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Does membership of the EMU matter for economic and financial outcomes?

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Abstract

This study examines the effects of joining the European Monetary Union (EMU) using propensity score matching to address self-selection bias. Findings indicate that EMU membership leads to reduced volatility in inflation, output growth, and bond yields. However, it also reveals fiscal deterioration in member states during the pre-financial crisis period, even excluding Greece, Ireland, Portugal, and Spain. These countries experienced favorable bond market conditions pre-crisis. The study underscores varying EMU effectiveness across different periods and countries, emphasizing the importance for policymakers to consider these variations when adopting EMU strategies.

KEYWORDS
bond market, European monetary union, fiscal stance, sovereign debt crisis, treatment effects

JEL CLASSIFICATION
E44, E52, F36

1 | INTRODUCTION

The establishment of the European Monetary System and the formation of the Common Economic and Monetary Union in 1992 preceded the adoption of the euro by the European Monetary Union (EMU) in 1999. The primary objective of the EMU was to promote the integration of goods and financial markets by eliminating exchange rate volatility risks, reducing transaction costs, and dismantling regulatory barriers to international financial trade. On the monetary policy front, the European Central Bank (ECB) was established to manage the euro and implement economic and monetary policies within the EMU. Its main goal is to maintain price stability, thus supporting economic growth and job creation. In recent history, only a few economic experiments of the scale of the EMU have been undertaken. Consequently, policymakers and researchers have shown significant interest in understanding the impact of the EMU on macroeconomic and financial outcomes in member countries. These studies encompass a wide range of topics, including the effect of monetary unification on price stability (Brada et al., 2005; McKinnon, 1963; Orlowski, 2005; Rogers, 2007), interest rate stability (Beetsma & Giuliodori, 2010), openness and real exchange volatility (Rogers, 2007), interest rate convergence (Abad et al., 2010; Bhatt et al., 2017; Ehrmann et al., 2011), and yield spread (Faini et al., 2006; Gomez-Puig, 2009).

Abbreviations: ATT, Average Treatment Effect on the Treated; ECB, European Central Bank; EMU, European Monetary Union; EU, European Union; GARCH, Generalized Autoregressive Conditional Heteroskedasticity; GDP, Gross Domestic Product; GPIS, Greece, Ireland, Portugal, and Spain; SGP, Stability and Growth Pact.

Although a significant amount of research has been conducted on the impact of the EMU on macroeconomic and financial outcomes in member countries, a consensus on its effectiveness has not been reached. Furthermore, the recent debt crisis in the Eurozone has reignited the debate surrounding the efficacy of the EMU. The main challenge in estimating the impact of the EMU lies in determining the counterfactual scenario for member countries. Specifically, it is difficult to ascertain what macroeconomic and financial outcomes would have been if countries had not joined the monetary union. If the decision to join were random, calculating the mean differences in outcome variables between members and non-members would be feasible. However, a self-selection issue arises when a country's decision to join the EMU is non-random. In particular, a systematic correlation between the choice to become a member and other covariates introduces a self-selection problem that leads to biased estimates. We find evidence for the existence of this problem.

The membership variable is correlated with covariates, such as interest rate spread, money growth, and measures of financial market development. To address the self-selection problem, we employ a widely used method in applied microeconomics literature called propensity score matching. This method allows us to estimate the treatment effects of joining the EMU. Specifically, we utilize this approach to estimate the average treatment effect on the treated (ATT) for EMU members. The ATT is the difference in mean outcomes between countries that have adopted the euro. This method has been previously applied in the macroeconomic literature, particularly in studies examining the effectiveness of inflation targeting (Ardakani et al., 2018; de Mendonca and de Guimaraes, 2012; Lin & Ye, 2007) and fiscal policy (Jordà & Taylor, 2016). Propensity score matching enables us to estimate the counterfactual outcomes of EMU countries by selecting EMU and non-EMU countries with similar distributions of observed covariates. In practice, we use a two-step approach where the propensity score is estimated in the first step, and the ATT is estimated using matched samples by plugging in the estimated propensity score in the second step.

Our paper advances the existing literature in two significant ways. First, prior studies have not adequately addressed the self-selection bias resulting from the non-random nature of countries' decisions to join the EMU. This bias has the potential to mask true causal relationships, leading to misleading conclusions. Second, existing literature has not thoroughly investigated the varied impacts of EMU membership on individual member countries. Our research bridges these gaps by accounting for the self-selection bias, which allows us to better isolate the treatment effect of EMU membership. Moreover, we study how economic and financial outcomes differ among member states, underscoring the need for adequate economic policies.

We utilize data spanning from 1990 to 2019, encompassing 19 EMU member countries and 20 non-member European countries, to investigate the treatment effect of joining the EMU on various outcomes. These outcomes include the level and volatility of inflation, real Gross Domestic Product (GDP) growth, bond yield level and volatility, and the fiscal stance measured by the debt-GDP ratio. To ensure robustness, we conduct several additional analyses that consider different sample periods and membership based on different stages of the monetary union's formation.[1] To the best of our knowledge, our study employs the most comprehensive data on macroeconomic and financial outcomes in both EMU and non-EMU countries, contributing to the literature that explores the effectiveness of the EMU.

Our findings are summarized as follows: First, the ATT estimates on the volatility of inflation, real GDP growth, and bond yield are negative and statistically significant, implying that the members have experienced lower volatility in these broad macro indicators than non-members. In addition to the impact on volatility, very interesting results emerge if we split the sample into the pre-crisis (1990–2008) and the post-crisis (2009–2019) periods in one case and exclude Greece, Ireland, Portugal, and Spain (GIPS) from the sample in another. The ATT on inflation becomes negative and statistically significant in the post-crisis period, suggesting sustained downward pressure on prices in the countries under the EMU after the financial crisis of 2008–2009. The results also indicate that positive and statistically significant ATT on the debt-GDP ratio was driven by the post-crisis period, even if GIPS are not excluded from the sample. The crisis experienced by periphery countries led to a decoupling of GIPS from the rest of the EMU members, as indicated by the increased importance of idiosyncratic factors in each of these countries. Finally, the ATTs on the bond yield and debt-GDP ratio are particularly sensitive to excluding GIPS from the sample. We find positive and significant ATT on the debt-GDP ratio in the pre-crisis period if GIPS are excluded from the sample. These results challenge the conventional wisdom that GIPS were solely responsible for the increasing debt-GDP ratio in the EMU. Instead, our results suggest that EMU members experienced higher debt before the crisis, as demonstrated by the positive and statistically significant ATT in the pre-crisis period after the exclusion of GIPS. However, the ATT on yields varies in the post-2008 sample period, indicating that the bond market treated some periphery countries differently than the core EMU countries. This finding suggests that the market may have recognized differences in the countries' economic fundamentals, such as their debt levels, and adjusted their bond yields.

Our findings carry significant policy implications. We demonstrate that EMU membership has reduced volatility in key economic indicators. The EMU should leverage this strength by offering guidance and tools to help member states further stabilize these metrics. Given our observation that fiscal challenges were more pervasive than initially thought, the EMU should provide robust oversight and monitor fiscal situations across all member states, not just those traditionally viewed as problematic. This could entail stricter reporting requirements. Furthermore, our results indicate that the impacts of the EMU vary among member countries, suggesting that a one-size-fits-all approach may not be suitable. Consequently, the EMU should promote collaboration among member states to exchange experiences, insights, and solutions for mutual challenges.

The rest of the paper is organized as follows. Section 2 reviews the literature on the impacts of the EMU on macroeconomic and financial outcomes. Section 3 describes the estimation framework to capture the causal effect of monetary unification. Section 4 describes data. Section 5 presents the empirical findings of propensity score and treatment effect estimates of joining the EMU. Section 6 presents additional robustness checks and sensitivity analysis to ensure a comprehensive evaluation and validation of our findings. Section 7 provides some concluding remarks and policy implications.

2 | BACKGROUND

The literature on the impacts of the EMU on macroeconomics and finance has garnered substantial attention from scholars and policymakers. The concept of a currency union, which influenced the first wave of papers examining its impacts, is rooted in the classic work of Mundell (1961) on the theory of optimum currency areas. The theoretical literature on currency unions is also connected to the impossible trinity, which posits that the free movement of capital, a fixed foreign exchange rate, and an independent monetary policy cannot coexist.

Some scholars, like Wyplosz (1997), have argued that a single currency in the form of a monetary union is more beneficial than a floating exchange rate, given the freedom of capital flows, and eliminates the time inconsistency problem associated with monetary policy. Others, such as Alesina and Barro (2002) and Pappa (2004), suggest that a single currency enhances credibility and reduces the welfare costs of the policy. Furthermore, adopting a single currency could improve economic outcomes in member countries. These views are based on the notion that a single currency would increase labor market flexibility, reducing European structural unemployment. As noted by von Hagen (1999), the common currency would create competition among governments in the regulatory and tax policy realm. It would encourage governments to undertake long overdue structural reforms, theoretically setting the EMU economy on a higher growth path. Additionally, Gyoerk (2017) offers a generalized examination of the EMU's costs and benefits, highlighting the trade-offs that member countries face. This perspective enriches the understanding of the EMU's implications beyond monetary aspects, encompassing socio-economic factors that resonate with the views of Alesina and Barro (2002) and Pappa (2004) regarding enhanced credibility and welfare improvement.

The second wave of studies on the EMU focuses on evaluating its effectiveness after its formation. However, the findings are mixed. On the one hand, Angeloni et al. (2014) argue that inflation persistence has decreased in the eurozone, but this decline was also observed in other countries such as the UK and US. On the other hand, Caporale and Kontonikas (2009) find that the EMU was less effective in lowering inflation uncertainty and showed that inflation uncertainty had increased in the euro area. In contrast, Meller and Nautz (2012) provided some evidence on the effectiveness of the EMU, reporting that inflation persistence had decreased in the member countries. These findings were inconsistent with the arguments presented in Beetsma and Giuliodori (2010) and Rogers (2007), who suggest that unification leads to more stable prices. In addition, Orlowski (2005) further elaborates on the objective of price stability in the eurozone. Some studies also examined the heterogeneity in the effectiveness of the EMU among different member countries. For instance, Busetti et al. (2006) study the effect of joining the EMU on inflation and suggested heterogeneity among the members. They find that two clusters existed within the eurozone, one including members such as Germany, France, Belgium, Austria, and Finland, who had experienced lower inflation, and the other consisting of southern members such as Spain, Greece, Portugal, and Ireland, who had experienced higher inflation. Vinturis (2022) examines fiscal rules within the EMU compared to the non-members, illustrating the disparities in economic outcomes attributable to these regulatory differences. The results corroborate the findings of Busetti et al. (2006) concerning heterogeneity among member countries, pointing to the significance of tailored fiscal governance in controlling inflation and other economic indicators.

The impact of the EMU on real economic activity is an area that has received relatively little attention from researchers. However, some studies have examined the real effects of the EMU. For example, Lane (2006) identifies five main aspects of financial and trade integration, labor mobility, fiscal policy, and the political viability of the euro. Calmfors (2001) finds that the EMU has reduced unemployment through labor market reforms. Recent studies have focused on real and financial synchronicity, such as employment Furceri et al. (2020) and Bayoumi and Eichengreen (2020).

Regarding fiscal sustainability, Auerbach and Gorodnichenko (2017) and Caselli and Wingender (2021) shed light on the impact of government spending and the Maastricht treaty. Auerbach and Gorodnichenko (2017) finds that government spending shocks are unlikely to cause long-lasting increments in debt-to-GDP ratios or borrowing costs, particularly during economic downturns. They also suggest that fiscal stimulus during sluggish economic periods can enhance fiscal sustainability. Similarly, Caselli and Wingender (2021) find that the Maastricht treaty's fiscal criterion affected the distribution of general government deficits in European Union (EU) countries, reducing large deficits and improving the fiscal stance even when members did not fully comply with the rule.

