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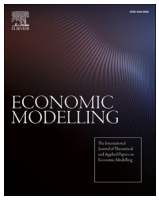

Sovereign spread divergence owing to inflation and redenomination risk countered by unconventional monetary policy in the Eurozone

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ABSTRACT

Using a panel vector error correction (VECM) model, we assess sovereign spread divergence in the Eurozone. Recent literature defines redenomination risk as a member state's unilateral exit from the Eurozone, estimated by the quanto Credit default swaps (CDS) spread (qCDS). We show that sovereign spread divergence is driven not only by the qCDS but also by inflation and US dollar liquidity shocks. We also find evidence that the balance sheet structure better describes the European Central Bank's (ECB) unconventional monetary policy (UMP) shocks than the shadow rate. Such policy shocks had a greater impact in the early 2020s than between the global financial crisis and the COVID-19 pandemic (2008Q1–2019Q4). Thus, this paper makes a new contribution to the debate on the ECB's instruments to maintain price stability objectives and avoid divergence of sovereign bond yields while emphasizing cross-central bank swap lines.

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1. Introduction

Asset prices have a stronger common movement under extraordinary market events, as defined by the financial contagion-related literature. However, sovereign yields in the Eurozone tend to have a strong correlation, which is a practical requirement of the Maastricht criteria.[2] Therefore, unlike the stock market, sovereign spreads tend to increase during turbulent times, referred to as *divergence* (Bearce, 2002). Therefore, sovereign spreads reflect domestic and external funding imbalances and changes in monetary policy.

As member states of the Eurozone monetary union issue bonds in a single currency over which they do not have full control, sovereign debt accumulates. The central banks of the countries in the Eurozone lose much of their capacity to provide liquidity to the sovereigns to avoid defaulting. Hence, these countries not only lose an economic policy instrument (interest rate or exchange rate) but also the confidence of investors, subsequently pushing countries into defaulting in a self-fulfilling manner (De Grauwe, 2012; Saka et al., 2015). Hence, the Eurozone is fragile in structure (De Grauwe and Ji, 2022). The sovereign debt crisis of the 2010s led to some major reforms in Europe. These periods were characterized by the development of the institutional

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[2] In order to adopt the euro, long-term interest rates cannot be 2 percentage points above the rate of the three best-performing member states in terms of price stability.

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Table 1
Data sources.

Notation	Variable (2005Q1-2021 Q3)	Source
$10Y_{i,t} - 10Y_{EUR,t}$	Sovereign premium: difference between 10-year sovereign bond yield of the ith country from the average Eurozone 10-year sovereign bond yields	Refinitiv Eikon
$VIX_{STOXX50E,t}$	EURO Stock VIX index representing the investors' risk aversion and investor's uncertainty	Refinitiv Eikon
$CBS_{EURUSD,t}$	5- year currency basis swap rate against USD	Refinitiv Eikon
$\frac{debt_{i,t}}{debt_{EZ,t}}$	ith country's share from the overall debt of the eurozone	Eurostat
$qCDS_{i,t}$	Redenomination risk measured by qCDS	Refinitiv Eikon
$CPI_{i,t}$	The deviation from the targeted inflation	OECD
$LSFX_{ECB,t}$	Loans and securities in the ECB's balance sheet to foreign exchange reserve ratio	ECB
$Shr_{ECB,t}$	Shadow rate for the ECB	Jing Cynthia Wu database
dummy_ESM	liquidity support for the ith member state from the European Stability Mechanism (ESM)	ESM
dummy_rec_EZ	recession in the Eurozone (1: recession in the EZ)	European Commission Business Cycle Clock
dummy_Eurozone membership	Being a member of Euro area	European Commission

Source: authors' edition

background of the Eurozone: these reforms included introducing the European Stability Mechanism (ESM) and combining long-term lending and asset purchase programs (as an unconventional[3] extension of monetary policy instruments) at the European Central Bank (ECB) (Bénassy-Quéré and Weder di Mauro, 2020a,b). However, financial markets in the Eurozone remained fragmented, and the Eurozone was not economically or financially strong enough to face the new crisis; additionally, the retraction of exceptional lending programs and liquidity facilities might cause further financial distress (Mallick and Sousa, 2013). Recently, Eurozone governments have been forced to adopt various extraordinary lockdown measures due to COVID-19. Lang and Schadner (2021) argued that the COVID-19 pandemic re-exposed the fragile nature of Eurozone's construction and the inefficiency of previous national fiscal policies in constructing sufficient buffers. Moreover, the Russia–Ukraine conflict left Europe with stronger inflationary pressures and considerable increases in commodity prices. This fragility of the financial structure of the Eurozone can manifest itself in sovereign debt spread. These spreads measure the market risk and risk premium that investors demand to compensate for the risk of holding bonds in countries whose creditworthiness and fundamentals are weaker than higher-ranked debt securities (e.g., US Treasury debt security).

Credit default swaps (CDS) provide insurance against a credit event (bankruptcy, restructuring, or nonpayment) of a reference entity. The CDS spread is defined as the ratio of annual payments to the notional principal (Hull, 2018). Therefore, CDSs can be used to estimate the risk-free rate from the credit spread, in many cases, making it the primary measure of credit risk to provide information about global-to-domestic (or global-to-industry) or default-to-currency devaluation spillovers (Benbouzid et al., 2022). However, a CDS contract does not require ownership of the underlying bond, which opens a gap between the concepts of sovereign spread (with the difference between two sovereign bonds' long positions) and CDS spreads (which *can* also include long sovereign bond positions), opening the latter more because of the changing nature of market sentiment. Meanwhile, bond spreads remain the primary benchmark for Euro-adoption or ESM lending, making them a key motivation for studying the differences between sovereign and CDS spreads.

Sovereign spreads are affected by several domestic and external factors. Domestic macroeconomic variables, such as GDP growth, inflation rate, and the real exchange rate, are particularly important (Tebaldi et al., 2018; Mpapalika and Malikane, 2019). In contrast, Hartelius et al. (2008) claimed that the sovereign spread is better explained by global factors (e.g., short-term US interest rates and volatility in global liquidity conditions) compared with domestic macroeconomic fundamentals. The ECB's monetary policy communications and emergency measures are also considered key instruments for mitigating sovereign spreads in the Eurozone (Falagiarda and Reitz, 2015; Lang and Schadner, 2021; Ortmans and Tripier, 2021). Moreover, owing to the substantial economic consequences of COVID-19 and energy security challenges for European countries' public finances, extraordinary actions and policies at the European level are needed to mitigate the pressure on each member, which can lead to divergence.

