-high stress), where the PTM identifies the largest North-South transmission gap, estimating 12-quarter-ahead impulse responses to assess whether the documented state-dependent heterogeneity represents a transitory impact effect or persists through financial accelerator mechanisms. This dynamic perspective completes the empirical narrative, transforming static regime-specific estimates into a full characterization of how monetary policy shocks transmit across regions, regimes, and time.

5 Results

This section presents empirical findings on state-dependent monetary policy transmission heterogeneity in the euro area. The analysis tests whether transmission differences between Northern and Southern European countries depend on financial stress conditions, using high-frequency identified monetary policy shocks from Jarociński and Karadi (2020), the Composite Indicator of Systemic Stress (CISS) as the threshold variable and Hansen (1999) PTM, complemented by Local Projections Jordà (2005).

5.1 Threshold Estimation and Regime Identification

We implement Hansen's (1999) sequential testing procedure to determine the optimal number of thresholds. Table 5.1 reports likelihood ratio test statistics based on 1,000 bootstrap replications with 5% trimming. The single-threshold specification does not significantly improve over the linear model (LR = 26.59, p = 0.403), and the double-threshold specification does not significantly improve over the single-threshold model (LR = 53.74, p = 0.128). However, the triple-threshold model provides highly significant improvement over the double-threshold specification (LR = 69.53, $p < 0.001$). This pattern suggests that monetary policy transmission exhibits a complex, multi-regime structure that simpler threshold specifications cannot adequately capture. We therefore adopt the triple threshold specification, identifying four distinct financial stress regimes.

Table 5.1: Sequential Likelihood Ratio Tests for Threshold Effects

Model	Null Hypothesis	LR Stat	Boot. p	Decision
Single	No threshold (linear)	26.59	0.403	Accept H_0
Double	One threshold	53.74	0.128	Accept H_0
Triple	Two thresholds	69.53	0.000	Reject H_0

Note: Bootstrap p-values based on 1,000 replications. The triple threshold specification is selected.

The grid search procedure identifies three threshold values: $\hat{\gamma}_1 = 0.085$ (95% CI: [0.085, 0.085]), $\hat{\gamma}_2 = 0.337$ (95% CI: [0.321, 0.360]), and $\hat{\gamma}_3 = 0.429$ (95% CI: [0.429, 0.429]). Notably, the confidence intervals for $\hat{\gamma}_1$ and $\hat{\gamma}_3$ collapse to their point estimates, indicating that these thresholds are precisely identified in the data. As Hansen (1999) shows, this occurs when regime-switching effects are large, causing the likelihood ratio function to peak sharply at the threshold estimate. The likelihood ratio functions from the sequential testing procedure are presented in Appendix A (Figures .1–.3). These thresholds partition the sample into four financial stress regimes: Regime 1 (Very Low Stress, CISS < 0.085, 29% of observations), Regime 2 (Low-Moderate Stress, CISS $\in [0.085, 0.337)$, 51%), Regime 3 (Moderate-High Stress, CISS $\in [0.337, 0.429)$, 11%), and Regime 4 (Systemic Crisis, CISS ≥ 0.429, 9%). The estimated thresholds align with major euro area financial events: Regime 3 encompasses the Lehman aftermath and much of the European sovereign debt crisis, while Regime 4 captures the peak Global Financial Crisis and most severe sovereign crisis phases. The evolution of the CISS over the sample period is illustrated in Appendix B.

5.2 Regime-Specific Transmission Coefficients

Both control variables behave as expected, as shown in Table 5.2, lagged HICP inflation displays a negative but statistically insignificant association with GDP growth. In contrast, the first difference of the government debt-to-GDP ratio exhibits a strongly significant negative effect, indicating that increases in public indebtedness are systematically linked to weaker subsequent output performance. These controls enter linearly and do not vary across financial stress regimes.

Table 5.2: Regime-independent controls (constant across all regimes)

Variable	Coefficient	White SE	t-statistic	Significance
HICP (T−1)	-0.094	0.088	-1.07	
Δ Govt Debt/GDP (T−1)	-0.420	0.115	-3.65	***

Note: Dependent variable: GDP growth (year-on-year %). White heteroskedasticity-robust standard errors. *** p<0.01, ** p<0.05, * p<0.10. Coefficients represent percentage point change in GDP growth per unit monetary policy shock.

Table 5.3: Regime-Dependent Monetary Policy Transmission by Region

Regime	CISS Range	Region	Coefficient	White SE	t-statistic	Significance
Regime 1	< 0.085	North	−0.556	0.138	−4.02	***
		South	−0.401	0.130	−3.09	***
Regime 2	$[0.085, 0.337)$	North	0.021	0.066	0.32	
		South	0.128	0.084	1.53	
Regime 3	$[0.337, 0.429)$	North	−0.346	0.167	−2.07	**
		South	−2.443	0.807	−3.03	***
Regime 4	≥ 0.429	North	−0.486	0.150	−3.23	***
		South	−0.265	0.120	−2.20	**

Note: Dependent variable: GDP growth (year-on-year %). White heteroskedasticity-robust standard errors. *** p<0.01, ** p<0.05, * p<0.10. Coefficients represent percentage point change in GDP growth per unit monetary policy shock.

As shown in Table 5.3, three key patterns emerge from the regime-dependent transmission coefficients. First, monetary policy transmission is highly state-dependent, with coefficients varying dramatically across regimes. Second, regional heterogeneity depends critically on the prevailing stress environment. Third, while Regimes 1, 3, and 4 exhibit significant transmission effects, Regime 2 (containing 51% of observations) shows no statistically significant transmission for either region, likely reflecting limited power to detect effects during normal business cycle fluctuations where other factors dominate GDP variation.