The Stability and Growth Pact (SGP), introduced in 1997, provides a set of rules and guidelines to ensure fiscal discipline and stability in the eurozone. However, Herwartz and Theilen (2022) find no evidence that the SGP has caused the fiscal policy to become more pro-cyclical. Ioannou and Stracca (2022) show that the SGP has not significantly impacted the fiscal outcome. Overall, these studies provide insights into the impact of fiscal policies and regulations on members' fiscal stability, shedding light on the effectiveness of various policies in promoting fiscal sustainability in the eurozone. Barbier-Gauchard et al. (2021) advocate using the average treatment effect on the treated for assessment in fiscal policy, especially in the context of macroeconomic reforms. Their research underscores the role of fiscal policy in shaping reform outcomes, a dimension that resonates with the discussions on fiscal sustainability by Auerbach and Gorodnichenko (2017) and Caselli and Wingender (2021). This approach strengthens the argument that vigilant fiscal strategizing is indispensable in harnessing the full potential of macroeconomic reforms within the EMU framework. The use of treatment effect methods, as discussed by Barbier-Gauchard et al. (2021), is instrumental in isolating the effect of the treatment on the treated group, thus offering more precise estimations of policy effectiveness and outcomes. This is particularly relevant in the EMU context, where varying fiscal strategies among member countries necessitate an approach that accounts for heterogeneity in policy impacts.

In another strand of literature, several studies have investigated the impact of the EMU on the bond markets in member countries. The underlying idea is that a single currency facilitates financial integration in the region by eliminating exchange rate risks and transaction costs embedded in international financial trades and paving the way for regulatory reforms conducive to such integration (Jappelli & Pagano, 2008). For example, Fratzscher (2002) and Kim et al. (2004) employ time-varying GARCH models and find that the reduction in exchange rate uncertainty due to the drive toward the EMU played a fundamental role in the financial integration process in the region. Similarly, Ehrmann et al. (2011) find evidence for substantial convergence in the euro area sovereign bond markets and attribute such convergence to eliminating exchange rate risk and adopting a common monetary policy. Pagano and von Thadden (2004) document increasing integration in the European markets for both sovereign and private bond yields. They argue that slight differences between bond yields of member countries can be attributed to differences in fundamental risks. Baele et al. (2004) documents a smaller spread between yields in the various eurozone bond markets and Germany. They identify convergence-underlying fundamentals, such as exchange rates and inflation expectations, as essential determinants of bond market integration in the euro area. Pozzi and Wolswijk (2012) use a standard capital asset pricing model to show almost perfect bond market integration among the five EMU countries (Belgium, France, Germany, Italy, and the Netherlands). Gomez-Puig (2009) finds that yield spreads declined after the formation of the currency union before the financial crisis of 2008. In order to identify the sources of changes in bond yield spreads, Kerstin and Burcu (2012) examine whether these changes are due to the change in macroeconomic fundamentals or the change in the pricing of sovereign risk. They find that the factors changing yield spreads vary over time. Heinemann et al. (2014) also study sovereign bond premia within the eurozone and link the bond yield spread to fiscal stability.

The recent financial crisis of 2008 led to dramatic changes in the economic environment in the member countries. For example, the co-movement of the EMU members' bond yields was broken down. This led to a recent surge in studies on the impact of the EMU, especially on the effect on sovereign bond yields. Most of these studies conclude that before the financial crisis, the bond market did not respond to the fundamentals of the member countries, as there was an implicit assumption about risk sharing among the member countries. However, after the financial crisis, the market realized this was not the case and hence started responding to fundamentals (Bhatt et al., 2017; Costantini et al., 2014; Mody & Sandri, 2012). For this reason, Lane (2012) also concluded that a monetary union is fragile under crisis

conditions. In this context, one issue that has received prominent attention from the media and policymakers is the public debt behavior in member countries. This was explicit during the crisis as the significant increase in spread and high public debt kept reinforcing each other in some periphery countries. Recently, a few papers have used causal inference techniques to examine the impacts of the EMU and European integration (Campos et al., 2019; De Grauwe & Ji, 2014; Puzzello & Gomis-Porqueras, 2018).

Most papers in the current literature suffer from selection bias, as the decision to join the EMU is not randomly made. Our paper aims to overcome this problem by utilizing an alternative approach to estimate the causal effect of the EMU on the macroeconomic and financial performance of member countries. To address the selection bias problem, we employ the propensity score matching method, a popular technique used in the applied microeconomics literature. We use this method to investigate the causal effect of the EMU on economic and financial variables such as inflation, GDP, bond yield, and the volatility of these variables. Furthermore, we analyze the impact of the EMU on the public debt-GDP ratio, as this was the primary concern during the debt crisis. This allows us to answer whether the EMU played a role in the accumulation of public debt in member countries. We recognize the methodological challenges in the existing literature, notably the selection bias in EMU membership. We draw on previously established causal inference techniques to provide a comprehensive analysis. By employing propensity score matching, we isolate the EMU's causal effect for studying its implications on member economies.

The literature on evaluating the effectiveness of joining the EMU has recently employed various causal inference techniques. These include difference-in-differences, regression discontinuity, synthetic controls, and propensity score matching. However, the difference-in-differences and regression discontinuity methods do not effectively address selection bias. One commonly used approach is the synthetic control method initially introduced by Abadie and Garderazabal (2003) and further developed by Abadie et al. (2010). This method limits extrapolation bias at the expense of interpolation bias, whereas propensity score matching has an opposite property (Kellogg et al., 2021). In the context of joining the EMU, the extrapolation bias arises when countries with different pre-euro characteristics are combined using a traditional adjustment, such as linear regression. The interpolation bias, however, uses a convex weighted average of the non-EMU countries to create non-EMU synthetic countries with pre-euro characteristics similar to the EMU members. The main difference between synthetic control and propensity score matching is within the matching process. The synthetic control method uses only pre-euro covariates in matching. In contrast, propensity score matching uses the entire pre and post-euro variables for matching. Also, the synthetic control method is helpful when we have very few treatment units. Correcting the selection bias and having multiple treated units (i.e., EMU members) are why propensity score matching is preferred.

3 | FRAMEWORK

We estimate the causal effect of monetary unification by employing a non-randomized propensity score matching technique. This method is beneficial when assigning countries randomly to treatment (joining the EMU) is challenging. Randomization is important in establishing causal relationships and ensuring that the observed effects are due to the EMU membership rather than external factors. We first estimate the propensity score for countries joining the EMU, which addresses the issue of non-randomness and reduces dimensionality. Subsequently, we utilize the propensity score to ensure a balanced distribution of covariates between the country groups and estimate the treatment effects. In this process, countries are categorized into treatment groups (EMU members) and control groups (non-EMU countries).

We assume each country i has two potential outcomes (Y_{0i}, Y_{1i}) corresponding to the control and treated groups for $i = 1, ..., N$. We define a binary variable U_i, where $U_i = 1$ denotes the country joins the EMU (i.e., monetary unification) and $U_i = 0$ denotes a non-EMU country. And also, let $\mathbf{x}$ be a set of observed covariates, such as country-level characteristics. The parameter of interest is the average treatment effect on the treated (ATT) defined as

$$\tau_{att} = \mathbb{E}[(Y_1 - Y_0)|U = 1], \tag{1}$$

which is a function of counterfactual outcomes, (Y_{0i}, Y_{1i}). The fundamental problem of this causal inference is that we observe either Y_{0i} or Y_{1i} (not both) for each country i (Holland, 1986). To be specific, the observed outcome can be written as

$$Y_i = U_i Y_{1i} + (1 - U_i) Y_{0i}. \tag{2}$$

The question is how we recover τ_{att} using the observed outcome Y_i. To this end, we adopt the propensity score matching approach.

Let $\pi(\mathbf{x})$ be the propensity score defined as the conditional probability of joining the EMU, given the observed covariates

$$\pi(\mathbf{x}) = \mathbb{P}(U = 1|\mathbf{x}), \tag{3}$$

where $\mathbb{P}(\cdot)$ is the conditional probability. We assume two conditions introduced in Rosenbaum and Rubin (1983): (1) $E[Y_0|\mathbf{x}, U] = E[Y_0|\mathbf{x}]$, known as conditional (mean) independence or selection on observables and (2) $\pi(\mathbf{x}) < 1$ for all $\mathbf{x}$, known as overlap or the common support. The assumption of selection on observables states that the potential outcome in a non-EMU country is independent of the treatment conditional on an available set of covariates $\mathbf{x}$. As a result, selection into treatment becomes random conditioning on the covariates $\mathbf{x}$ so that the ATT can be obtained by comparing outcomes in EMU members to those in non-EMU countries with the same values of the covariates. The overlap assumption imposes the common support condition, guaranteeing sufficient overlap between the propensity score distributions across EMU and non-EMU countries. Given these conditions, the ATT can be identified and estimated. Rosenbaum and Rubin (1983) suggest using the propensity score $\pi(\mathbf{x})$ instead of the covariates $\mathbf{x}$ in the case that the number of covariates is so large that there is a dimensionality problem.

We can get the following results from the assumptions:

$$\begin{aligned} E[Y|\mathbf{x}, U = 1] - E[Y|\mathbf{x}, U = 0] = E[Y_0|\mathbf{x}, U = 1] - E[Y_0|\mathbf{x}, U = 0\,] \\ + E[Y_1 - Y_0|\mathbf{x}, U = 1] = E[Y_1 - Y_0|\mathbf{x}, U = 1]. \end{aligned} \tag{4}$$

Then we get

$$\tau_{att} = E\Big[E[Y_1 - Y_0|\mathbf{x}, U = 1]\Big] = E\Big[E[Y|\mathbf{x}, U = 1] - E[Y|\mathbf{x}, U = 0]|U = 1\Big], \tag{5}$$

or

$$\tau_{att} = E\Big[E[Y|\pi(\mathbf{x}), U = 1] - E[Y|\pi(\mathbf{x}), U = 0]|U = 1\Big] \tag{6}$$

Note that the right-hand side is a function of observed variables so that it can be estimated from the data.

We employ statistical tests to verify the conditional independence and common support assumptions. These tests ensure sufficient overlap in propensity scores between treated and control units and verify the conditional independence assumption by implementing a balancing test. The latter evaluates whether conditional on the propensity scores, the covariates are independent of treatment assignment, ensuring that covariate imbalances do not drive the treatment effect. Such testing procedures have also been detailed in Apeti et al. (2023).

In practice, we use a two-step approach where the propensity score is estimated in the first step, and the ATT is estimated in the second step by plugging in the estimated propensity score. The first step affects the large sample distribution of propensity score matching estimators (Abadie & Imbens, 2016). We estimate the propensity score using logistic regression (logit model), where the logistic regression is written as

$$\pi(\mathbf{x}) = \frac{e^{\mathbf{x}\beta}}{1 + e^{\mathbf{x}\beta}} \tag{7}$$

with parameters β. Having the estimated propensity scores $\hat{\pi}(\mathbf{x})$, we then use them to match EMU members with non-EMU ones. The propensity score matching estimator for the ATT can be defined as

$$\hat{\tau}_{att} = \frac{1}{N_1}\sum_{i=1}^{N} U_i\left(Y_i - \frac{1}{M}\sum_{j\in\mathcal{J}_M}(i)Y_j\right), \tag{8}$$

where $N_1 = \sum_{i=1}^{N} U_i$ is the number of countries in the treated group, M is a fixed number of matches per country and $\mathcal{J}_M(i)$ is the set of matches for country i where we match on the estimated propensity scores $\hat{\pi}(\mathbf{x})$. The most common

approach is one-to-one matching (i.e., $M = 1$). For $M > 1$, one treated observation matches more than one control, and the matched units will include multiple matched control observations. We also utilize various estimators such as nearest-neighbor and radius matching (RM), following the methodology employed in Minea and Tapsoba (2014). The main results remain robust to the multiple matching.

The advantage of using the propensity score approach is two-fold: (1) it reduces dimensionality so that we can match based on one single score as opposed to multiple covariates and (2) it generates a homogeneous matched set so that we can select EMU and non-EMU members with the same distribution of observed covariates. In principle, the matched new sample corrects for the selection bias. The unbiasedness of the estimator lies in the conditions discussed above. In particular, if there are unobserved omitted variables in the EMU adoption decision, which also affect outcomes of non-EMU countries, then the conditional independence assumption can be violated. As a result, the propensity score matching estimator becomes biased. We address this possible endogeneity issue using a sensitivity analysis by following recommendations in Black and Smith (2004) and Heckman and Navarro-Lozano (2004). Note that the bias from the assumption violation is minimized at $\pi(\mathbf{x}) = 0.5$. Thus, the authors recommend that researchers estimate ATT using the "thick support region" of the propensity score as a sensitivity analysis (e.g., $.33 \leq \widehat{\pi}(\mathbf{x}) \leq .67$). The results from the sensitivity analysis are discussed in Section 6.5. We also control for the possibility of heteroskedasticity by computing the heteroskedasticity-robust standard errors in both stages throughout the paper (Abadie & Imbens, 2006, 2016; White, 1980).