This study investigates the development of sovereign spreads in the Eurozone from 2008Q1 to 2022Q3. Four major shocks occurred during this period: the subprime crisis, the sovereign debt crisis, COVID-19 pandemic, and Russia–Ukraine conflict-induced energy crisis. In this study, we compared this period with the nonpandemic sample period between 2008Q1 and 2019Q4, which later created different institutional changes[4] within the Eurozone to test the successful application of the next set of crises, that is, when supply chain and energy price shocks occurred owing to the COVID-19 pandemic and the Russia–Ukraine conflict.

This study also explores the association between redenomination risk (fundamental doubts over the integrity of the Eurozone) and sovereign premiums as well as country-specific macroeconomic fundamentals, including the share of the overall Eurozone's public debt (as a proxy for fiscal condition) and inflation. To proxy for redenomination risk in the Eurozone, we used the sovereign quanto credit default swap (qCDS) based on De Santis (2015) and Borri (2019). Additionally, we employ the euro–dollar base swap rate as a proxy for the scarcity of dollar funding in the Eurozone and the EURO Stock VIX index to capture the effect of investors' risk aversion and uncertainty on the sovereign premium in the Eurozone.

Furthermore, this study aims to determine the effectiveness of the ECB's unconventional monetary policy, especially the asset-purchasing programs, in reducing sovereign bond spreads in the Eurozone over both examined periods, 2008Q1–2022Q3 and 2008Q1–2019Q4, as a lender of last resort. We use the balance sheet structure because of quantitative easing and the shadow rate owing to the zero lower bound to proxy for the ECB's monetary policy shocks. Some studies have proven the vital role of the ECB's interventions in countering the effects of sovereign debt crisis (Roman and Bilan, 2012; Falagiarda and Reitz, 2015). Ortmans and Tripier (2021) emphasized the effectiveness of the ECB's unprecedented monetary policy responses to COVID-19 in suppressing sovereign default risk volatility in the Eurozone. According to their estimation, without the ECB's monetary support, by March 18, sovereign yields would have risen to 4.2%, 12.5%, and 19.5% in France, Spain, and Italy, respectively.

We employed the panel vector error correction model (VECM) and both the impulse response function and variance decomposition tools for the data of 16 Eurozone countries (after excluding Estonia, Croatia, Cyprus, and Luxembourg owing to the limited data available on these

[3] It can be characterized as the combination of long-term lending and purchasing programs, close-to-zero key policy rate and forward guidance.

[4] The introduction of the European Stability Mechanism to stabilize public debt funding, the European Semester to restore fiscal discipline, and the asset purchase programs of the ECB around 2014.

countries) to achieve the study's goals.

The findings show that sovereign spreads in the Euro-area in both sample periods are negatively associated with inflation. Furthermore, it depended mainly on sentiment about the intra-Eurozone redenomination risk and the ECB balance sheet changes during both the non-pandemic period and the entire sample period. Each member state's share of the total Eurozone debt also positively influenced the sovereign spread in both periods, although at different degrees of significance. Although the European stock exchange index had an insignificant impact on sovereign spreads in the nonpandemic period, the results showed that it had quite a stable, negative impact in the long run, highlighting the importance of portfolio-rebalancing effects. Moreover, the findings show that sovereign spreads reacted differently to USD liquidity scarcity (negative CBS) in the nonpandemic period compared to the whole sample period.

This study contributes to the growing empirical literature by validating the importance of the ECB's asset composition relative to the sovereign spread owing to the LSFX (loan, securities to foreign exchange reserve) ratio application. Conversely, the less turbulent pre-COVID-19 period, which contained only two main regional and global crises, was compared with the more turbulent period of the early 2020s (by adding two additional global crises). Moreover, we believe our study is the first comprehensive empirical study to observe the patterns of the Eurozone's sovereign spread divergence in reaction to shocks from macroeconomic fundamentals, external funding conditions, and the ECB's unconventional monetary policy over a period covering four major shocks (e.g., the subprime crisis, sovereign debt crisis, COVID-19 pandemic, and Russia–Ukraine conflict). Applying the panel VECM model also considers not only short-run changes but also long-term equilibrium among some of the variables.

The remainder of this paper is structured as follows: Section 2 reviews the literature on Eurozone's sovereign bond spreads to introduce the theoretical model. Section 3 describes the data and explains the methods. Section 4 presents the results of the VECM model estimation: the main diagnostics, impulse response functions, and variance decompositions. Finally, Section 5 concludes the study and provides policy implications.

2. Literature review

There are different viewpoints regarding the effectiveness of the ECB's monetary policies and purchasing programs in the sovereign bond markets of Eurozone's member states. Leombroni et al. (2021) found that the ECB's monetary policy communications during the European sovereign debt crisis led to a significant yield spread. This increased the spread between peripheral (Italy and Spain) and core (Germany and France) countries by increasing the credit risk premiums. However, De Santis (2020) developed and employed a discussion intensity index related to the asset purchase program (APP) news in the Eurozone based on Bloomberg to capture market sentiment and expectations about QE by the ECB. A country-panel error correction model was used to examine APP's effectiveness in explaining the Eurozone's sovereign bond yield. Their results showed that between September 2014 and February 2015—when QE was the main policy issue under discussion during this period—the GDP-weighted 10-year Eurozone sovereign yield fell by 64 basis points. Lang and Schadner (2021) also argued that the ECB's emergency monetary policies have been one of the most essential public-supporting instruments for Euro-area countries. Some studies have encouraged the ECB's involvement as a lender of last resort to overcome the negative economic and health consequences of COVID-19 (e.g., Blanchard, 2020; Giavazzi and Tabellini, 2020; Allen-Coghlan et al., 2020). The ECB has implemented various monetary policies through its Governing Council and widened the existing APP by initiating the Pandemic Emergency Purchase Program (PEPP). Moreover, the ECB announced a third series of its targeted long-term refinancing operations to keep bank lending channels operational. Moessner and de Haan (2022) concluded that implementing PEPP by the ECB had a more spread-compressing impact on Euro-area countries with higher sovereign risk.