The most dramatic asymmetry emerges in Regime 3, where Southern countries experience an extremely large contractionary effect (−2.443, t= −3.03) seven times larger than Northern countries (−0.346, t= −2.07), representing a 2.10 percentage point differential. This regime, encompassing the European sovereign debt crisis, represents the critical zone for understanding North-South divergence. The disproportionate Southern response likely reflects financial accelerator mechanisms: sovereign-bank doom loops, credit rationing in peripheral economies, capital flight to core countries, and balance sheet vulnerabilities that amplify monetary tightening.

5.3 Hypothesis Testing: Regional Heterogeneity and State-Dependent Amplification

5.3.1 H1: Baseline Regional Heterogeneity

We test whether transmission coefficients differ significantly between North and South within each regime: $H_0 : \beta_j^{North} = \beta_j^{South}$ for regime j. Table 5.4 presents results across all four regimes.

Table 5.4: Regional Heterogeneity Tests Across Financial Stress Regimes

Regime	CISS Range	North	South	Diff(S-N)	t-stat	Result
1: Very Low	< 0.085	−0.556	−0.401	0.155	0.82	No difference
2: Low-Mod	$[0.085, 0.337)$	0.021	0.128	0.107	1.00	No difference
3: Mod-High	$[0.337, 0.429)$	−0.346	−2.443	−2.097	−2.55	**REJECT H0****
4: Crisis	≥ 0.429	−0.486	−0.265	0.221	1.15	No difference

Note: ** p<0.05. Regional heterogeneity is state-dependent: significant North-South differences emerge exclusively in Regime 3 (t = −2.55, p = 0.011). The differential of −2.10 pp indicates Southern GDP contracts seven times more than Northern GDP in response to identical monetary tightening during moderate-high stress.

Regional heterogeneity in monetary policy transmission is state-dependent. Statistically significant North-South differences emerge exclusively in Regime 3 (t = −2.55, p = 0.011), where Southern GDP responds seven times more strongly than Northern GDP. The three other regimes exhibit no significant regional differences. This reveals that the North-South asymmetry is a regime-specific phenomenon that activates when financial frictions bind in peripheral economies without reaching full systemic collapse. This finding aligns with Ciccarelli et al. (2013), who document that the monetary transmission mechanism is time-varying and amplified by the financial fragility of sovereigns, banks, and firms, particularly in stressed euro area countries where credit constraints and balance sheet channels become binding.

5.3.2 H2: Directional Attenuation

Having established that heterogeneity exists specifically in Regime 3, we test whether financial stress amplifies transmission asymmetrically by comparing the change in coefficients as the economy transitions from Regime 2 (Low-Moderate Stress) to Regime 3 (Moderate-High Stress). Define $\Delta^{Region} = \beta^{Region,R3} - \beta^{Region,R2}$. The directional attenuation hypothesis predicts Southern transmission deteriorates more: $H_0 : \Delta^{South} = \Delta^{North}$ versus $H_1 : \Delta^{South} - \Delta^{North} < 0$. Table 5.5 presents the results.

Table 5.5: Directional Attenuation Test: Regime 2 → Regime 3 Transition

	Regime 2 (Low-Mod)	**Regime 3** (Mod-High)	**Change** (Δ)	
Northern Europe	0.021	−0.346	−0.367	
Southern Europe	0.128	−2.443	−2.571	
Differential Deterioration	South − North:		−2.204	***
	p-value (one-sided):		0.004	

Note: *** p<0.01. As financial stress transitions from low-moderate to moderate-high, Southern transmission deteriorates 2.20 pp more than Northern transmission (t = −2.65, p = 0.004, one-sided), confirming directional attenuation.

The test provides strong evidence for directional attenuation (t = −2.65, p = 0.004). Northern transmission deteriorates modestly by 0.37 percentage points when stress rises, while Southern transmission deteriorates dramatically by 2.57 percentage points. This asymmetric response reveals why regional heterogeneity manifests specifically in Regime 3: both regions experience deteriorating transmission, but the deterioration is six times larger in Southern Europe. This finding supports the ”sovereign-bank nexus” hypothesis documented by Cantero-Sáiz et al. 2016, where higher sovereign risk in peripheral economies tightens bank lending conditions disproportionately. Furthermore, it aligns with Gilchrist et al. 2023, who show that financial heterogeneity and balance-sheet constraints in the periphery amplify the adverse effects of monetary and financial shocks.

5.4 Local Projections: Dynamic Validation

To assess whether state-dependent heterogeneity persists dynamically, we estimate Local Projections tracing impulse responses over 12 quarters. Figure 5.1 displays results for Regime 3, where the PTM identified significant North-South transmission differences. Results for the remaining regimes are presented in Appendix E.