Guo and Fraser (2015) illustrate that a correct specification of the first-step model depends on including proper variables and correctly specifying the functional form of conditional variables. The former relies on prior studies and theoretical relevance. Propensity score matching also has potential limitations, as pointed out in Guo and Fraser (2015). Propensity scores do not adjust for unobserved covariates, work better in large samples, and do not handle cases where a covariate is related to treatment assignment but not to the outcome. To address the limitation on specification and dealing with unobserved covariates, we follow the recommendation of Rubin (1997) by performing a thorough sensitivity analysis. Following Michalopoulos et al. (2004), we also select the control units from European countries with relatively similar backgrounds.

In summary, propensity score matching involves estimating the probability of EMU membership based on observed characteristics of the countries. Once these probabilities are estimated, the EMU and non-EMU members can be matched based on their propensity scores to create balanced groups comparable to observed characteristics. This approach can reduce bias in treatment effect estimates by ensuring that the two groups are balanced on observed characteristics. This can improve the accuracy of the results by reducing the potential for confounding variables to influence the treatment effect estimates. Second, propensity score matching can improve the comparability of EMU and non-EMU countries, particularly when selecting control groups is challenging. In our study, including countries with unique economic characteristics or fixed exchange rates with the euro could have affected the accuracy of the treatment effect estimates. Propensity score matching can address these issues by creating balanced control groups comparable to the treatment group.

4 | DATA

The EU comprises 27 Member States that have fulfilled the Copenhagen criteria. The Copenhagen criteria must be fulfilled for a country to join the union. These criteria included political, economic, and community acquis. The overarching principles are the rule of law, the existence of a functioning market economy, and the ability to accept and maintain the obligations of membership. A few studies, such as Deravi and Metghalchi (1988), have investigated the performance of this European monetary system. Among 28 members, 19 countries (the EMU members) replaced their national currency with the euro, a single currency. The common currency imposes a uniform monetary policy system. Any country that satisfies the Copenhagen criteria can apply to join the EU, while a member state must meet only the economic criteria to join the EMU. The initial years of EU membership are devoted to maintaining the minimum economic and political stability level and adjusting the administrative and technical capacity.

To adopt the euro, the country must be an EU member state and achieve a high degree of sustainable economic convergence. The convergence criteria ensure that the member state is ready to join the EMU. Therefore, the ECB carefully screens the candidate as a precaution against economic breakdown—joining a new member should not cause economic risks to the entire eurozone. Joining the EU is a long-term process; adjustments usually begin before joining and align with the domestic and EU institutional frameworks. Although the EU institutional structure can be explicit,

defining explicit adjustments based on domestic arrangements can be challenging. Domestic institutions must find suitable ways of processing EU membership over the long term. The candidate countries for joining the EU are Albania, Moldova, Montenegro, North Macedonia, Serbia, Turkey, and Ukraine.

The euro countries compose the treated group, and 20 other European countries not part of the EMU form the control group. Table 1 lists all countries in the treated and control groups with the dates of joining the EMU. Michalopoulos et al. (2004) note that propensity scores correct less well and can be biased when the treated and control groups do not form the same "social context/milieu" and are not exposed to the same environment/background. To address this issue, we select our control group from countries with relatively similar idiosyncratic characteristics. This is also helpful in dealing with being unable to adjust for unobserved covariates, as one of the limitations of propensity score matching. Although, for the reasons discussed above, we think the control group should include only the European countries, we expanded the analysis by including 20 industrial countries in control group. The results are robust and included in Section 6.1. The alternative control group contains EU members who did not adopt the euro as well as non-EU members. Among the latter group are countries that are very different from EMU members.

The euro was first introduced in 1999. Initially, 11 European countries adopted the currency, and eight more countries joined the EMU subsequently: Cyprus (2008), Estonia (2011), Greece (2001), Latvia (2014), Lithuania (2015), Malta (2008), Slovakia (2009), and Slovenia (2007). The treaty was introduced in three stages: Stage 1 (July 1, 1990, to December 31, 1993) included the free movement of capital among the members; Stage 2 (January 1, 1994, to December 31, 1998) resulted in the convergence of members' economic policies; and Stage 3 (underway since January 1, 1999) began the gradual introduction of the euro as the single currency and implemented a common monetary policy under the ECB supervision. In our panel data analysis, we include an unbalanced panel, where the treatment time varies for members depending on their EMU status and the time they joined the EMU. The benchmark sample examines the treatment effect on the complete set of EMU members as the treated group.

Our entire sample ranges between 1990 and 2019 to account for the abovementioned stages. Hence, the entire sample considers that price convergence in founding members occurred before 1999 since the list of initial EMU members had been known before 1999. We must also differentiate between founding members and those who joined the union in 1999. We consider the founding members as the six states of the European Communities. These six countries are Belgium, France, Germany, Italy, Netherlands, and Luxembourg. These countries in the literature are called the "inner six." We include these six countries in the treated group from 1990 to 1999. To compare the results before and after the European sovereign debt crisis, we consider the two subsamples of pre-crisis (1990–2008) and post-crisis (2009–2019). To examine the impacts of joining the EMU on the early adopters, we also consider a different treated group of EMU members who joined in 1999. These countries are Austria, Belgium, Finland, France, Germany, Ireland, Italy, Luxembourg, Netherlands, Portugal, and Spain. We also consider the period from 1994 to 2019 for further robustness checks. The results of this exercise are reported in Section 6.2. Section 6.2 also includes treatment effect estimates for the 1990 to 2019 sample in which all the 11 EMU members who adopted the euro in 1999 have been treated since 1990.

The panel data are annual since the higher frequency data are unavailable. Table 2 summarizes sample sizes across treated and control groups across full, pre-, and post-crisis periods. The complete sample includes a total of 39 countries. The treated group comprises 19 EMU members, while the control comprises 20 countries. The total observations for the full, pre-, and post-crisis samples are 1,170, 741, and 429. The early adopters' sample includes 31 countries with 11 original EMU members in the treated group. The total observations for the full, pre-, and post-crisis samples are 930, 589, and 341.

The covariates considered in propensity score estimations are the first lag of inflation, GDP growth, real money growth, debt, spread, openness, and the central bank asset ratio. The first stage employs the macroeconomic outcomes determining the likelihood of joining the EMU. These outcomes are selected based on the theoretical and empirical literature on the impacts of the EMU. Alesina and Barro (2002), among others, use the equilibrium models to show the effects of currency unions. The main determinants in their models are trading costs and monetary policy credibility. Lower trading costs lead to higher output and consumption, while a higher degree of credibility reduces inflation (Ardakani & Kishor, 2018). The empirical studies are built upon the theoretical foundation and include these determinants. We include openness measured by import plus export as a percentage of GDP to consider trade as one of the main determinants of the likelihood of joining the EMU. We also account for GDP growth, debt, and inflation as the economy's leading indicators. Also, the primary goal of the ECB is price stability, and it is essential to include inflation and inflation volatility. The central bank's asset ratio and money growth highlight the central bank's role in the currency union.

TABLE 1 Treated and control groups.

Treated Group	Date Joined	Treated Group	Date Joined	Control Group	Control Group
Austria	1999	Latvia	2014	Albania	Monaco
Belgium	1999	Lithuania	2015	Belarus	Montenegro
Cyprus	2008	Luxembourg	1999	Bulgaria	Norway
Estonia	2011	Malta	2008	Croatia	Poland
Finland	1999	Netherlands	1999	Czech	Romania
France	1999	Portugal	1999	Denmark	Russia
Germany	1999	Slovakia	2009	Hungary	Sweden
Greece	2001	Slovenia	2007	Iceland	Switzerland
Ireland	1999	Spain	1999	Liechtenstein	UK
Italy	1999			Moldova	Ukraine

TABLE 2 Sizes of the samples across treated and control groups.

	Complete sample			Early adopters		
Sample periods	Treated	Control	Total	Treated	Control	Total
Full sample	426	744	1170	276	654	930
Pre-crisis	230	511	741	155	434	589
Post-crisis	196	233	429	220	121	341
No. of countries	19	20	39	11	20	31

The second stage focuses on the effectiveness of the EMU and employs the macroeconomic and financial outcomes commonly used in the existing literature. The choice of outcomes also depends on the availability of data. The overarching choice of macroeconomic and financial outcomes helps us better determine the effectiveness of the EMU and the main reason we considered all these outcomes. We aim to cover the most prominent macroeconomic and financial outcomes. It is conceivable that other variables may affect the decision to join the union. As explained above, our approach controls for unobserved omitted variables by estimating the ATT using the "thick support region" of estimated propensity scores as a sensitivity analysis. This also minimizes the bias when the conditional independence assumption does not hold.

Table 3 describes how these covariates are calculated. The data are obtained from the World Bank's World Development database. In the treatment effects estimation, outcomes are inflation, inflation volatility, GDP growth, GDP growth volatility, debt, bond yield, and bond yield volatility. The bond yield is the rate on the 10-year government bonds. The literature employs a volatility measure calculated on a rolling basis for annual data, where a 3-year moving average of standard deviations is computed. See Lin and Ye (2007) for example, This measure does not suffer from the misspecification problem associated with model-based volatility measures like a GARCH model. We use volatility and variability interchangeably since standard deviations are used. However, we are not addressing uncertainty. Volatility and uncertainty are two different concepts. "Volatility measures the dispersion of short-term shocks around a long-term mean, while uncertainty measures the difficulty to forecast the distribution of returns, including its long-term mean" (Ait-Sahalia et al., 2021).

5 | IMPACTS OF EMU MEMBERSHIP

In this section, we present the results of the treatment effect of joining the EMU on macroeconomic and financial variables that include inflation, real GDP, bond market indicators, and fiscal stance as measured by the debt-GDP ratio. These outcome variables provide us with a much more comprehensive look at the impact of the EMU than investigating

a very small subset of variables. In addition to inflation, GDP, and interest rates, we also examine the impact on the volatility of these variables. The treatment effect is estimated in two steps: In the first step, we estimate the propensity scores. The true scores are unknown but can be estimated by the logistic regression model. In the second step, we match the observations using the estimated propensity scores and estimate the average treatment effects. As explained earlier, the decision to join the EMU is not random; therefore, we expect the conditional probability of joining the monetary union to depend upon the most important economic indicators and different measures of financial development.

The first-stage propensity scores are estimated using the logit model, and the results are shown in the first two columns of Table 4. We have also used a probit model, and the estimates are similar to the logit, so we omit them for brevity. The results for the propensity score analysis clearly show that the decision to join the EMU is non-random with the conditional probability of joining the union affected by lagged GDP growth, lagged money growth, lagged debt,

TABLE 3 Covariates used in propensity score estimations.

Covariate	Description
Inflation	The annual percentage change in the consumer price index
GDP growth	The annual percentage change in real GDP
Money growth	Broad money growth as an annual percentage minus inflation
Debt	Central government debt as a percentage of GDP
Spread	The spread between the country's bond yields and the average Yields of French and German bonds.
Openness	Trade as a percentage of GDP
Asset ratio	The percentage of central bank assets to GDP

TABLE 4 Propensity scores and treatment effects (1990–2019).

Propensity score		Propensity score matching	
Regressor	**Logit**	**Outcome**	τ_{att}
Lagged inflation	−0.0001	Inflation	4.80
	(0.0004)		(3.87)
Lagged GDP growth	−0.031**	Inflation volatility	−18.84***
	(0.012)		(4.01)
Lagged money growth	−0.0005***	GDP growth	−0.31
	(0.0001)		(0.25)
Lagged debt	0.005***	GDP growth volatility	−0.73***
	(0.001)		(0.15)
Lagged spread	0.301***	Debt	8.82**
	(0.024)		(3.71)
Lagged openness	0.003***	Bond yield	−0.02
	(0.001)		(0.22)
Lagged assets ratio	−0.016***	Bond yield volatility	−0.72***
	(0.005)		(0.11)
Observations	1,170		
Akaike inf. Crit.	1,329		
McFadden's Pseudo R^2	0.19		

Note: The average treatment effect on the treated is denoted by τ_{att}. The heteroskedasticity robust standard errors are reported in parentheses.
*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

lagged spread, lagged openness, and the lagged assets ratio. We use the lagged value of the variables to account for the potential endogeneity issue in the first stage of regression specification. Lagged openness is one of the most widely used indicators of financial market development (Campos et al., 2019; Ehrmann et al., 2003; Hope, 2016). Figure 1 represents the propensity score distributions for treated and control groups. The left panel depicts the distribution of propensity scores for the two groups. In contrast, the right panel displays the histograms of propensity scores for observations before and after the matching process. This comparison assesses the balance between EMU and non-EMU members in the pre- and post-matching stages, demonstrating a notable improvement in the balance following the matching process. Additionally, Figure 2 provides Q-Q plots with accompanying 95% confidence intervals for each covariate. When the empirical distributions are identical between EMU and non-EMU members, the data points align along the 45-degree line. Deviations from this line signify differences in the empirical distribution between the groups, which can help evaluate the effectiveness of the propensity score matching and the comparability of the matched groups.