Some studies have investigated whether redenomination risk has increased sovereign bond yields across Euro-area countries. Redenomination risk is the risk that one or more member countries will unilaterally exit the European Monetary Union and redenominate their public and private liabilities in a devalued legacy currency. These studies argued that a significant increase in sovereign bond yields in the most troubled countries is not only attributed to fundamental factors but also represents a redenomination risk and intensification of the crisis in the Eurozone. De Santis (2015) introduced a time-varying, country-specific market perception measure for intra-Eurozone redenomination risk. This measure is defined as the difference between a member country's quanto CDS (qCDS) and that of Germany, the benchmark member country. Quanto CDS was calculated based on the difference between CDS quotes in US dollars and euros. Using this measure, they found that redenomination risk shocks significantly affect sovereign yield spreads. Klose and Weigert (2014) estimated the risk redenomination or market sentiments toward a (partial) disintegration of the Eurozone using a novel indicator based on Intrade, a virtual trading platform. They found that this indicator had a time-varying correlation with the sovereign yield spreads of each country. Corradin et al. (2021) considered redenomination risk to be one of the five components of Eurozone sovereign bond yields. They used the difference between sovereign CDS spreads under the International Swaps and Derivatives Association contract terms, CT2014 and CT2003, to measure redenomination risk. They found that the ECB's PEPP announcement on 18 March 2020 reduced yields in vulnerable countries (especially Italy and Spain) but increased those in France and Germany. The largest reduction in yields was recorded for Italy at 78 bps over two days following the event, which can be attributed to default risk (by 35 bps), redenomination risk (by 14 bps), and segmentation premiums (by 16 bps). Practically, from an institutional point of view, all fiscal disciplinary rules introduced by the European Commission during the 2010s (like the European Semester, the ESM, etc.) aimed to counteract redenomination risks.

Among the researchers considering the impact of macroeconomic fundamentals, Dumičić and Ridzak (2011) showed that changes significantly influence the EU's sovereign bond yields in market sentiment and domestic macroeconomic variables. Moreover, they found that the external imbalances did not significantly affect the sovereign spread before the crisis, but played a significant role in raising spreads as the crisis broke out. Rho and Saenz (2021) investigated the impact of the interlinkage between macroeconomic fundamentals and financial stress on sovereign spreads. They found that sovereign spreads are positively associated with public debt, higher inflation, and exchange rate overvaluation. Conversely, higher real GDP growth, GDP per capita, and global growth narrowed the sovereign spreads. Their results also showed that both local and global financial stress significantly amplified the impact of public debt, the level of international reserves, and GDP per capita on sovereign spreads. Using Bayesian model averaging, Maltritz (2012) reported that global financing conditions, market sentiments, and country-specific drivers may influence the sovereign yield spreads of European Monetary Union (EMU) member states. Costantini et al. (2014) and Gómez-Puig and Sosvilla-Rivero (2016) concluded that inflation and fiscal condition positively impacted the sovereign spread. In contrast, our study shows that sovereign spreads are negatively associated with inflation.

The impact of macroeconomic fundamentals on sovereign yield spreads gradually changes over time and follows time-varying coefficient models. A shift in the model coefficients shows these fundamentals' altering risk pricing over time. In this context, using a semiparametric time-varying coefficient model, Bernoth and Erdogan (2012) identified the determinants of sovereign bond yield spreads across 10 EMU countries and found a time-varying relationship between fiscal policy variables, general investors' risk aversion, and sovereign

yield spreads. Kumar et al. (2022) also used VAR models with time-varying coefficients to examine the impact of investors' risk aversion and uncertainty about future equity and bond prices. These are represented by the VIX and MOVE indices on the government bond term premium and key macroeconomic variables. They controlled possible changes in the transmission mechanism using time-varying VAR models, particularly after the global financial crisis.

Exogenous shocks are represented by the dummy variables ($dummy_{d,i,t}$); recession in the Eurozone and the ESM's liquidity provisions for targeted member states and is a member of the Eurozone (based on the European Commission Business Cycle Clock and the European Commission website, respectively).

$$\left(10Y_{i,t}-10Y_{EUR,t}\right)=const.+\beta_1 VIX_{\mathrm{STOXX50E},t}+\beta_2 CBS_{EURUSD,t}+\beta_3\frac{debt_{i,t}}{debt_{EZ,t}}+\beta_4 qCDS_{i,t}+\beta_5\ CPI_{i,t}+\beta_6 LSFX_{ECB,t}+\beta_5 ShR_{ECB,t}+\beta_{7:9} dummy_{d,i,t} \quad (1)$$

2.1. Theoretical model

The theoretical model focuses on the gap between the sovereign spread divergence and the qCDSs in the Eurozone to assess UMP's countering effects. We focused on the changes in the difference between each member state's 10-year sovereign bond yields and the average Eurozone 10-year sovereign bond yields to measure sovereign spread divergence. Since international uncertainties easily spill over into country-specific uncertainties (Kumar et al., 2021), the development of the Eurozone member state long-term yields can be captured through changes in the external funding conditions (e.g., stock market volatility and ease of funding in the US dollar), country-specific macro conditions (e.g., share from the overall public debt, redenomination risk, and inflation), and monetary conditions established by the ECB (e.g., balance sheet structure and shadow rate owing to the quantitative easing and zero lower bound, respectively).

The model's external funding conditions include the EURO Stoxx50E VIX index ($VIX_{\mathrm{STOXX50E},t}$) to represent investors' risk aversion and stock market uncertainty, adding a portfolio-rebalancing effect into the model. According to Kumar et al. (2022), increasing uncertainty leads investors to demand greater compensation for risky assets (e.g., long-term government bonds). One US-related indicator was also used (e.g., the EUR–USD currency base swap that defines the US dollar funding scarcity in the Eurozone–$CBS_{EURUSD,t}$) as a global funding proxy parameter. Since 2007, cross-central bank swap lines have managed time-variant US dollar scarcity to allocate short-term US dollar liquidity to the domestic banking system (Kiss et al., 2020).