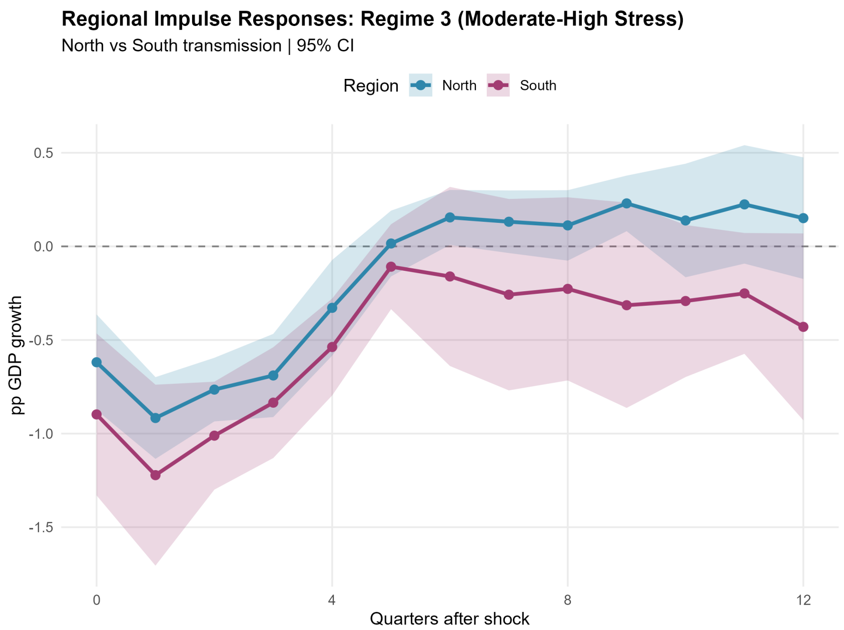

Figure 5.1: Regional Impulse Responses in Regime 3 (Moderate-High Stress)
Note: Impulse responses to one-unit monetary policy shock estimated via Local Projections. Lines represent point estimates; shaded areas denote 95% confidence intervals. Blue: Northern Europe; pink: Southern Europe. The North-South gap persists over the full 12-quarter horizon, with Northern countries beginning recovery by 15 to 18 months while Southern countries remain in contractionary territory through three years.

The Local Projections analysis validates the PTM findings. In Regime 3, the initial North-South gap persists and evolves over the full 12-quarter horizon, with Northern countries beginning recovery by 15–18 months while Southern countries remain in negative territory through three years. This multi-quarter persistence confirms that the massive contemporaneous amplification identified in the PTM translates into sustained output divergence. In contrast, Regimes 1, 2, and 4 show no statistically significant North-South gaps at any horizon, confirming that regional heterogeneity is specifically a Regime 3 phenomenon.

6 Robustness, Limitations and Future Extensions

This section addresses methodological limitations of the baseline PTM specification and outlines promising avenues for future research. While the empirical findings particularly the large North-South transmission gap in Regime 3 (moderate-high stress) emerge robustly across both the static threshold analysis and the complementary Local Projections estimates, several extensions could strengthen inference and assess the sensitivity of results to alternative econometric assumptions.

6.1 Standard Errors and Cross-Sectional Dependence

The baseline PTM estimates employ White heteroskedasticity-robust standard errors, which account for heteroskedasticity across panel units but ignore two potentially important sources of dependence in the error structure. First, euro area countries share common monetary policy shocks and face correlated macroeconomic developments, inducing cross-sectional dependence in regression residuals. Second, GDP growth exhibits serial correlation, as output adjustments following monetary policy shocks unfold gradually over multiple quarters. Ignoring these dependencies may lead to underestimated standard errors and overstated statistical significance, particularly for coefficients estimated from regimes with fewer observations.

A natural robustness extension would re-estimate the model using Driscoll and Kraay (1998) standard errors, which are robust to general forms of cross-sectional and temporal dependence in panel data. This approach constructs a nonparametric covariance matrix estimator that accounts for both spatial correlation across countries and serial correlation within countries, yielding valid inference even when residuals exhibit complex dependence structures. Alternatively, clustering standard errors at the country level would address within-country serial correlation while allowing for arbitrary heteroskedasticity and autocorrelation within clusters.

Implementing these alternative inference procedures represents a straightforward robustness check that would assess whether the central empirical findings especially the highly significant 2.10 percentage point North-South differential in Regime 3 ($t = -2.55$, $p = 0.011$), survive more conservative inference. While the economic magnitude of the estimated asymmetry is unlikely to change, the statistical significance could weaken if cross-sectional dependence or serial correlation is substantial. Given the strong rejection of the null hypothesis in the baseline specification, however, we expect the core finding of state-dependent regional heterogeneity to remain statistically significant under alternative standard error specifications.

6.2 Static versus Dynamic Panel Threshold Models

The baseline empirical framework follows Hansen's (1999) static PTM, which estimates contemporaneous effects of monetary policy shocks on GDP growth conditional on the prevailing financial stress regime. This specification implicitly assumes that lagged GDP growth does not directly influence current growth beyond the indirect channels captured by control variables and fixed effects. While the static framework offers computational simplicity and transparent interpretation, it may fail to capture the persistence in output dynamics and the potential for lagged dependent variables to interact with regime-switching behavior. A natural methodological extension would estimate a dynamic panel threshold model following Kremer et al. (2013), which allows for lagged dependent variables and potentially endogenous regressors while maintaining threshold effects in the relationship between monetary policy and output. The dynamic specification takes the form,

$$y_{it} = \mu_i + \rho y_{i,t-1} + \beta_r(q_{t-1})' x_{it} + \delta' z_{it-1} + \varepsilon_{it} \tag{6.1}$$

where the autoregressive coefficient ρ captures output persistence and the threshold function $\beta_r(q_{it-1})$ permits regime-dependent monetary policy effects. Estimation proceeds via GMM using forward orthogonal deviations to eliminate fixed effects while preserving instrument validity and addressing the endogeneity of lagged dependent variables.