Using lagged covariates in estimating propensity scores can be considered a potential solution to endogeneity, but it may also create an issue since joining the EMU can be lengthy. The EU countries must meet the conditions designed to ensure economic convergence, and the assessment of the convergence criteria done by the European Commission and the ECB may span multiple years (Puzzello & Gomis-Porqueras, 2018). To address this issue, we replaced the lagged variables in the first step with 2-year moving averages. Considering a larger window (number of years) for the moving average process sounds reasonable but at the expense of losing observations. This can be problematic for smaller samples, particularly in the post-crisis period. These results are reported in Section 6.3. Tables 12 and 13 indicate that results remain robust, and signs and significance levels do not change across samples.

The results from the propensity score estimation suggest that a country with a higher level of financial development, as measured by the degree of openness, has a higher propensity to join the monetary union. This is consistent with the idea that countries that were not the original members had to fulfill specific criteria to enter the union. One criterion is a functioning market economy and the capacity to cope with competition and market forces in the EU. A well-developed financial market helps improve the ability to cope with market forces and aids in integrating the economy into the overall union. Hope (2016) also focuses on the trade balances of the EMU members. His results suggest a deterioration in the current account balances of France, Greece, Italy, and Spain and their improvements for Austria. The results for lagged money growth suggest a negative relationship between money growth and the conditional probability of joining the union. The use of lagged money growth as a covariate has been motivated by several studies using it as a proxy for financial development (Calderon & Liu, 2003; Rose & Engel, 2002). The coefficient on lagged real GDP growth shows a negative and statistically significant relationship, implying that the countries joining the EMU had lower growth than those in the control sample. On the other hand, the coefficients on lagged debt-GDP ratio and lagged

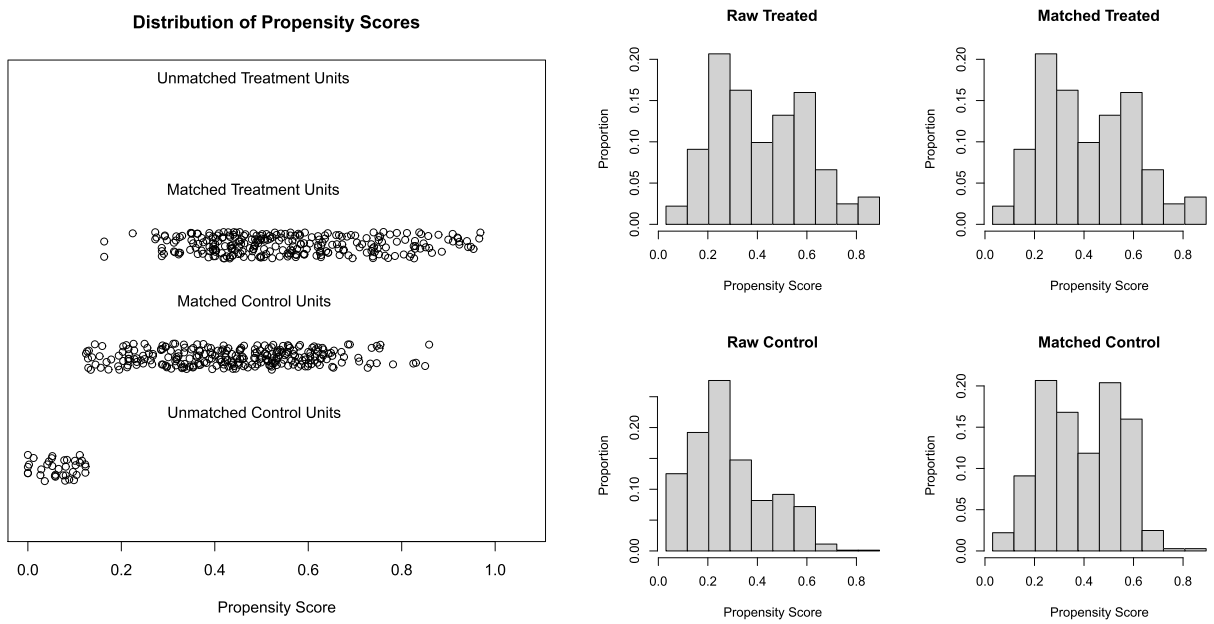


FIGURE 1 Distributions of propensity scores in treated/control groups before and after matching.

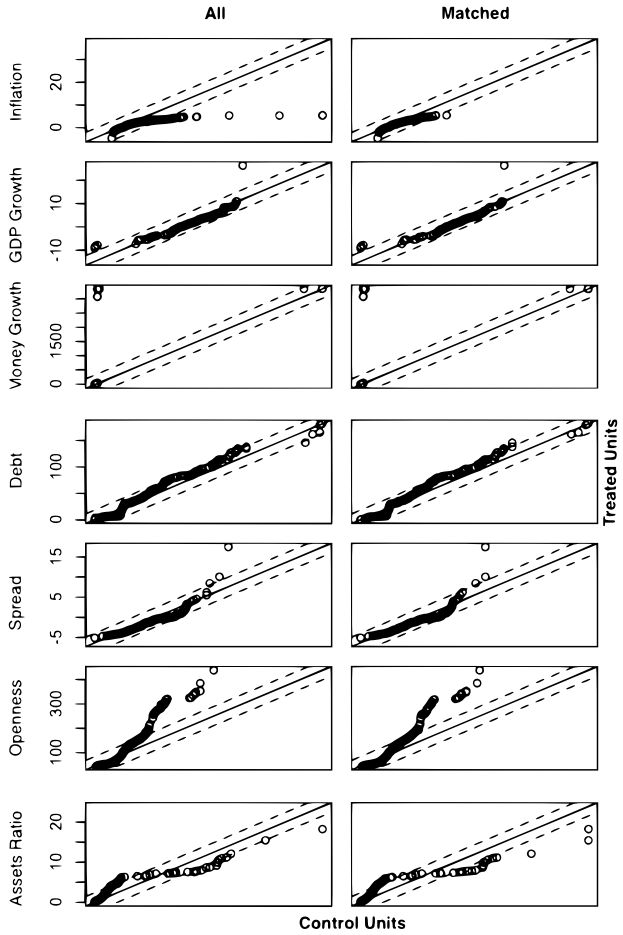


FIGURE 2 Q-Q plots for each covariates (real lines) with 95% confidence intervals (dashed lines).

spread are positive and statistically significant. The results indicate that the countries joining the EMU had higher debt than those not. Not surprisingly, countries with higher debt-GDP ratios have a higher yield spread.

We employ the results of the first stage to estimate the treatment effects in the second stage. The ATT estimates using the propensity score estimates are presented in the right panel of Table 4. Summarizing our findings, the propensity score matching results indicate that being a union member reduces volatilities of inflation, real GDP growth, and bond yields. However, the ATT on the levels of these variables is statistically insignificant.

The reduction in volatilities of inflation, real GDP growth, and bond yields encourages the ECB to fulfill its mandate on inflation and overall macroeconomic stability as countries that join the union relinquish control over their monetary policy. These results also align with the benefits of a credible currency union, where a centralized monetary policy can serve as a credible anchor. Thus, our findings suggest that the ECB successfully mitigates the volatility of these key economic indicators within the EMU region.

Our study contributes to the existing literature by using propensity score matching in estimating the treatment effects in the second stage, building upon previous research by scholars such as Carare and Stone (2006) and Taylor (1999). The main advantage of propensity score matching is its ability to balance the distribution of covariates between the treated and control groups, thereby reducing bias in estimating the treatment effect. In contrast, previous studies relied on regression models for individual countries, susceptible to omitted variable bias. By using EMU members as the treated group, our approach allows for a more precise examination of the effects of union membership on the leading economic indicators in the eurozone.

In recent years, the literature has presented empirical studies utilizing various causal inference techniques introduced in microeconometrics. For instance, Puzzello and Gomis-Porqueras (2018) employ the synthetic control method to examine the effectiveness of the EMU and find that EMU members have experienced lower income per capita. Similarly, Fernández and Garcia-Perea (2015) find that the impact of EMU membership on GDP is insignificant for some EMU members like Germany, Netherlands, and Austria. At the same time, countries such as Ireland, Spain, and

Greece have benefited from joining the EMU. On a different note, Campos et al. (2019) find that joining the EU leads to higher per capita GDP. However, their study focuses on EU membership rather than the EMU, utilizing different sets of European countries and sample periods.

It is important to note that the ATT on GDP growth may not be statistically significant due to various factors, including the 2008–2009 financial crisis and variations in economic performance among different member states. For instance, Beblavy et al. (2011) demonstrate that the economic performance of EMU members varied significantly between 1999 and 2011, with some countries experiencing substantial declines in GDP growth while others achieved growth rates comparable to or higher than non-EMU countries. Furthermore, Ehigiamusoe and Lean (2019) illustrate that the effectiveness of monetary policy in promoting economic growth in EMU members was influenced by factors such as the degree of fiscal coordination among member states and the extent of structural reforms undertaken by individual countries. These factors could help explain why the treatment effect of GDP growth is not higher in EMU members than non-EMU countries.

The finding of lower bond yield volatility suggests that member countries have benefited from the perceived risk-sharing nature of the EMU in the bond market. This result aligns with studies that have emphasized the significant role played by the EMU in the integration of equity and bond markets in Europe (Baele et al., 2004; Ehrmann et al., 2011; Fratzscher, 2002; Gomez-Puig, 2009; Pagano and von Thadden, 2004). As we will discuss later, the bond market's perception of this risk-sharing nature changed during the financial crisis of 2008–2009.

As part of the EU treaty, EU member states must adhere to the SGP, which serves as a framework to ensure fiscal responsibility. The SGP has set identical limits for government budget deficits and debt, as specified in the convergence criteria. According to these criteria, the ratio of gross government debt relative to GDP at market prices should not exceed 60% at the end of the preceding fiscal year. To examine this aspect, we analyze the average treatment effect (ATT) on the debt-GDP ratio and find that adopting the euro leads to an increase in the debt-GDP ratio for member countries. This result contradicts the objective outlined in the SGP. However, it is not surprising, given that many countries have repeatedly violated this requirement of the pact. Our findings support the conclusions of Koehler and König (2015), who utilized the synthetic control method to study the effectiveness of the SGP in the eurozone. They also found that the SGP experienced numerous violations, and government debt in certain European countries would have been lower without their EMU membership. The subsequent section delves further into the relationship between debt and EMU membership.

The findings also indicate different impacts of EMU membership on levels versus volatility of key macroeconomic indicators. This distinction between level and volatility effects underscores the implications of economic policy coordination within a monetary union. The absence of significant changes in inflation and GDP growth levels aligns with the findings of Fernández and Garcia-Perea (2015), who examine an insignificant impact of EMU membership on the GDP of certain member states like Germany, Netherlands, and Austria. However, our study diverges from their analysis on the volatility front, highlighting the stabilizing effect of the EMU on macroeconomic volatility. This stabilization is particularly significant, as Beblavy et al. (2011) note the variance in economic performance among EMU nations, suggesting that while level effects might be muted due to averaging out across diverse economies, the collective policy coordination and centralized monetary stance of the EMU contribute to smoothing out cyclical fluctuations and extremities in individual economic indicators. In addition, the insights from Ehigiamusoe and Lean (2019) are particularly instructive in understanding the dichotomy between level and volatility effects. They argue that the effectiveness of monetary policy in the EMU context is contingent on several factors, including fiscal coordination and structural reforms, which might explain the stability without concurrent level shifts. This stability, without level changes, suggests that while immediate economic growth and inflation trajectories of member countries may not align, the institutional framework of the EMU provides a buffer against economic volatility.