The country-specific macroeconomic conditions are represented by the redenomination risk, inflation ($CPI_{i,t}$), and share from debt. Share from debt ($\frac{debt_{i,t}}{debt_{EZ,t}}$) shows each member state's share of the total Eurozone's debt. Both capture the relative size of their debt and act as a gravity proxy (Ostrihoň et al., 2023). Moreover, to capture intra-Eurozone redenomination risk, we used qCDS, a country-specific market perception measure introduced by De Santis (2015). Quanto CDS is the difference between the CDS quotes of each member state and that of Germany and then from the US CDS quotes ($qCDS_{i,t} = CDS_{i,t} - CDS_{DE,t} - CDS_{US,t}$).

The monetary determinant is represented by the ECB's shadow policy rates ($ShR_{ECB,t}$) and $LSFX_{ECB,t}$, which measures the ratio of loans (L: provided by the ECB to the banking system) and securities (S: issued by residents) to the foreign exchange reserve (FX), showing structural changes on the asset side of the central bank balance sheet (Mészáros and Kiss, 2020). Shadow rates can be used to estimate the prevailing short-term interest rate without considering the zero lower bound; thus, it can take negative numbers (Potjagailo, 2017). Therefore, plugging the shadow rate into the model provides a better assessment of the ECB's additional easing through unconventional policies (quantitative easing and forward guidance) than the usual short-term rates of the Zero Lower Bound (ZLB) (Ouerk et al., 2020; Lombardi and Zhu, 2014; Sági and Ferkelt, 2020; Heryán and Tzeremes, 2017).

We run the model twice to determine how the results of the COVID-19 pandemic and the Russia–Ukraine conflict have affected supply chain and energy price shocks. The first instance covers the nonpandemic sample period between 2008Q1 and 2019Q4, and the second covers the entire period between 2008Q1 and 2022Q3. The model represents each ith ($i = \{1:16\}$) Eurozone country after excluding Estonia, Croatia, Cyprus, and Luxembourg due to a lack of data on the sovereign premium.

3. Methodology and data

3.1. Data

This study uses the quarterly data of 16 Eurozone countries between 2008 Q1 and 2022 Q3. We mostly used the Refinitiv Eikon, OECD, and Eurostat databases to collect quarterly macroeconomic and funding variables data for 16 Eurozone member states. We excluded four countries from our sample as the data from these countries were unavailable during the research period. Table 1 lists the explanatory variables, abbreviations, and data sources.

3.2. Methods

We studied endogenous relations among the cointegrated variables using the panel VECM and showed the Eurozone's sovereign rate reaction to the selected macroeconomic and monetary variables utilizing the accumulated impulse response functions and variance decomposition.

The variables are cointegrated, and there is a long-term relationship between them. Conversely, the endogenous relationship is present, and the panel VECM can provide efficient estimations for the model (Holtz-Eakin et al., 1988). The panel unit root tests revealed some of the input variables' I(1) nature. The panel cointegration test showed the existence of a long-term relationship among them. For the panel data with M variables, the following N cross-sectional units (countries; I = 1, …, N) over T periods (quarter of years; t = 1, …,k, …T) were used:

$$\Delta Y_{i,t}=\Phi D_{i,t}+\Pi Y_{i,t-1}+\sum_{t=1}^{p}\Gamma_{p-1}\Delta Y_{i,t-p+1}+\varepsilon_{i,t}.$$

where the long-run impact matrix (Π) captures adjustments toward the long-run equilibrium and contains cointegrating relationships, such as $\Pi = \Pi_1 + \ldots + \Pi_p - I_n$. The cointegrating matrix (Π) defines the various ways of combining the cointegrating series. The unobserved error correction term (I_n) provides information for the long-term equilibrium level. $D_{i,t}$ contains all regressors associated with the deterministic terms $D_{i,t} = u_{i,0} + u_{i,1}t$. Short-run deviations from the equilibrium are captured in the Γ_k short-run impact matrix. Only rank r (r < M) linear combinations are cointegrated, and k is the optimal lag length determined by the Bayesian information criterion. A stable VECM model comprises one endogenous variable and r cointegrating vectors. The companion matrix (of the inverse roots of the characteristic AR polynomial) contains l-r

Table 2
Identity-matrix structure.

		shock							
		$VIX_{STOXX50E,t}$	$CBS_{EURUSD,t}$	$\frac{debt_{i,t}}{debt_{EZ,t}}$	$qCDS_{i,t}$	$CPI_{i,t}$	$LSFX_{ECB,t}$	$ShR_{ECB,t}$	$(10Y_{i,t} - 10Y_{EUR,t})$
variable	$VIX_{STOXX50E,t}$	f11	0	0	0	0	0	0	0
	$CBS_{EURUSD,t}$	f21	f22	0	0	0	0	0	0
	$\frac{debt_{i,t}}{debt_{EZ,t}}$	f31	f32	f33	0	0	0	0	0
	$qCDS_{i,t}$	f41	f42	f43	f44	0	0	0	0
	$CPI_{i,t}$	f51	f52	f53	f54	f55	0	0	0
	$LSFX_{ECB,t}$	f61	f62	f63	f64	f65	f66	0	0
	$ShR_{ECB,t}$	f71	f72	f73	f74	f75	f76	f77	0
	$(10Y_{i,t} - 10Y_{EUR,t})$	f81	f82	f83	f84	f85	f86	f87	f88

Source: authors' edition

unit moduli (Ortegón and Alexander, 2018; Lütkepohl and Krätzig, 2005).

The effects of a unit shock on a given model variable can be estimated using impulse response functions. Moreover, the shocks can be determined using variance decomposition; which variables are influential in the short- and long-term evolution of certain variables is determined by estimating the proportion of the impact of uncertainty of variable *i* on the *j*th shock after period *h*.

This paper introduces Table 2 as an identity matrix to identify how the shocks from the theoretical model affect the outcome variable. In this hierarchical order, the market volatility index or the dollar-scarcity indicator has a widespread effect, while the country-specific relative debt size, the redenomination risk, and inflation affect the monetary conditions and, therefore, the final sovereign spread.

4. Results

4.1. Descriptive statistics

This section first presents descriptive statistics of the dataset to show that centered, similarly scaled, and I(1) inputs were used. Impulse response functions and variance decomposition of the panel VECM model were then presented to highlight the dynamic interactions among the variables and show that model stability requirements could be met.