This extension would serve two purposes. First, it would assess whether the documented state-dependent heterogeneity particularly the large North-South gap in Regime 3 persists, once richer adjustment dynamics are explicitly modeled. If the static specification omits important dynamic interactions between lagged growth and regime transitions, the estimated regime-specific coefficients could be biased. Second, the dynamic framework would provide estimates of output persistence that vary across financial stress regimes, potentially revealing whether adjustment speeds differ between Northern and Southern economies under different stress conditions.

However, dynamic panel threshold estimation is computationally demanding and requires careful treatment of multiple sources of endogeneity simultaneously. The combination of threshold nonlinearities, lagged dependent variables, country fixed effects, and potentially endogenous regressors poses significant identification challenges. For these reasons, we leave the dynamic extension to future research, noting that the broad agreement between our static threshold estimates and the horizon-specific Local Projections results which inherently capture dynamic adjustment provides some reassurance that omitted dynamics are not driving the main findings.

6.3 Sample Period and External Validity

The empirical analysis restricts the sample period to 2001Q1 to 2019Q4, deliberately excluding the COVID-19 pandemic and subsequent recovery. This choice reflects a trade-off between structural stability and external validity. By ending the sample in 2019Q4, we avoid extraordinary disruptions, including simultaneous supply and demand shocks, unprecedented fiscal interventions, and zero lower bound constraints with large-scale asset purchases, that fundamentally altered monetary transmission mechanisms in ways inconsistent with the threshold framework.

However, this sample restriction limits the external validity of our findings to the pre-pandemic monetary policy regime. Two complementary extensions would assess robustness to alternative sample specifications. First, re-estimating the model including the COVID-19 and post-pandemic periods would test whether the identified thresholds and North-South transmission patterns remain stable. Second, updating the sample through 2024 to 2025 would incorporate the high-inflation, rapid-tightening environment that emerged in 2022 to 2023, offering valuable variation that differs from the accommodative policy environment characterizing much of 2014 to 2019. Examining whether the estimated CISS thresholds continue to delineate regimes with distinct transmission properties would strengthen confidence in the generalizability of our estimates.

The main trade-off involves complexity versus interpretability. Including the pandemic and recent tightening cycle may require more flexible threshold specifications, potentially time-varying parameters or alternative threshold variables, that better capture the evolving nature of financial stress. Future research extending the sample period would need to carefully balance these considerations while preserving the economic interpretability that makes the threshold framework attractive for policy analysis.

7 Conclusion

This work project investigated whether ECB monetary policy transmission to GDP growth differs systematically between Northern and Southern European countries depending on financial stress conditions. Using Hansen's (1999) PTM with high-frequency identified shocks from Jarociński and Karadi (2020) and the Composite Indicator of Systemic Stress as the threshold variable, I analysed quarterly data for twelve founding euro area members from 2001Q1 to 2019Q4.

The empirical analysis yields three principal findings. First, regional heterogeneity in monetary transmission is fundamentally state-dependent rather than a permanent structural feature. Significant North-South differences emerge exclusively in Regime 3 (moderate-high stress, CISS 0.337 to 0.429), where Southern European GDP contracts 2.10 percentage points more than Northern GDP in response to identical monetary tightening. Second, as financial stress transitions from low-moderate to moderate-high levels, Southern transmission deteriorates by 2.57 percentage points compared to only 0.37 percentage points in the North. Third, Local Projections validate these findings dynamically, showing that the North-South gap persists over twelve quarters, with Northern economies recovering by fifteen to eighteen months while Southern economies remain contractionary through three years.

These findings extend the literature by confirming that the breakdown in homogeneous transmission documented by Ciccarelli et al. (2013) is driven by nonlinear responses to financial fragility. While Corsetti et al. (2020) identify structural factors as drivers of heterogeneity, the present results suggest financial stress acts as a potent amplifier of these divergences. The regional sensitivity anticipated by Arnold (2001) proves dormant during tranquil conditions but becomes binding precisely when systemic stress makes cohesion most critical. The economic mechanism connects to the sovereign-bank nexus: when stress enters the moderate-high range, sovereign spreads widen, bank funding costs increase and credit rationing intensifies disproportionately in Southern economies with greater sovereign exposure and bank-dependent corporate sectors.

Several limitations warrant acknowledgment. The static Panel Threshold Model abstracts from output persistence dynamics, and the sample ends in 2019Q4, excluding the post-pandemic tightening cycle. Future research could estimate dynamic panel threshold models following Kremer et al. (2013), incorporate country-specific thresholds, and extend the sample to assess regime stability in the high-inflation environment.

These findings carry direct implications for ECB policy design. The intermediate stress regime where transmission is strongest is precisely where North-South asymmetries are largest. Tightening calibrated for core economies risks disproportionate peripheral contractions. The CISS thresholds identified here, particularly the 0.337 boundary, could serve as early warning signals for when standard calibration may generate unintended regional divergence. When financial stress approaches this threshold, policymakers should anticipate that uniform rate adjustments will produce heterogeneous real effects across member states. This asymmetry cannot be resolved through interest rate policy alone, underscoring complementary roles for macroprudential tools to address financial fragmentation and fiscal stabilizers to cushion peripheral economies during tightening cycles.

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Appendix

A Sequential Threshold Testing

This appendix presents the likelihood ratio functions from Hansen's (1999) sequential testing procedure. The procedure begins by testing a single threshold against no threshold, then tests for a second threshold conditional on the first, and finally tests for a third threshold conditional on the first two. In each panel, the horizontal dashed line indicates the 95 percent critical value of 7.35, derived from Hansen's (1999, Theorem 1) asymptotic distribution. Confidence intervals comprise all threshold values for which the likelihood ratio statistic falls below this critical value.