In conclusion, our findings suggest that joining the EMU reduces volatilities of inflation, real GDP growth, and bond yields, highlighting the success of the ECB in stabilizing these crucial economic indicators. However, we also observe an increase in the debt-GDP ratio for member countries, which contradicts the objectives outlined by the SGP. This implies that fiscal responsibility remains a challenge for some member countries.

5.1 | EMU membership and the sovereign debt crisis

In the previous section, we presented the results for the full sample starting from 1990. However, the global economy, including the eurozone, was significantly impacted by the sovereign debt crisis of 2008–2009. This crisis gave rise to a

debt crisis within the EMU, which raised concerns about its future. Consequently, we explore whether this crisis led to substantial changes in the average treatment effects (ATT) on macroeconomic and financial outcomes in the member countries. To address this question, we divided the sample into two distinct periods: the pre-crisis period (1990–2008) and the post-crisis period (2009–2019). The findings for these two sub-samples are presented in Table 5. It is important to highlight that the post-crisis period exhibited significant alterations in the ATT, which could have implications for the future of the EMU. The following points merit attention.

TABLE 5 Propensity scores and treatment effects (pre-/post-crisis).

Propensity score		**Propensity score matching**	
Regressor	**Logit**	**Outcome**	τ_{att}
Pre-crisis (1990–2008)			
Lagged inflation	0.0002	Inflation	−1.66
	(0.0004)		(4.79)
Lagged GDP growth	0.011	Inflation volatility	−19.5***
	(0.015)		(5.31)
Lagged money growth	−0.0004**	GDP growth	−0.87**
	(0.0001)		(0.41)
Lagged debt	0.004***	GDP growth volatility	−0.99***
	(0.001)		(0.22)
Lagged spread	0.253***	Debt	5.90
	(0.039)		(6.46)
Lagged openness	−0.001	Bond yield	0.31
	(0.002)		(0.29)
Lagged assets ratio	−0.010	Bond yield volatility	−0.97***
	(0.008)		(0.14)
Post-crisis (2009–2019)			
Lagged inflation	−0.089***	Inflation	−1.82***
	(0.04)		(0.46)
Lagged GDP growth	−0.104***	Inflation volatility	−2.45***
	(0.036)		(0.37)
Lagged money growth	−0.001***	GDP growth	−0.21
	(0.0001)		(0.33)
Lagged debt	0.006***	GDP growth volatility	−0.27
	(0.002)		(0.21)
Lagged spread	0.330***	Debt	16.79***
	(0.096)		(3.84)
Lagged openness	0.006***	Bond yield	−0.45
	(0.001)		(0.28)
Lagged assets ratio	−0.023***	Bond yield volatility	−0.45***
	(0.008)		(0.15)

Note: The average treatment effect on the treated is denoted by τ_{att}. The heteroskedasticity robust standard errors are reported in parentheses.
*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

1. The ATTs on inflation volatility and bond yield volatility are similar across both periods. However, the post-crisis period showed a significant increase in the ATT on inflation, indicating that the EMU member countries experienced sustained downward pressure on prices after the crisis compared to non-EMU countries.
2. The most significant effect observed is for the debt-GDP ratio, where the positive sign became statistically significant, and the magnitude more than doubled in the post-crisis period. This finding is consistent with other studies that have documented a significant increase in the debt-GDP ratio for the Eurozone countries after the global financial crisis (see, e.g., citetDeGrauweJi:2013).
3. In the aftermath of the crisis, the ATT for inflation becomes statistically significant, indicating persistent downward pressure on prices within the EMU region. This highlights the impact of the European sovereign debt crisis on the monetary union's macroeconomic and financial outcomes.
4. In the post-crisis period, the effectiveness of the SGP has been questioned even further. Our findings also suggest that the SGP has failed to prevent countries from running up large deficits and debts and has contributed to the economic difficulties faced by countries in the eurozone. The efficacy of the SGP in promoting fiscal discipline in the EU has been debated, particularly in the wake of the global financial crisis of 2008–2009 (Fjelstul, 2022). Before the crisis, some countries in the EU could maintain low debts while others struggled with high deficits and debts. The SGP was meant to address this issue by setting rules for fiscal discipline. However, the SGP was criticized for being rigid and inflexible, as it did not consider economic conditions that might make it difficult for countries to meet these targets (Fatas et al., 2003). This criticism was particularly strong during the crisis, as many countries faced high unemployment and weak economic growth, making it difficult to reduce their deficits and debts.

Overall, the results indicate that the debt crisis in the EMU has had significant implications for macroeconomic and financial outcomes in the member countries, particularly evident in the debt-GDP ratio. The source of an increase in debt can have positive and negative economic implications. On one hand, higher government debt can contribute to investments in infrastructure, education, and healthcare, stimulating economic growth. On the other hand, elevated debt levels can raise concerns about debt repayment capacity, leading to higher interest rate demands from investors. This, in turn, can result in increased borrowing costs for the government, decreased investment, and slower economic growth (Spolaore, 2013). Notably, Auerbach and Gorodnichenko (2017) found that expansionary government spending shocks in weaker economies did not lead to increased debt.

One issue that arises when using the debt-GDP ratio as an outcome variable is the distinction between stock and flow variables. While the debt-GDP ratio represents a stock variable, other outcomes are considered flow variables. Consequently, debt levels in different years exhibit a high degree of correlation. To address this concern, we have introduced the percentage change in debt, transforming it into a flow variable. This adjustment helps overcome the challenges of treating debt as a stock variable and mitigates the observed high correlation in debt levels across different years.

The findings in Table 6 align with our main results. These findings reinforce our main conclusions, revealing positive ATTs for debt growth across all samples. Furthermore, the coefficient is statistically significant for the full sample, insignificant for the pre-crisis period, and statistically significant for the post-crisis period.

Table 7 summarizes the results of the propensity score statistics and the statistical significance of the ATT estimates. We refer to +/− signs as statistically significant and positive/negative treatment effects. Statistically insignificant effects are indicated by zero. The panel compares the treatment effect estimates for all sample periods, including pre- and post-crisis. The findings indicate consistent results for inflation volatility, bond yield, and bond yield volatility across the different sample periods. However, some noteworthy changes are observed when the sample is split into pre- and post-crisis periods. Figure 3 presents the distribution of propensity scores in the treated and control groups for the pre-crisis and post-crisis subsamples. We can see that the distribution of propensity scores changes across different samples. The pre-crisis sample has no observation for the unmatched treatment units. This does not hold for the post-crisis subsample. We use the matched treated and control observations for the second stage, treatment effect estimation. Figure 4

TABLE 6 Treatment effects of debt growth across all samples.

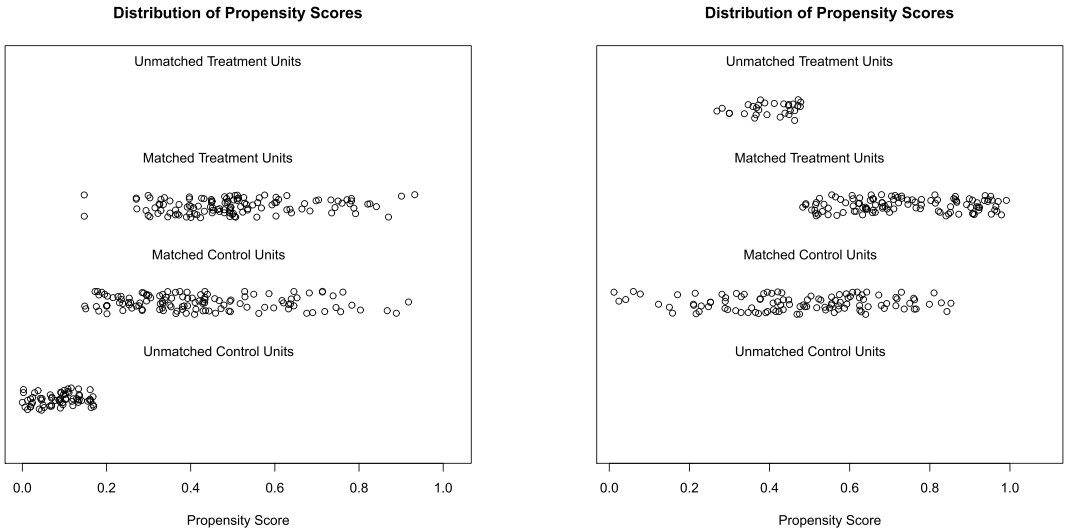
Full sample	Pre-crisis	Post-crisis
23.59**	14.74	24.40*
(10.46)	(16.67)	(14.18)

Note: The average treatment effect on the treated are reported for treatment effects. The heteroskedasticity robust standard errors are reported in parentheses.
*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

TABLE 7 Propensity scores and treatment effects across all samples.

	Full sample	Pre-crisis	Post-crisis
(a) Propensity score statistics			
Observations	1170	741	429
Akaike inf. crit.	1329	775	539
McFadden's Pseudo R^2	0.19	0.26	0.12
(b) ATT statistical significance			
Inflation	0	0	−
Inflation volatility	−	−	−
GDP growth	0	−	0
GDP growth volatility	−	−	0
Debt	+	0	+
Bond yield	0	0	0
Bond yield volatility	−	−	−

Note: The + sign indicates statistically significant and positive ATTs, 0 shows insignificant ATTs and the − sign indicates statistically significant, negative effects.



Pre-crisis Post-crisis

FIGURE 3 The distribution of scores in the treated and control groups (pre-/post-crisis).

also shows the histograms of the estimated propensity scores before and after matching across the two subsamples. This figure indicates how the density of propensity scores changes in control and treated groups after matching. For the control group, score densities change across the two subsamples after matching. Figures 3 and 4 show that the balance between the groups improves after matching.

The literature includes studies that examine the effects of joining the EMU, focusing mainly on its macroeconomic implications (Lane, 2006). However, less attention has been devoted to studying how this decision can impact welfare. Our study employs propensity score matching to estimate the treatment effect of joining the EMU, echoing the methodological approach of Dehejia and Wahba (2002). We find that joining the EMU is associated with lower inflation rates after a financial crisis, which aligns with the findings of Levin et al. (2004). This outcome could imply welfare benefits as lower inflation can result in reduced interest rates, thereby stimulating borrowing and investment (Bernanke and Gertler, 2004). Furthermore, we observe a reduction in GDP growth volatility before the financial crisis. This stabilization of economic growth has welfare implications, as illustrated by Acemoglu and Robinson (2015). Stable

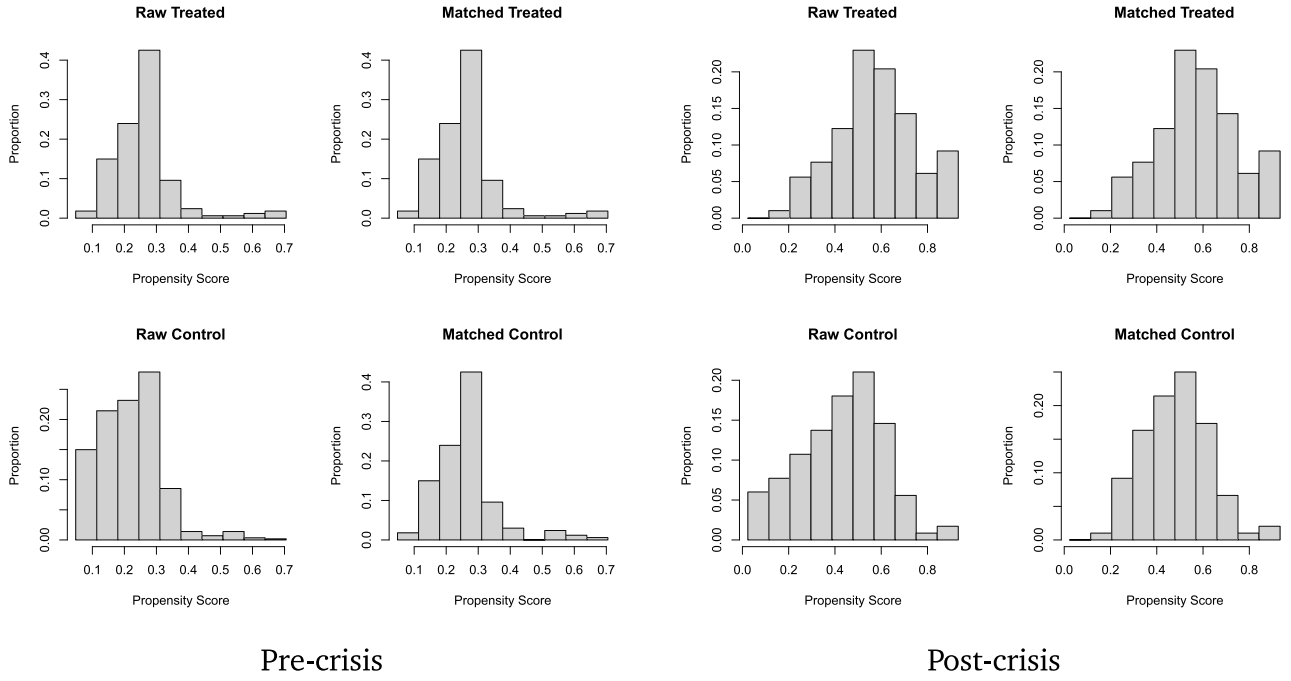


FIGURE 4 Histograms of scores before and after matching (pre-/post-crisis).

economic growth can lead to diminished uncertainty. While our study documents the macroeconomic benefits of joining the EMU, such as lower inflation rates and reduced GDP growth volatility, it also underscores the welfare implications of this decision by facilitating a stable economic environment that reduces uncertainty and stimulates investment. Stable economic conditions provide a conducive environment for social welfare programs. With lower inflation and lower volatility, governments may find it easier to plan and implement effective social policies, such as poverty reduction initiatives, healthcare programs, and education reforms. This stability allows for more efficient allocation of resources toward social welfare, leading to improved living standards for citizens.