Appendix 1 shows the descriptive statistics of the input data representing a centered and similarly scaled dataset after the differentiation and usage of the logarithm. Owing to the existence of fat tails for some of the variables to detect the outliers and structural breaks in the model, it is necessary to include dummy variables. Moreover, the result of the unitroot tests ($p < 0.05$) showed that no unit root exists in input variables at the level of first differentials.

Table 3
Panel Johansen–Hendry–Juselius cointegration test results.

2008q1 2022q3		2008q1 2019q4	
Unrestricted Cointegration Rank Test (Trace)			
Hypothesized		Hypothesized	
No. of CE(s)	Prob.**	No. of CE(s)	Prob.**
None *	0.0000	None *	0.0000
At most 1 *	0.0000	At most 1 *	0.0000
At most 2 *	0.0000	At most 2 *	0.0000
At most 3 *	0.0000	At most 3 *	0.0000
At most 4 *	0.0000	At most 4 *	0.0000
At most 5 *	0.0000	At most 5 *	0.3404
At most 6	0.4663	At most 6	0.9978
At most 7	0.9929	At most 7	0.9833
Unrestricted Cointegration Rank Test (Maximum Eigenvalue)			
None *	0.0000	None *	0.0000
At most 1 *	0.0000	At most 1 *	0.0000
At most 2 *	0.0000	At most 2 *	0.0000
At most 3 *	0.0000	At most 3 *	0.0000
At most 4 *	0.0000	At most 4 *	0.0000
At most 5 *	0.0000	At most 5 *	0.0380
At most 6	0.1989	At most 6	0.9935
At most 7	0.9929	At most 7	0.9833

Source: authors' calculation in EViews 13

4.2. Panel cointegration test

After specifying the VECM model, a panel Johansen–Hendry–Juselius test was fitted on the model (Table 3) with the set of endogenous and exogenous variables with 1–4 lag. Trace and maximum-eigenvalue tests indicate five cointegrating equations at the 0.05 level for the pre-COVID-19 (2008Q1-2019Q4) and the entire period.

4.3. Stability test

We determined the optimum number of lags for the VECM model using the information criteria, where the Akaike information criterion, Bayesian information criterion, and Hannan–Quinn information criterion (HQ) have their lowest values at around four, which seems reasonable as an annual model consists of four quarters. Meanwhile, using four lags provided an AR graph (Fig. 1), wherein the VEC specification imposes three-unit root(s) for the eight-variable model with five cointegration relationships. This indicates the stability of the VECM model for the entire time set. Similarly, for the pre-COVID-19 period, the VEC specification imposed three-unit roots for the eight-variable model with five cointegration relationships, indicating the stability of the VECM model.

4.4. Eurozone's sovereign spread in the nonpandemic period (2008Q1–2019Q4)

The main question posed in this section is how the gap between the sovereign spread and the qCDS was affected by the near-deflationary environment and then implementing the UMP as one of the institutional responses against divergence, while dollar liquidity was scarce at some levels during the whole period.

a) Response of sovereign premium to the selected variables

The impulse response function (Fig. 2) displays the response of the sovereign premium on the shocks from the different variables of the global financial crisis (2008) to the COVID-19 pandemic. Rising implied volatility on the European stock exchanges had an insignificant impact overall, indicating an insulation between the bond and stock markets and the lack of the portfolio-rebalancing effect. However, the rise of the USD liquidity scarcity in the form of more negative currency base swaps increased the sovereign premium in the first quarter, after which it had a

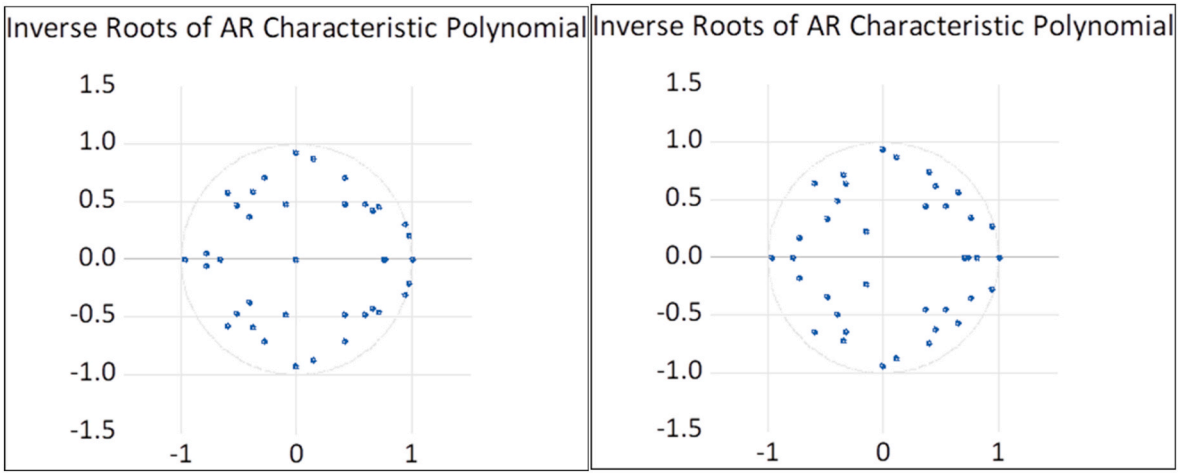

Fig. 1. AR graph for stability check for the entire period (left) and pre-COVID-19 period (right).
Source: Authors' calculation in EViews 13