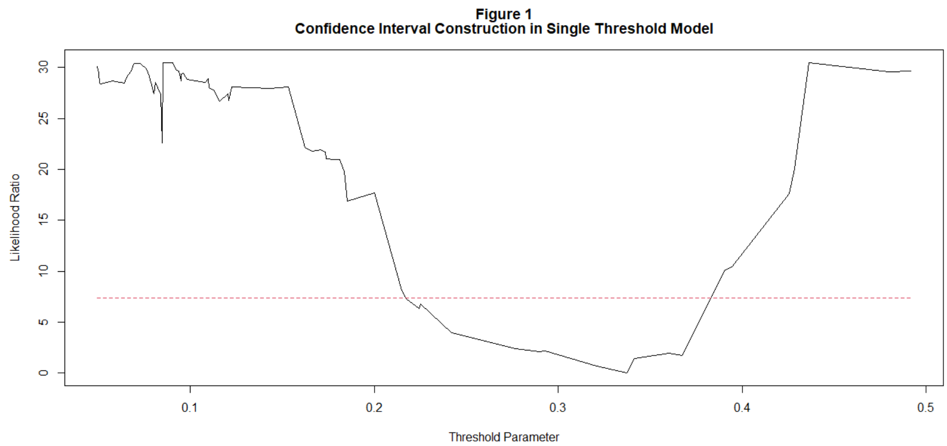

Figure .1: Confidence Interval Construction in Single Threshold Model

Note: This panel displays the concentrated likelihood ratio statistic from Hansen's (1999) grid search over candidate threshold values when testing for a single threshold against the null of no threshold. The minimum occurs at $\hat{\gamma} = 0.337$, with the 95 percent confidence interval comprising all values where $LR(\gamma) \leq 7.35$ (horizontal dashed line). The wide region below the critical value indicates moderate precision in threshold identification at this stage of sequential testing.

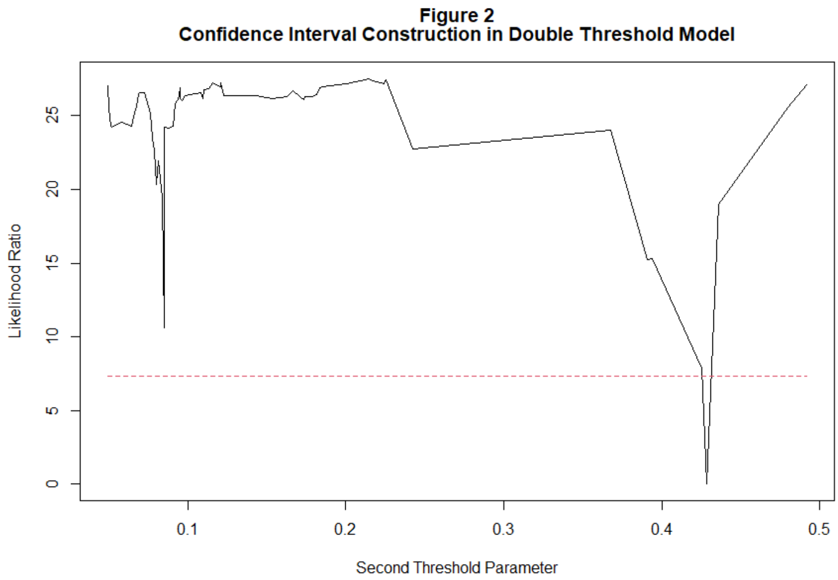

Figure .2: Confidence Interval Construction in Double Threshold Model

Note: This panel displays the likelihood ratio statistic for the second threshold parameter when testing for a double threshold against the single threshold specification. Conditional on the first threshold, the grid search identifies $\hat{\gamma}_2 = 0.429$. The sharp minimum with the likelihood ratio exceeding the critical value everywhere except at the point estimate indicates precise threshold identification.

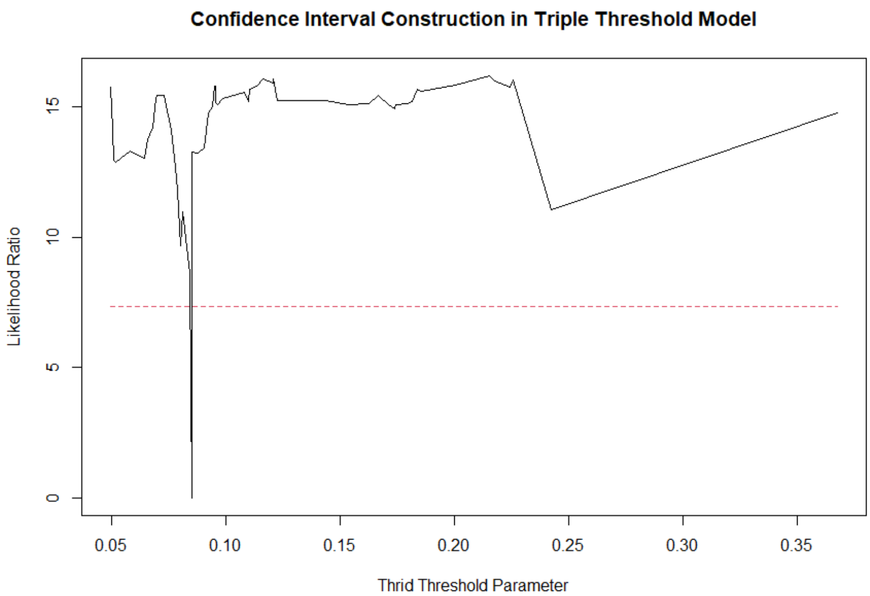

Figure .3: Confidence Interval Construction in Triple Threshold Model

Note: This panel displays the likelihood ratio statistic for the third threshold parameter when testing for a triple threshold against the double threshold specification. The minimum at $\hat{\gamma}_3 = 0.085$ exhibits a sharp drop below the critical value at essentially a single point, resulting in a confidence interval that collapses to the point estimate. This pattern indicates strong regime-switching effects at this threshold.