5.2 | The impact of GIPS within the EMU

The European debt crisis brought to light the significant divide among different members of the Eurozone. This division became apparent through the notable breakdown in the co-movement of bond yields among EMU countries. Researchers such as Bhatt et al. (2017) have demonstrated how the crisis experienced by periphery countries led to the decoupling of their bond markets from the rest of the EMU, emphasizing the increased influence of idiosyncratic factors in these countries. Consequently, examining whether a few countries within our sample disproportionately influence the treatment effects is crucial.

To address this concern, we conducted a revised analysis by excluding GIPS from the treated countries. We selected these countries based on a commonly used criterion in the literature, identifying them as most significantly affected by the European debt crisis. This criterion is based on the substantial increase in their bond yield spreads during the crisis compared to other EMU members, as documented in various studies, including Belke et al. (2017), Lane (2012), and Kalbaska and Gątkowski (2012). Although there were other peripheral countries, such as Italy, Finland, and Estonia, we focused on the GIPS countries due to the severity of their crisis experience. This led to a significant divergence of their bond yield spreads from the core EMU countries, as documented in Santis (2012).

The results of this analysis are presented in Table 8, revealing some interesting findings. When examining the results closely, the prominent role of the GIPS countries becomes apparent. The baseline results for the ATT on inflation volatility, real GDP, and bond yields remain largely unchanged. However, the ATTs for bond yields and the debt-GDP ratio show a heightened sensitivity when the GIPS countries are excluded. The ATT becomes larger and statistically significant in the pre-crisis period under the exclusion of GIPS, contradicting the conventional belief that these countries were the drivers of the increasing debt-GDP ratio. We find the opposite to be true. In the pre-crisis period, we observe a statistically significant impact on bond yields compared to non-member countries after excluding the GIPS

TABLE 8 Treatment effects: The exclusion of GIPS.

Outcome	Full sample	Pre-crisis	Post-crisis
Inflation	−0.38	−0.30	−1.77***
	(5.70)	(7.39)	(0.56)
Inflation volatility	−25.06***	−30.13***	−2.78***
	(5.30)	(4.45)	(0.44)
GDP growth	−0.06	0.09	−0.45
	(0.29)	(0.42)	(0.30)
GDP growth volatility	−0.79***	−1.30***	−0.23
	(0.16)	(0.24)	(0.19)
Debt	9.94***	18.15**	9.74**
	(4.43)	(7.73)	(4.19)
Bond yield	−0.25	1.49***	−0.97***
	(0.27)	(0.35)	(0.27)
Bond yield volatility	−1.02***	−0.92***	−0.70***
	(0.14)	(0.15)	(0.14)
Propensity score stats			
Observations	1050	665	385
Akaike inf. Crit.	1156	662	476
McFadden's Pseudo R^2	0.21	0.29	0.13

Note: The average treatment effect on the treated (τ_{att}) is reported. The heteroskedasticity robust standard errors are reported in parentheses.
*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

countries. This result contrasts with the insignificant impacts reported in the complete analysis, including all countries as presented in Table 5.

After excluding the GIPS countries, the positive and significant ATT on the debt-GDP ratio and bond yields in the pre-crisis period indicate that higher debt is associated with higher yields. However, this relationship breaks down in the post-2008 sample period, suggesting that the bond market treated certain periphery countries differently from the core EMU countries. These findings align with previous studies suggesting that the market's perception of sovereign risk significantly changed after the crisis, with bond yields responding more to country-specific fundamentals (Kilponen et al., 2015). Additionally, these results suggest that the GIPS countries benefited from lower bond yields in the pre-crisis period due to their membership in the EMU.

Overall, the influence of the European debt crisis and the inclusion of the GIPS countries are evident in estimating the treatment effects of the EMU and assessing its effectiveness. Furthermore, these findings highlight the impact of excluding the GIPS countries from the analysis of the treatment effects.

Further robustness checks have been conducted, and the results are presented in Section 6. In Section 6.4, we first examine the robustness of our findings by focusing on the treatment group consisting of early adopter states that joined the union in 1999. We find that the estimated treatment effects remain similar, indicating that our results are not driven by the inclusion of late adopters.

Next, we address a potential endogeneity issue in the primary results. This issue may arise from violating the conditional independence assumption, which assumes that the assignment to the treatment group (i.e., joining the EMU) is independent of potential outcomes, given the observed covariates. If this assumption is violated, it may result in biased treatment effect estimates. To mitigate this issue, we estimate the treatment effects focusing on the *thick support region* of estimated propensity scores. In propensity score matching, the thick support region refers to the range of propensity scores with substantial overlap between the treatment and control groups (Caliendo & Kopeinig, 2008). By focusing on this region, we can minimize bias by comparing units with different characteristics. The results presented in Section 6.5 suggest that our estimated treatment effects remain robust when we apply this approach, indicating that our results are not sensitive to the potential endogeneity issue.

6 | ROBUSTNESS CHECKS AND SENSITIVITY ANALYSIS

This section provides robustness checks and sensitivity analysis under various alternative samples and methods. Specifically, we consider an alternative control group, study the effects of adjusting sample periods, examine the influence of lagged covariates, and analyze the impact of early adopters. We also address endogeneity, ensuring our results are robust and bias-free, and provide the results of alternative matching methods and sensitivity tests.

6.1 | An alternative control group

The euro countries compose the treated group, and 20 other European countries not part of the EMU form the control group. We expand the analysis by including 20 industrial countries in control group. Although the results remain robust, the alternative control group contains countries that differ from EMU members. Russia and Belarus, for instance, do not meet the Copenhagen criteria and could not join the EU or EMU since they have very different economic and political systems. The covariates influencing economic fundamentals are primarily unobserved. The countries in the alternative control group include Albania, Denmark, Monaco, Russia, Belarus, Hungary, Montenegro, Sweden, Bulgaria, Iceland, Norway, Switzerland, Croatia, Liechtenstein, Poland, UK, Czech, Moldova, Romania, and Ukraine. Table 9 reports the results based on this alternative control group.

6.2 | Treatment effects for alternate sample periods

The implementation of the EMU took place in three stages: Stage 1 (1990–1993) involved the free movement of capital between the member states; Stage 2 (1994–1998) involved strengthening cooperation between the members; and the introduction of the currency and the EMU took place in 1999, which was Stage 3 of the process. These implementation stages were known a priori, at least with a high degree of certainty, before 1999 due to the explicit convergence criteria set out in the Maastricht treaty and the time lags of the corresponding political process. The 11 early adopters were treated before 1999. Rogers (2007) finds that most price convergences occurred before 1999. To account for this issue, in addition to the entire sample, we also examine the sample periods covering the last two stages of the EMU as outlined in

TABLE 9 Propensity scores and treatment effects (1990–2019).

Regressor	Logit	Outcome	τ_{att}
Lagged Inflation	0.00005	Inflation	−0.81
	(0.015)		(1.763)
Lagged GDP growth	−0.020	Inflation volatility	−25.61***
	(0.013)		(4.60)
Lagged money growth	−0.0004***	GDP growth	0.20
	(0.0001)		(0.28)
Lagged debt	0.006***	GDP growth volatility	−0.75***
	(0.001)		(0.14)
Lagged spread	0.186***	Debt	16.98***
	(0.024)		(3.78)
Lagged openness	0.004***	Bond yield	0.30
	(0.001)		(0.24)
Lagged assets ratio	−0.022***	Bond yield volatility	−0.65***
	(0.006)		(0.11)

Note: The average treatment effect on the treated is denoted by τ_{att}. The heteroskedasticity robust standard errors are reported in parentheses.
*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

the treaty. In particular, we analyze the following datasets. Samples in which the treated group containing the founding member states joined in 1999 are assigned as treated in 1990 and 1994. Those who joined later are assigned as treated at the time they joined. For example, Malta joined in 2008 and was treated after 2008. On the other hand, Austria joined in 1999, once treated in 1990, and once treated in 1994.

We compare the results of the full sample (1990–2019) and a sub-sample including the period from Stage 2 onwards in Tables 10 and 11 with our main findings. The ATTs for inflation, GDP growth, and bond yield volatilities remain negative and statistically significant. For the debt outcome, the treatment effect is not statistically significant in the main results but becomes positive and statistically significant when the 1994 and 1990 samples are used. For the 1990

TABLE 10 Average treatment on the treated for the 1994–2019 sample.

	EMU members			The exclusion of GIPS		
Outcome	**Full sample**	**Pre-crisis**	**Post-crisis**	**Full sample**	**Pre-crisis**	**Post-crisis**
a) Main results						
Inflation	−3.14***	−2.20	−1.82***	−3.26**	−1.67	−1.76***
	(1.09)	(2.57)	(0.46)	(1.41)	(2.48)	(0.55)
Inflation volatility	−5.38***	−6.49***	−2.45***	−7.32***	−8.73***	−2.83***
	(1.19)	(1.94)	(0.37)	(1.63)	(2.57)	(0.44)
GDP growth	−0.37	−0.86***	−0.21	−0.44	−1.04**	−0.42
	(0.26)	(0.35)	(0.32)	(0.27)	(0.47)	(0.31)
GDP growth volatility	−0.51***	−0.89***	−0.27	−0.76***	−0.76***	−0.22
	(0.15)	(0.20)	(0.21)	(0.17)	(0.26)	(0.19)
Debt	6.93*	−4.94	16.79***	2.37	13.16*	8.86**
	(3.52)	(6.01)	(3.82)	(3.97)	(7.26)	(4.25)
Bond yield	−0.52**	−0.35	−0.45	−0.66***	0.16	−0.92***
	(0.22)	(0.29)	(0.29)	(0.22)	(0.31)	(0.28)
Bond yield volatility	−0.80***	−0.86***	−0.45***	−0.84***	−1.01***	−0.71***
	(0.11)	(0.12)	(0.15)	(0.10)	(0.15)	(0.15)
b) Early adopters						
Inflation	−5.08***	−7.06***	−1.97***	−3.81*	−2.89	−3.40***
	(1.62)	(2.75)	(0.64)	(2.17)	(3.43)	(0.80)
Inflation volatility	−8.30***	−13.59***	−2.95***	−9.29***	−12.72***	−3.65***
	(1.72)	(3.03)	(0.49)	(2.37)	(3.15)	(0.66)
GDP growth	−0.36	−0.71*	−0.62	−0.44	−0.80**	−1.00**
	(0.28)	(0.40)	(0.38)	(0.32)	(0.39)	(0.42)
GDP growth volatility	−0.70***	−1.02***	−0.11	−0.89***	−1.14***	−0.51**
	(0.16)	(0.21)	(0.25)	(0.18)	(0.26)	(0.22)
Debt	8.79**	−4.91	13.39***	4.80	−3.83	1.81
	(4.26)	(6.50)	(5.14)	(4.32)	(7.30)	(4.92)
Bond yield	−0.30	−0.05	−0.39	−0.70**	−0.51	−1.22***
	(0.21)	(0.29)	(0.28)	(0.29)	(0.41)	(0.37)
Bond yield volatility	−0.86***	−1.11***	−0.54***	−1.08***	−1.28***	−1.07***
	(0.11)	(0.16)	(0.16)	(0.14)	(0.20)	(0.24)

Note: The heteroskedasticity-robust standard errors are reported in parentheses.