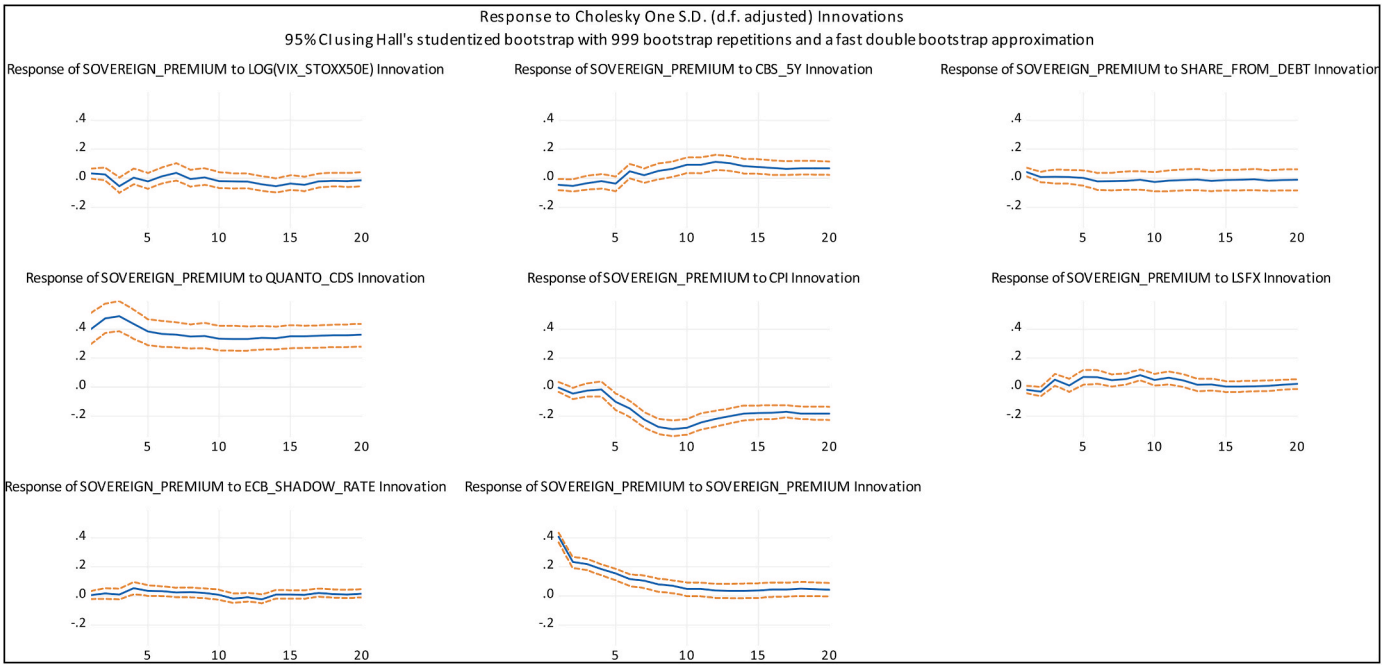

Fig. 2. Impulse response of sovereign spread to the selected variables (2008Q1–2019Q4).
Source: Authors' calculation in Eviews 13

moderating long-run effect as the European banks were able to adapt and tap the regional funding channels due to cross-central bank swap lines. An increasing share of the total debt of the Eurozone had a small but positive impact in the first quarter; hence, relative

indebtedness had only an immediate feedback compared to other variables. Redenomination risk is represented by the qCDS, which had the strongest influence on the sovereign premium, as most of the country-specific risks are captured in them relative to the US and Germany. The negative influence of the Consumer Price Index (CPI) highlights the impact of deflationary pressure, a strong indicator of the flight to safety patterns from investors. Meanwhile, the steady accumulation in the provided loans and security portfolio to the foreign exchange reserve at the ECB has a moderate but positive effect, as the ECB purchases government bonds in the secondary market by its shareholder composition and does not smooth out the country-specific disturbances. Meanwhile, an increase in the shadow rate provides a short, but positive response to what is reasonable, as tightening of short-run funding also has a transmission on long-term funding conditions.

b)Variance decomposition of sovereign spread

The variance of the sovereign spread is mainly driven by the redenomination risk (qCDS) in all periods (Table 4). Conversely, the inflation and the currency base swap conditions have long-term influence. Notably, the central bank balance sheet structure gains minor importance in the long term, which later dissipates.

4.5. Eurozone's sovereign spread during the whole period (2008Q1–2022Q3)

While the early 2010s were characterized by fiscal and monetary mitigations of the aftereffects of the global financial crisis in a

Table 4
Variance decomposition of sovereign spread (2008Q1–2019Q4).

Period	LOG(VIX_STOXX50E)	CBS_5Y	SHARE_FROM_DEBT	QUANTO_CDS	CPI	LSFX	ECB_SHADOW_RATE	SOVEREIGN_PREMIUM
1	0.32	0.62	0.56	48.34	0.00	0.09	0.01	50.06
2	0.28	0.78	0.31	62.27	0.32	0.21	0.05	35.77
3	0.52	0.66	0.22	68.35	0.28	0.43	0.04	29.50
4	0.42	0.57	0.18	71.31	0.24	0.35	0.29	26.63
5	0.39	0.59	0.16	72.19	0.99	0.68	0.34	24.65
6	0.36	0.67	0.17	72.57	2.32	0.91	0.38	22.62
7	0.40	0.62	0.17	71.87	4.97	0.94	0.37	20.66
8	0.36	0.68	0.17	70.35	8.34	1.00	0.36	18.73
9	0.32	0.81	0.16	68.77	11.38	1.22	0.34	17.00
10	0.31	1.11	0.17	67.51	13.74	1.22	0.31	15.61
11	0.31	1.37	0.17	66.94	15.06	1.30	0.30	14.56
12	0.31	1.75	0.17	66.66	15.87	1.29	0.29	13.66
13	0.35	2.02	0.16	66.72	16.33	1.23	0.29	12.90
14	0.43	2.14	0.16	66.99	16.56	1.17	0.28	12.27
15	0.45	2.23	0.16	67.40	16.70	1.12	0.27	11.69
16	0.49	2.27	0.15	67.77	16.82	1.06	0.25	11.18
17	0.48	2.28	0.15	68.23	16.87	1.01	0.26	10.72
18	0.47	2.31	0.15	68.57	16.99	0.97	0.25	10.30
19	0.46	2.33	0.15	68.89	17.10	0.93	0.24	9.91
20	0.44	2.35	0.14	69.19	17.20	0.91	0.24	9.53

Source: authors' calculation in Eviews 13

deflationary environment, the different shocks of the early 2020s brought back the inflation and the increasing funding costs on the bond markets. The continuous increase in the bond yields underlies the sovereign spread divergence re-remergence.