B Financial Stress Dynamics

This appendix presents visualizations of the Composite Indicator of Systemic Stress (CISS) used as the threshold variable in the Panel Threshold Model estimation.

Figure .4 displays the evolution of the CISS over the sample period. The three estimated thresholds partition the indicator into four distinct regimes. Shaded areas indicate the Global Financial Crisis (2007Q3–2009Q2) and the European Sovereign Debt Crisis (2010Q2–2012Q3), illustrating how the estimated thresholds align with major euro area financial events.

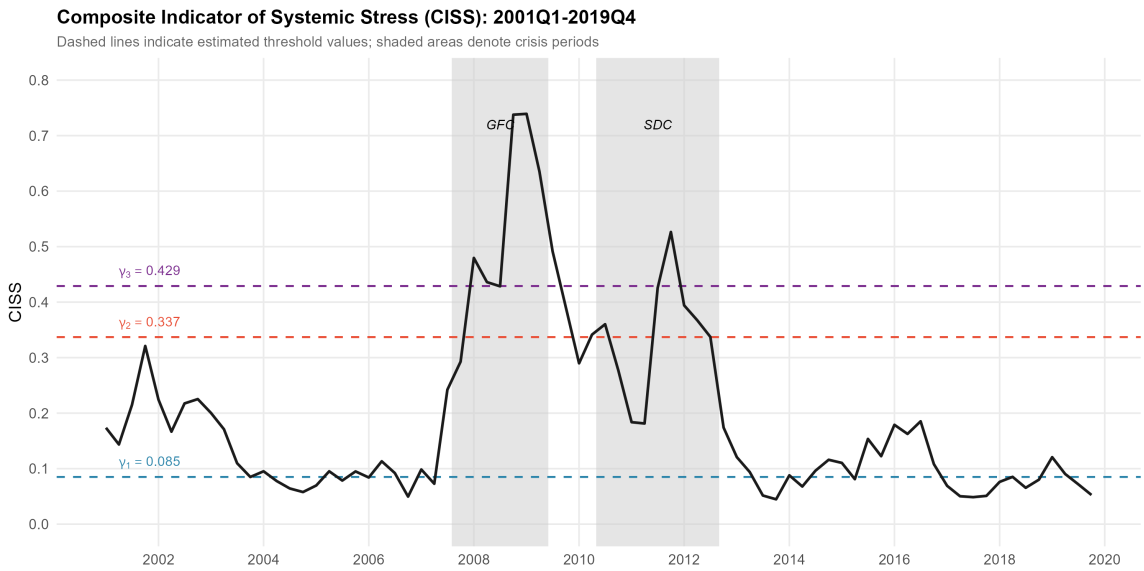

Figure .4: Composite Indicator of Systemic Stress (CISS): 2001Q1–2019Q4. Dashed horizontal lines indicate estimated threshold values ($\hat{\gamma}_1 = 0.085$, $\hat{\gamma}_2 = 0.337$, $\hat{\gamma}_3 = 0.429$). Shaded areas denote crisis periods: Global Financial Crisis (GFC, 2007Q3–2009Q2) and Sovereign Debt Crisis (SDC, 2010Q2–2012Q3).

Figure .5 presents the distribution of CISS values across the sample period, with regime boundaries indicated by vertical dashed lines. The majority of observations (80%) fall within Regimes 1 and 2, corresponding to tranquil and low-moderate stress conditions. Regimes 3 and 4, capturing elevated and systemic stress, account for 20% of the sample, concentrated during the 2008–2012 crisis period.