*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

TABLE 11 Average treatment on the treated for the 1990–2019 sample.

	EMU members			The exclusion of GIPS		
Outcome	**Full sample**	**Pre-crisis**	**Post-crisis**	**Full sample**	**Pre-crisis**	**Post-crisis**
a) Main results						
Inflation	−1.37	3.02	−1.82***	−2.24	−5.31	−1.71***
	(4.58)	(7.88)	(0.46)	(4.98)	(6.75)	(0.55)
Inflation volatility	−24.84***	−44.29***	−2.45***	−30.12***	−28.77***	−2.79***
	(4.41)	(7.95)	(0.37)	(5.79)	(6.24)	(0.44)
GDP growth	0.22	0.85*	−0.21	−0.22	0.31	−0.42
	(0.29)	(0.45)	(0.33)	(0.29)	(0.49)	(0.31)
GDP growth volatility	−0.65***	−1.12***	−0.27	−0.86***	−1.23***	−0.22
	(0.14)	(0.20)	(0.21)	(0.16)	(0.22)	(0.19)
Debt	16.01***	17.14***	16.79***	8.36**	19.43***	9.61**
	(3.73)	(5.85)	(3.8)	(4.18)	(7.16)	(4.15)
Bond yield	0.43*	1.03***	−0.45*	−0.07	1.33***	−0.90***
	(0.24)	(0.36)	(0.27)	(0.28)	(0.32)	(0.27)
Bond yield volatility	−0.60***	−0.83***	−0.45***	−0.89***	−0.97***	−0.67***
	(0.11)	(0.15)	(0.15)	(0.11)	(0.14)	(0.15)
b) Early adopters						
Inflation	0.56	7.30	−1.71***	0.89	−3.66	−3.39***
	(4.79)	(7.21)	(0.63)	(6.09)	(5.62)	(0.80)
Inflation volatility	−30.19***	−44.98***	−3.30***	−32.08***	−34.56***	−3.58***
	(5.42)	(8.22)	(0.53)	(6.70)	(7.61)	(0.66)
GDP growth	−0.10	−0.25	−0.67	0.22	−0.16	−0.95**
	(0.28)	(0.33)	(0.42)	(0.35)	(0.44)	(0.42)
GDP growth volatility	−0.68***	−1.00***	−0.18	−1.23***	−1.06***	−0.47**
	(0.16)	(0.20)	(0.22)	(0.18)	(0.22)	(0.23)
Debt	20.95***	18.14***	14.85***	11.71**	14.65*	2.50
	(4.10)	(5.35)	(4.92)	(5.11)	(7.41)	(4.95)
Bond yield	0.60**	1.13***	−0.24	0.01	0.93**	−1.22***
	(0.27)	(0.33)	(0.37)	(0.28)	(0.39)	(0.37)
Bond yield volatility	−0.75***	−0.93***	−0.39***	−1.16***	−1.26***	−1.07***
	(0.13)	(0.16)	(0.19)	(0.12)	(0.17)	(0.24)

Note: The heteroskedasticity-robust standard errors are reported in parentheses.

*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

sample, this coefficient remains statistically significant and positive in the pre and post-crisis periods. We also performed the analysis for a 1999–2019 sample, and the results are qualitatively consistent with our benchmark findings. Note that the results of the top panel third column of Tables 10 and 11 are the same because the samples are identical for the post-crisis period. The difference arises for the pre-crisis period since one starts in 1994 and the other starts in 1990. The same applies to the post-crisis period for other samples. The slight differences are due to the algorithm, but the signs and significance level remain unchanged.

6.3 | Lagged covariates in estimating the propensity scores

While using lagged macroeconomic variables in estimating propensity scores can be considered a potential solution to endogeneity, it can be problematic since joining the EMU may be lengthy. The EU countries must meet the conditions designed to ensure economic convergence, and the assessment of the convergence criteria done by the European Commission and the ECB may take several years (Puzzello & Gomis-Porqueras, 2018). We address this issue by replacing the lagged covariates in the first stage with 2-year moving average variables. Tables 12 and 13 present the propensity score and treatment effect estimates for lagged and 2-year moving average covariates. The results remain robust, and signs and significance levels do not change across samples.

6.4 | Treatment effects for early adopters

In this section, we discuss the treatment effects of the early adopters of the euro, consisting of the 11 countries that formed the EMU and adopted the euro in 1999. These countries implemented the monetary policy strategies introduced by the ECB, and the EMU later expanded to include eight other member states. To provide a balanced treatment group, we focus on the 11 early adopters, including Austria, Belgium, Finland, France, Germany, Ireland, Italy, Luxembourg, Netherlands, Portugal, and Spain. Table 14 presents the second-stage estimates of the ATT for this sample, and the reported results are broadly similar to the benchmark sample. The treatment effects on bond yields are negative and statistically significant for the pre-crisis period, suggesting that Greece may have played an outsized role in its influence on bond yields. We also find that the ATT on real GDP growth became negative and statistically significant in the post-crisis period, reflecting the disproportionate impact of the crisis on real activity measures in the early adopters. Overall, the results suggest that the treatment effects remain robust when considering the sample of early adopters of the euro.

6.5 | Robustness in the presence of endogeneity

The conditional independence assumption states that the decision to join the EMU is unrelated to potential outcomes. However, if an unobserved variable influences the decision to join, this assumption is violated, resulting in endogeneity

TABLE 12 Lagged covariates versus 2-year moving averages in estimating the propensity scores: First- and second-stage estimates (1990–2019).

Propensity score estimates			Treatment effect on the treated		
Regressor	**Lagged**	**2-year MA**	**Outcome**	**Lagged**	**2-year MA**
Inflation	−0.0001	0.001	Inflation	4.80	−3.92
	(0.0004)	(0.001)		(3.87)	(3.18)
GDP growth	−0.031**	−0.029*	Inflation volatility	−18.84***	−15.29***
	(0.012)	(0.016)		(4.01)	(3.03)
Money growth	−0.0005***	−0.001***	GDP growth	−0.31	−0.47
	(0.0001)	(0.0002)		(0.25)	(0.27)
Debt	0.005***	0.008***	GDP growth volatility	−0.73***	−0.71***
	(0.001)	(0.001)		(0.15)	(0.14)
Spread	0.301***	0.204***	Debt	8.82**	14.52***
	(0.024)	(0.024)		(3.71)	(3.95)
Openness	0.003***	0.001	Bond yield	−0.02	0.36
	(0.001)	(0.001)		(0.22)	(0.24)
Assets ratio	−0.016***	−0.030***	Bond yield volatility	−0.72***	−0.62***
	(0.005)	(0.006)		(0.11)	(0.11)

Note: The heteroskedasticity-robust standard errors are reported in parentheses.

*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

TABLE 13 Lagged covariates versus 2-year moving averages in estimating the propensity scores: First- and second-stage estimates (pre-/post-crisis).

Propensity score estimates			Treatment effect on the treated		
Regressor	**Lagged**	**2-year MA**	**Outcome**	**Lagged**	**2-year MA**
Pre-crisis (1990–2008)					
Inflation	0.0002	0.001	Inflation	−1.66	−9.17
	(0.0004)	(0.001)		(4.79)	(5.04)
GDP growth	0.011	0.015	Inflation volatility	−19.5***	−26.57***
	(0.015)	(0.020)		(5.31)	(6.34)
Money growth	−0.0004**	−0.001**	GDP growth	−0.87**	−0.75*
	(0.0001)	(0.0003)		(0.41)	(0.39)
Debt	0.004***	0.007***	GDP growth volatility	−0.99***	−1.05***
	(0.001)	(0.002)		(0.22)	(0.19)
Spread	0.253***	0.144***	Debt	5.90	6.59
	(0.039)	(0.035)		(6.46)	(5.70)
Openness	−0.001	−0.003	Bond yield	0.31	0.36
	(0.002)	(0.002)		(0.29)	(0.24)
Assets ratio	−0.010	−0.030***	Bond yield volatility	−0.97***	−0.57***
	(0.008)	(0.008)		(0.14)	(0.14)
Post-crisis (2009–2019)					
Inflation	−0.089***	−0.220***	Inflation	−1.82***	−1.13***
	(0.04)	(0.043)		(0.46)	(0.44)
GDP growth	−0.104***	−0.138***	Inflation volatility	−2.45***	−2.57***
	(0.036)	(0.037)		(0.37)	(0.36)
Money growth	−0.001***	−0.001***	GDP growth	−0.21	0.10
	(0.0001)	(0.0003)		(0.33)	(0.36)
Debt	0.006***	0.009***	GDP growth volatility	−0.27	−0.34
	(0.002)	(0.003)		(0.21)	(0.21)
Spread	0.330***	0.453***	Debt	16.79***	15.86***
	(0.096)	(0.101)		(3.84)	(4.14)
Openness	0.006***	0.007***	Bond yield	−0.45	−0.59
	(0.001)	(0.002)		(0.28)	(0.29)
Assets ratio	−0.023***	−0.034***	Bond yield volatility	−0.45***	−0.55***
	(0.008)	(0.010)		(0.15)	(0.15)

Note: The heteroskedasticity-robust standard errors are reported in parentheses.

*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

and biased estimates of the treatment effects. The bias is most significant for estimated propensity scores in the tails of the distribution. To address this, Black and Smith (2004) and Heckman and Navarro-Lozano (2004) suggest estimating the ATT using the "thick support region" of estimated propensity scores, which refers to values between 0.33 and 0.67. To test the robustness of our estimates, we estimated the ATTs on this region of thick support. Table 15 provides the propensity summary measures for the unrestricted and restricted propensity scores in the 1990–2019 main results. The restricted propensity scores, used in the thick support region, range between 0.33 and 0.67 and have an average of 0.45

TABLE 14 Treatment effects: The early adopters.

Outcome	Full sample	Pre-crisis	Post-crisis
Inflation	−3.23	4.63	−2.05***
	(6.01)	(7.96)	(0.64)
Inflation volatility	−32.31***	−38.24***	−3.12***
	(6.22)	(9.03)	(0.51)
GDP growth	0.17	−0.23	−0.62*
	(0.31)	(0.43)	(0.37)
GDP growth volatility	−0.78***	−1.30***	−0.11
	(0.18)	(0.22)	(0.26)
Debt	10.13***	0.14	14.25***
	(4.05)	(6.69)	(5.17)
Bond yield	−0.20	−0.74*	−0.39
	(0.26)	(0.39)	(0.28)
Bond yield volatility	−0.88***	−0.56***	−0.38**
	(0.10)	(0.17)	(0.16)
McFadden's Pseudo R^2	0.15	0.20	0.12

*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

TABLE 15 Propensity score summary measures.

Obs	Min	25%	Median	Mean	75%	Max
1170	0.06	0.30	0.38	0.39	0.49	0.86
752	0.33	0.37	0.45	0.45	0.52	0.67

with 752 observations. The estimates for the restricted propensity scores are similar to the unrestricted scores, suggesting that our results are robust to violations of the conditional independence assumption.

Table 16 shows treatment effect estimates when the thick support area of propensity scores is used. The findings suggest robust ATTs for most variables, indicating that the treatment effect estimates are not sensitive to violating the conditional independence assumption. Bond yields and fiscal situation results differ slightly from the original sample with negative and statistically significant ATT. However, the direction of the change in the ATT is the same if we split the sample and exclude GIPS from the sample. The results are also qualitatively robust if we consider the sample of early adopters for our analysis, as shown in the bottom panel of Table 16. EMU members have different policy responses to the global shock (e.g., the additional implicit support from the trading partners and other central banks). The member states, however, join the EMU before (independent of) events, such as financial crises, which does not affect the conditional independence assumption. Although this should not create a problem in estimation, we address this by estimating the treatment effects using the thick support region. The robust treatment effects imply that the estimates are not sensitive to violating the conditional independence assumption.