a) Response of sovereign premium to the selected variables

The impulse response function (Fig. 3) shows the sovereign premium response to the shocks, coming from the different variables of the whole sample with the supply shocks and war-driven inflation. Rising implied volatility of the European stock exchanges had a stable negative impact in the long run, which may be reasonable if investors rebalanced their portfolios from shares to bonds under such turbulent times. However, rising USD liquidity scarcity in the long run in the form of more negative currency base swaps decreased the sovereign premium as European banks were forced to utilize domestic funding channels, underscoring the importance of cross-central bank swap lines. An increasing share of the total debt of the Eurozone had an instantaneous positive impact. Redenomination risk is represented by the qCDS, which had the strongest influence on the sovereign premium, as most of the country-specific risks are captured in them relative to the US and Germany. This variable maintained its importance, especially in the short term. The negative influence of the CPI highlights the impact of deflationary pressure, which is a strong indicator of the flight to safety patterns from investors. Meanwhile, a steady accumulation in the provided loans and security portfolio to the foreign exchange reserve at the ECB has a clear long-run negative effect. Hence, these purchases have a significant calming effect in the long term if the continuous appearance of different funding and natural and political crises oversaturates the environment. An increase in the shadow rate provides a positive response to what is reasonable,

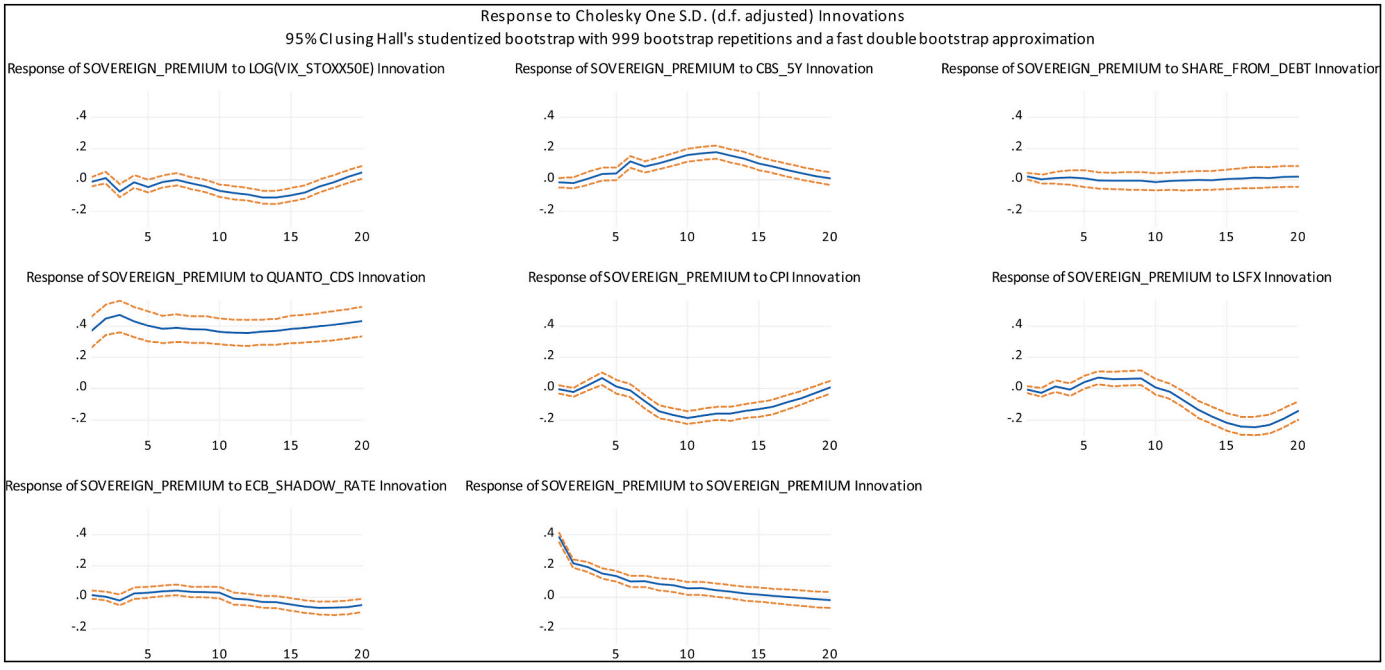

Fig. 3. Impulse response of sovereign spread to the selected variables (2008Q1–2022Q3).
Source: Authors' calculation in Eviews 13

Table 5
Variance decomposition of sovereign spread (2008Q1–2022Q3).

Period	LOG(VIX_STOXX50E)	CBS_5Y	SHARE_FROM_DEBT	QUANTO_CDS	CPI	LSFX	ECB_SHADOW_RATE	SOVEREIGN_PREMIUM
1	0.05	0.08	0.19	47.87	0.01	0.02	0.06	51.73
2	0.06	0.12	0.10	62.96	0.09	0.15	0.04	36.48
3	0.73	0.09	0.09	69.72	0.12	0.12	0.07	29.06
4	0.59	0.21	0.09	73.17	0.53	0.10	0.12	25.18
5	0.67	0.32	0.09	75.23	0.47	0.23	0.17	22.82
6	0.60	1.28	0.08	76.19	0.41	0.55	0.25	20.64
7	0.53	1.61	0.07	77.01	0.78	0.72	0.35	18.93
8	0.50	2.09	0.06	76.92	1.90	0.87	0.37	17.29
9	0.53	2.76	0.06	76.30	3.16	1.00	0.39	15.81
10	0.71	3.67	0.06	75.28	4.50	0.91	0.39	14.48
11	0.94	4.59	0.06	74.37	5.41	0.85	0.36	13.41
12	1.22	5.48	0.05	73.47	6.00	1.01	0.34	12.44
13	1.58	5.92	0.05	72.54	6.46	1.59	0.35	11.51
14	1.89	6.10	0.05	71.71	6.67	2.55	0.36	10.67
15	2.05	6.00	0.04	71.03	6.73	3.84	0.40	9.91
16	2.09	5.80	0.04	70.44	6.65	5.28	0.47	9.22
17	2.01	5.53	0.05	70.21	6.43	6.58	0.57	8.63
18	1.89	5.25	0.05	70.33	6.14	7.56	0.65	8.12
19	1.80	4.99	0.05	70.87	5.83	8.05	0.71	7.70
20	1.77	4.75	0.06	71.69	5.55	8.13	0.73	7.33

Source: authors' calculation in Eviews 13

because tightening in the short-run funding also transmits to long-term funding conditions.

b) Variance decomposition of sovereign spread

Considering the whole period by adding the turbulent early 2020s, the variance of the sovereign spread remains mainly determined by the redenomination risk (qCDS) on all periods (Table 5). However, the influence of inflation and the central bank balance sheet structure is also critical in the long term. The currency base swap maintained its previous long-term influence. Notably, the stock market's implied volatility and the ECB's shadow rate also gained minor importance.