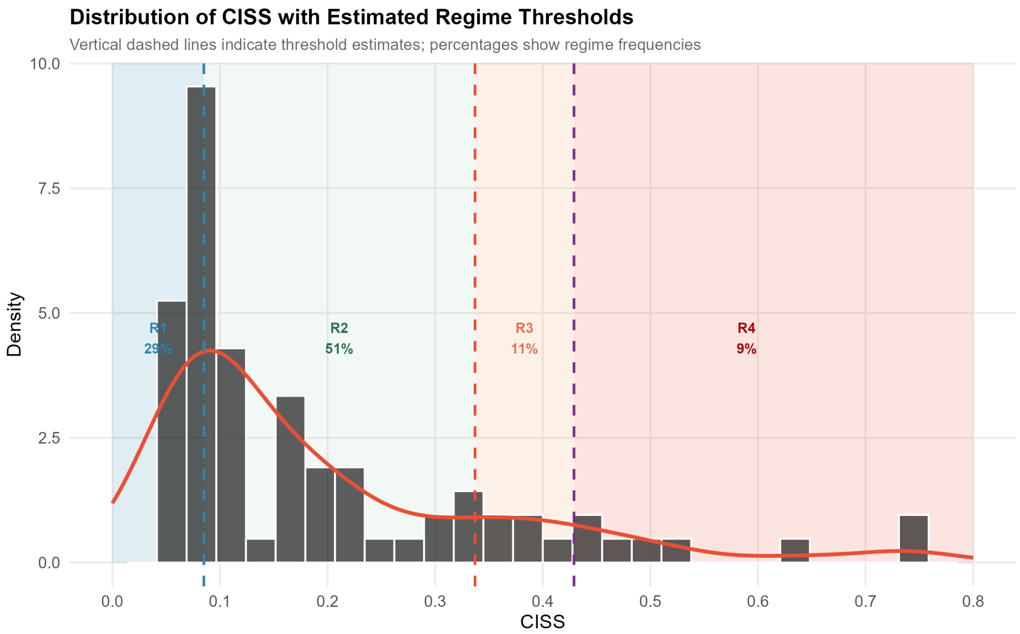

Figure .5: Distribution of CISS with Estimated Regime Thresholds. Vertical dashed lines indicate estimated threshold values. Shaded regions correspond to the four financial stress regimes: Regime 1 (Very Low Stress, CISS < 0.085, 29% of quarters), Regime 2 (Low-Moderate Stress, CISS ∈ [0.085, 0.337), 51%), Regime 3 (Moderate-High Stress, CISS ∈ [0.337, 0.429), 11%), and Regime 4 (Systemic Crisis, CISS ≥ 0.429, 9%).

C Hypothesis Testing Procedure for Regional Heterogeneity

The null hypothesis of equal transmission coefficients between Northern and Southern Europe within regime j is formulated as:

$$H_0 : \beta_j^{North} = \beta_j^{South} \quad \text{versus} \quad H_1 : \beta_j^{North} \neq \beta_j^{South}$$

The test statistic for this hypothesis is:

$$t = \frac{\hat{\beta}_j^{South} - \hat{\beta}_j^{North}}{SE(\hat{\beta}_j^{South} - \hat{\beta}_j^{North})}$$

Under the assumption that the coefficient estimates are asymptotically independent, the standard error of the difference is computed as:

$$SE(\hat{\beta}_j^{South} - \hat{\beta}_j^{North}) = \sqrt{SE(\hat{\beta}_j^{South})^2 + SE(\hat{\beta}_j^{North})^2}$$

The null hypothesis is rejected at the 5% significance level if $|t| > 1.96$.

D Hypothesis Testing Procedure for Directional Attenuation

The directional attenuation hypothesis tests whether financial stress amplifies transmission asymmetrically across regions. Define the change in transmission coefficients as the economy transitions from Regime 2 (Low-Moderate Stress) to Regime 3 (Moderate-High Stress):

$$\Delta^{Region} = \beta^{Region,R3} - \beta^{Region,R2}$$

The null and alternative hypotheses are:

$$H_0 : \Delta^{South} - \Delta^{North} = 0 \quad \text{versus} \quad H_1 : \Delta^{South} - \Delta^{North} < 0$$

The test statistic is:

$$t = \frac{(\Delta^{South} - \Delta^{North})}{SE(\Delta^{South} - \Delta^{North})}$$

Under the assumption of asymptotic independence across regime-region coefficient estimates, the standard error is computed as:

$$SE(\Delta^{South} - \Delta^{North}) = \sqrt{SE(\hat{\beta}^{South,R3})^2 + SE(\hat{\beta}^{South,R2})^2 + SE(\hat{\beta}^{North,R3})^2 + SE(\hat{\beta}^{North,R2})^2}$$

The null hypothesis is rejected at the 5% significance level if $t < -1.645$ (one-sided test).

E Local Projections for Regimes 1, 2, and 4

This appendix presents Local Projections impulse responses for the three regimes where no statistically significant North-South heterogeneity was identified in the PTM analysis. The overlapping confidence intervals at all horizons confirm that transmission heterogeneity is specifically a Regime 3 phenomenon.

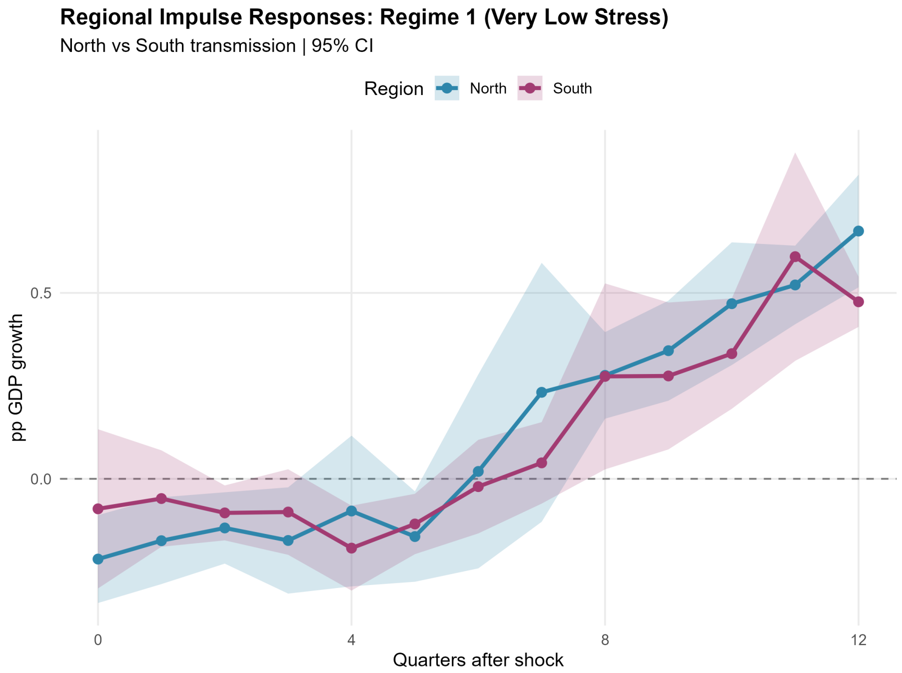

Figure .6: Regional Impulse Responses in Regime 1 (Very Low Stress)

Note: Impulse responses to one-unit monetary policy shock estimated via Local Projections. Lines represent point estimates; shaded areas denote 95% confidence intervals. Blue: Northern Europe; pink: Southern Europe.

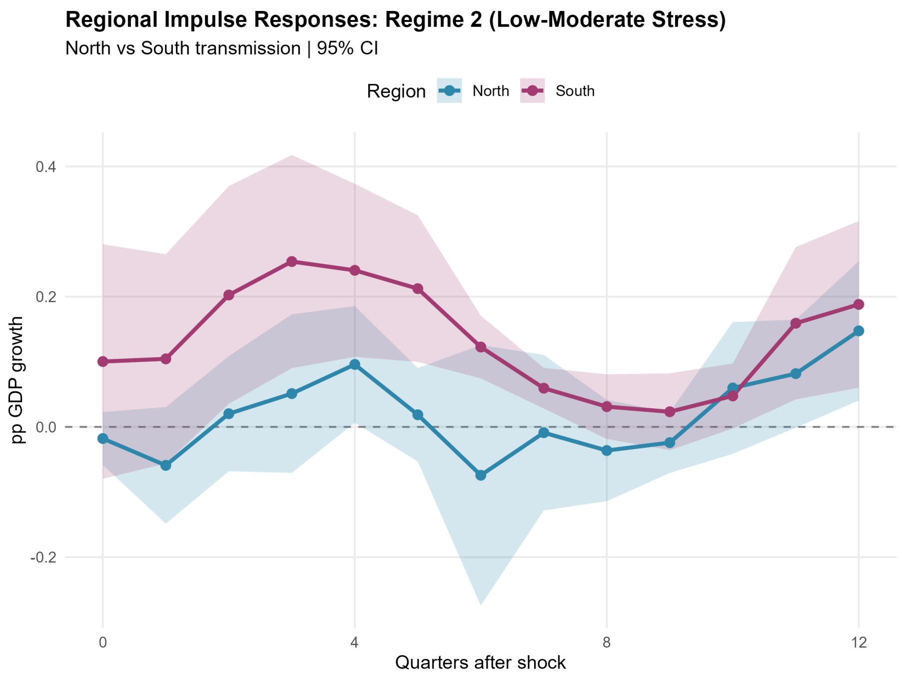

Figure .7: Regional Impulse Responses in Regime 2 (Low-Moderate Stress)

Note: Impulse responses to one-unit monetary policy shock estimated via Local Projections. Lines represent point estimates; shaded areas denote 95% confidence intervals. Blue: Northern Europe; pink: Southern Europe.

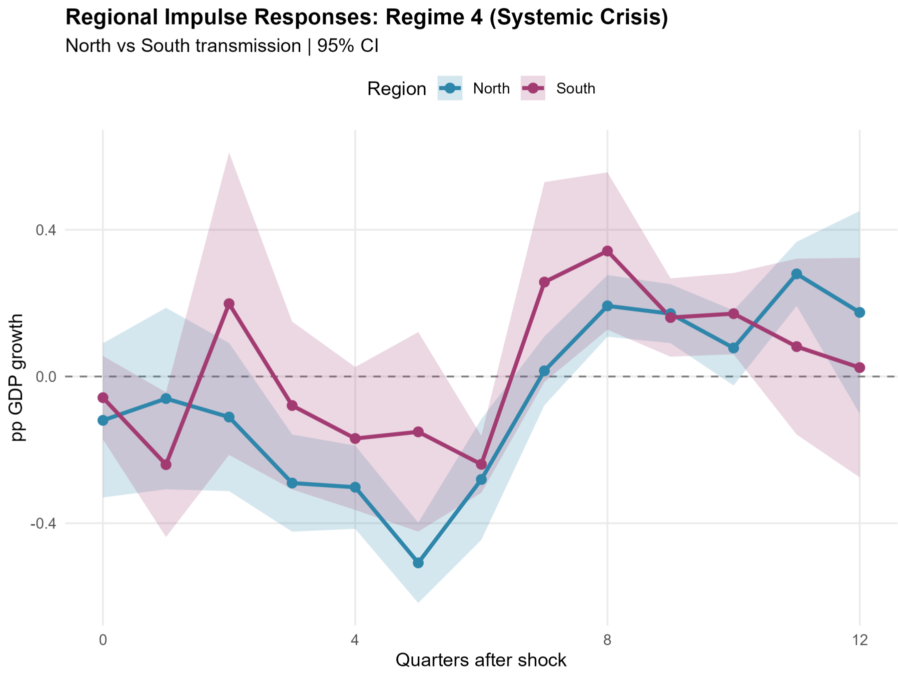

Figure .8: Regional Impulse Responses in Regime 4 (Systemic Crisis)

Note: Impulse responses to one-unit monetary policy shock estimated via Local Projections. Lines represent point estimates; shaded areas denote 95% confidence intervals. Blue: Northern Europe; pink: Southern Europe.