5. Conclusions

The Euro crisis revealed the high cost of EMU membership as member countries issued and accumulated debt in a currency over which they had no direct control. Hence, they cannot utilize monetary policy instruments to implement necessary adjustments or control inflation to decrease the real value of public and private debt. The fragile nature of yields was revealed once again during the COVID-19 pandemic, a decade after the sovereign debt crisis. Unprecedented price shocks from the COVID-19 pandemic and the Russia–Ukraine conflict nearly developed into another sovereign debt threat, which may have become a new unprecedented economic fallout for member states.

Sovereign spread divergence is defined as the growing difference between particular member states and Eurozone's average 10-year-long yields. In this study, we first examined the Eurozone's sovereign spread development from the first quarter of 2008 to the fourth quarter of 2019, when the two major crises were the 2008 global financial crisis and the 2012 Eurozone sovereign debt crisis. We then extended the sample for the period between 2008Q1 and 2022Q3 to add two major global crises: the COVID-19 pandemic starting in 2020 and the energy price shock in 2022. Moreover, to perform this research, we utilized both the panel VECM and the accumulated response functions, as well as variance decomposition techniques. We adopted this approach to evaluate the sovereign spread's reaction to the redenomination risk (to highlight risk aversion and investors' uncertainty), to the implementation of UMP instruments, to the country's specific fiscal conditions, to inflation, and the EURO–USD swap rate (as a proxy for external funding conditions) for both the nonpandemic and whole periods. To capture the ECB's monetary policy, we employed both the balance sheet structure and shadow rate, owing to the quantitative easing and zero lower bound, respectively.

One of our primary conclusions is that country-specific redenomination risk, characterized by qCDS, played a crucial role in causing sovereign spread divergence in both sample periods. This means that investors' sentiment remains critical in determining and fragmenting yields, regardless of introducing multiple safety lines (e.g., the Banking Union in the financial sector or the ESM and the European Semester in fiscal policy) as the last sovereign fragmentation event.

Second, the results emphasized the important role of the ECB's unconventional monetary policies and asset-purchasing programs in reducing sovereign spreads over the examined period. Applying unconventional instruments was captured better by our balance sheet structure indicator (LSFX ratio) than by the shadow rate. This covers major shocks, including the subprime crisis, sovereign debt crisis, and more recently, the COVID-19 pandemic and Russia–Ukraine conflict.

Third, the international dollar funding scarcity represented by the EUR–USD currency base swap significantly influenced long-term sovereign yields, highlighting the importance of the cross-central banks' swap lines.

Fourth, the sovereign spread is negatively associated with inflation in both sample periods. After a decade-long, near-deflationary period, inflation began to rise again in the early 2020s. This required further monetary tightening to maintain the central bank's credibility, which could increase the yields of sovereign bonds. Moreover, if this increase is asymmetric among member states, sovereign spread can also increase. Our findings mainly rejected this idea because sovereign spreads also rose in deflationary cases. This suggested that investors tended to cherry-pick bonds during these times; however, by introducing ESM, the ECB's APPs, and the more prudent fiscal policy rules, this effect later disappeared.

Moreover, our findings emphasized the significant role of redenomination risk in the divergence of sovereign spreads; therefore, the ECB and the European Commission should monitor the market tension associated with breakup fears. Our results help quantify the role of redenomination risk in determining asset prices to design monetary and fiscal policy in a timely manner. Because in our case the rebalanced asset side had a greater impact on the sovereign spread (especially during turbulent times), we suggest that policymakers and investors acknowledge that the central bank balance sheet structure is now the key indicator for monetary policy instead of the policy rate. Meanwhile, the somewhat hesitant nature of the ECB after 2020 can be understood as the gradual development of inflation and exogenous shocks that follow a different path in our model.

Credit authors statement

Herby, we are outlining their individual contributions to the paper: ***Sabri Alipanah:*** Investigation, Validation, Data curation, Writing-Original draft, Reviewing and Editing preparation. ***Gábor Dávid Kiss:*** Methodology, Software, Supervision, Reviewing and Editing preparation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

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Sovereign spread divergence owing to inflation and redenomination risk countered by unconventional monetary policy in the Eurozone (Original data) (Mendeley Data)

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.econmod.2023.106613.

Appendix

Appendix 1

Descriptive statistics of the differentiated variables

	LOG_VIX	CBS_5Y	SHARE_FROM_DEBT	QUANTO_CDS	CPI	LSFX	ECB_SHADOW_RATE	SOVEREIGN_PREMIUM
Mean	8.0323	−27.9279	0.0642	72.9856	1.4693	3.6548	−2.9480	0.2854
Median	8.0540	−25.7000	0.0251	32.0100	1.2952	2.7129	−2.5616	−0.1536
Maximum	8.3660	−7.7500	0.2645	1406.833	14.1136	7.5723	3.7537	14.1231
Minimum	7.6359	−68.8000	0.0005	−85.5700	−6.1278	1.5313	−7.7197	−4.6050
Std. Dev.	0.1632	13.0790	0.0846	148.7034	1.7761	1.8509	3.0154	1.7748
Skewness	−0.3080	−0.5743	1.2886	3.4466	1.3698	0.7719	−0.0169	2.8680
Kurtosis	2.6668	3.0884	2.9797	21.0706	10.1272	2.3442	1.6770	15.5042
Jarque-Bera	17.5	47.4	237.2	13357.1	2081.8	100.5	62.5	6758.0
Probability	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Observations	857	857	857	857	857	857	857	857
Levin. Lin & Chu t*	0.0000	0.0000	0.0000	0.0000	0.9747	0.0006	0.0000	0.0000
Im. Pesaran and Shin W-stat	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ADF - Fisher Chi-square	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
PP - Fisher Chi-square	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Note: Panel unit root test *p*-values are provided on the first difference with 1 lag.
Source: EViews 13, authors' edition

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