6.6 | Verifying propensity score matching assumptions

According to Rosenbaum and Rubin (1983), two assumptions are necessary to identify and estimate the ATT using this approach: conditional independence (or selection on observables) and overlap (the common support). The conditional independence assumption states that, after accounting for a set of observed covariates, the decision to join the EMU is independent of potential outcomes. Meanwhile, the overlap assumption requires a sufficient overlap in the propensity score distributions of EMU and non-EMU countries. To adhere to the micro tradition of measuring average effects, we ensure that these underlying assumptions are satisfied in our empirical data.

TABLE 16 Average treatment on the treated with restricted propensity scores (1990–2019).

	EMU members			The exclusion of GIPS		
Outcome	**Full sample**	**Pre-crisis**	**Post-crisis**	**Full sample**	**Pre-crisis**	**Post-crisis**
a) Main results						
Inflation	10.27	28.06	−0.72*	10.39	63.32	−1.14**
	(6.08)	(41.37)	(0.43)	(7.70)	(57.60)	(0.54)
Inflation volatility	−20.03***	−44.84*	−1.79***	−14.09***	−44.72	−2.20***
	(6.46)	(26.24)	(0.37)	(5.31)	(34.32)	(0.44)
GDP growth	−0.29	−0.52	−0.29	−0.10	1.10	−0.33
	(0.36)	(1.30)	(0.38)	(0.34)	(1.74)	(0.32)
GDP growth volatility	−0.28	−0.67	−0.10	−0.27	−1.89***	−0.10
	(0.20)	(0.61)	(0.20)	(0.17)	(0.77)	(0.21)
Debt	12.97***	−23.47***	16.38***	3.02	−18.08	8.77*
	(4.50)	(15.49)	(4.70)	(4.62)	(29.23)	(4.80)
Bond yield	−0.44	−1.29**	−0.15	−1.11***	−0.66	−1.03***
	(0.33)	(0.61)	(0.38)	(0.35)	(0.99)	(0.31)
Bond yield volatility	−0.59***	−1.11***	−0.33*	−0.62***	−1.07***	−0.60***
	(0.17)	(0.39)	(0.19)	(0.16)	(0.39)	(0.18)
b) Early adopters						
Inflation	5.58	1.44	−1.47***	4.15	−11.61	−2.85***
	(8.23)	(6.06)	(0.59)	(3.79)	(9.29)	(1.15)
Inflation volatility	−23.72***	−11.97***	−2.10***	−10.02***	−13.97	−2.83***
	(8.74)	(4.68)	(0.37)	(3.89)	(9.13)	(0.93)
GDP growth	0.25	−1.02	−0.58**	−0.06	−0.26	0.16
	(0.44)	(0.70)	(0.29)	(0.44)	(0.99)	(0.52)
GDP growth volatility	−0.33	−1.34***	−0.36	−0.80***	−1.26***	−0.45
	(0.25)	(0.36)	(0.30)	(0.30)	(0.48)	(0.31)
Debt	14.34***	−18.94***	12.67***	2.03	−1.73	−0.56
	(4.91)	(10.49)	(5.86)	(5.19)	(16.97)	(7.27)
Bond yield	−0.55*	−1.41***	−0.83**	−0.90***	0.01	−1.58***
	(0.32)	(0.49)	(0.38)	(0.30)	(0.48)	(0.50)
Bond yield volatility	−0.71***	−1.23***	−0.57***	−0.78***	−1.05***	−1.03***
	(0.16)	(0.25)	(0.24)	(0.17)	(0.31)	(0.36)

Note: The heteroskedasticity-robust standard errors are reported in parentheses.

*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

These assumptions, when satisfied, enhance the credibility of the matching process and the consequent causal interpretations. This section evaluates these assumptions, ensuring that individuals in the treated group (EMU members) can be matched with similar individuals in the control group (non-EMU members) based on their propensity scores. We visually examined the propensity score distributions across groups through histogram plots and confirmed sufficient overlap (Figures 1–4). This overlap assures us that our comparisons are drawn from similar observations and that our treated units have corresponding counterparts in the control group.

The conditional independence assumption states that potential outcomes are independent of treatment assignment and conditional on covariates. To verify this, we employ a balancing test post-matching, ensuring that the covariates are

balanced across the treatment and control groups and that the treatment assignment is quasi-random post-matching. Following the methodology outlined by Apeti et al. (2023), we confirm that there are no systematic differences between the groups on covariates once the propensity score is controlled for, validating the robustness of our matching process.

In addition to the primary propensity score matching approach, we employ various matching estimators to calculate the ATT and apply the Rosenbaum bounds sensitivity tests (Rosenbaum, 1987) for our results' sensitivity to the estimator's choice. Furthermore, instead of one-to-one matching, we use nearest-neighbor for each treated observation, following Minea and Tapsoba (2014). This method increases the pool of control units, potentially improving the estimation precision for ATT. We also employ RM, where treated units are matched with control units within a certain propensity score radius, providing a robust set of matches not limited to the closest neighbor. This method helps to mitigate the risk of poor matches, which can occur if the nearest neighbor is distant in propensity score terms.

Table 17 illustrates the ATTs using nearest-neighbor matching and RM across different sample periods. Notably, our results maintain consistent patterns of economic significance across different matching techniques, underscoring the robustness of our main findings. This approach provides an evaluation of the match quality.

Rosenbaum bounds quantify how robust the causal inferences are to potential hidden biases (Rosenbaum, 2005). Table 18 examines the robustness of the treatment effects across various outcomes under the potential influence of

TABLE 17 Average treatment on the treated using alternative matching methods.

	Full sample		Pre-crisis		Post-crisis	
Outcome	**NNM**	**RM**	**NNM**	**RM**	**NNM**	**RM**
Inflation	1.04	1.04	−13.07	−14.58	−1.65***	−1.63***
	(2.55)	(3.61)	(4.56)	(6.03)	(0.13)	(0.40)
Inflation volatility	−30.00***	−32.13***	−34.10***	−34.17***	−2.59***	−2.67***
	(2.46)	(3.41)	(4.50)	(5.67)	(0.11)	(0.35)
GDP growth	0.11	0.07	0.03	−0.07	−0.04	−0.65
	(0.15)	(0.20)	(0.25)	(0.29)	(0.11)	(0.33)
GDP growth volatility	−0.80***	−0.80***	−1.09***	−1.04***	−0.31	−0.29
	(0.07)	(0.11)	(0.12)	(0.14)	(0.06)	(0.19)
Debt	9.73***	11.54***	12.13	6.77	15.30***	13.82***
	(2.20)	(2.87)	(4.24)	(5.23)	(1.20)	(3.30)
Bond yield	0.42	0.59	1.33	1.28	−0.49	−0.65
	(0.13)	(0.18)	(0.23)	(0.29)	(0.30)	(0.40)
Bond yield volatility	−0.53***	−0.52***	−0.75***	−0.76***	−0.49***	−0.46***
	(0.06)	(0.08)	(0.11)	(0.13)	(0.04)	(0.13)

Note: Bootstrapped standard errors based on 500 replications reported in parentheses. NNM reports the nearest-neighbor matching. RM reports the radius matching under $r = 0.05$.

*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

TABLE 18 Rosenbaum bounds sensitivity tests.

Outcome	Γ	Lower bound	Upper bound	Unconfounded estimate
Inflation	6	0.00	1.00	1.00
Inflation volatility	6	0.00	1.00	1.00
GDP growth	6	0.00	1.00	0.96
GDP growth volatility	6	0.00	1.00	1.00
Debt	6	0.00	1.00	0.95
Bond yield	6	0.00	1.00	0.95
Bond yield volatility	6	0.00	1.00	1.00

unobserved confounding factors. The sensitivity parameter Γ, set at a threshold of 6, simulates a scenario where the odds of differential assignment due to unobserved covariates could be up to six times higher in one group compared to another. The strength of the hidden bias increases with the value of Γ (Rosenbaum et al., 2010). The lower and upper bounds indicate the extremities within which the *p*-values could fall if such a bias existed, testing the resilience of the causal inference. The unconfounded estimate values represent the original significance levels of the treatment effects without bias. An unconfounded estimate of 1.00 suggests that the treatment effect maintains its significance despite the assumed level of hidden bias. These estimates show high robustness for all the outcomes with values close to or equal to 1.00, implying that the results are unaffected by hidden bias under the $\Gamma = 6$ scenario. This sensitivity analysis highlights the robustness of the treatment effects.

6.7 | Alternative causal inference techniques

The EMU literature has recently employed various causal inference techniques to assess the impact of joining the EMU. These techniques include difference-in-differences, regression discontinuity, synthetic controls, and propensity score matching. Notably, difference-in-differences and regression discontinuity fail to account for selection bias. Researchers commonly use the synthetic control method to address this issue, first introduced by Abadie and Garderazabal (2003) and further developed by Abadie et al. (2010). The synthetic control uses weights that are calculated through an optimization process. As highlighted by Kellogg et al. (2021), the synthetic control method reduces extrapolation bias while increasing interpolation bias, whereas propensity score matching exhibits the reverse tendency. Extrapolation bias emerges when countries with distinct pre-euro attributes are combined using conventional adjustments, such as linear regression. On the other hand, interpolation bias occurs when a convex weighted average of non-EMU countries generates synthetic non-EMU countries exhibiting pre-euro characteristics comparable to those of EMU members.

The synthetic control method is helpful when we have very few treatment units. It builds a synthetic comparison group by taking a weighted average of other similar "donor" units. The main distinction between the synthetic control and propensity score matching methods lies in the matching processes. The synthetic control method relies solely on pre-euro covariates for matching, focusing on the similarities between countries before joining the EMU. Conversely, propensity score matching incorporates pre- and post-euro variables, comprehensively evaluating members' attributes before and after EMU membership. In practice, propensity score matching establishes matched groups of EMU and non-EMU countries that exhibit similar propensity score values. These scores are computed using the entire dataset, capturing a broader range of relevant factors. Correcting the selection bias and having multiple treated units (i.e., EMU members) are why propensity score matching is preferred. Propensity score matching is a non-experimental causal inference technique that balances the EMU members on the confounding factors to make them comparable to non-EMU countries so that we can conclude the causal impact of joining the EMU on macroeconomic and financial outcomes. Propensity score matching also reduces the bias before the country joins the EMU by matching the EMU and non-EMU members.

7 | CONCLUDING REMARKS AND POLICY IMPLICATIONS

This paper presents evidence on the effectiveness of the EMU in reducing inflation volatility and bond yields in its member countries. By utilizing propensity score matching to address the self-selection issue related to EMU participation, our study reveals that joining the EMU has a statistically significant negative impact on the volatilities of inflation, GDP growth, and bond yields. However, the effects on inflation and real GDP growth levels are found to be insignificant for the entire sample.

One noteworthy finding is that EMU membership is associated with a deterioration of the fiscal situation in member countries during the pre-crisis period, even when excluding GIPS from the analysis. Furthermore, our findings indicate that the bond market in these four countries experienced favorable conditions with lower yields prior to the debt crisis. Importantly, the effectiveness of the EMU varies across different sample periods and countries. For instance, we observe that including or excluding GIPS significantly impacts the estimated treatment effects, particularly regarding the debt-GDP ratio and bond yields during the pre-crisis period. These findings emphasize the need for policymakers to account for these variations when formulating strategies to enhance the effectiveness of the EMU.

The policy implications of the paper's findings take on added significance when considering the results obtained. Firstly, the negative and statistically significant average treatment effect (ATT) estimates on the volatility of inflation,

real GDP growth, and bond yield highlight the benefits of eurozone membership in reducing macroeconomic volatility. Policymakers should acknowledge and build upon this advantage by implementing measures that further stabilize these macro indicators. Policymakers can foster an environment conducive to sustainable economic growth by promoting price stability and minimizing inflation fluctuations.

Furthermore, the results reveal interesting dynamics when examining different periods and excluding certain countries from the sample. The negative and statistically significant ATT on inflation post-crisis period suggests downward pressure on prices in eurozone countries following the 2008–2009 financial crisis. Policymakers should be cognizant of this trend and develop policies that address potential deflationary pressures after a financial crisis. Additionally, the positive and statistically significant ATT on the debt-GDP ratio, particularly in the post-crisis period, points toward the aggressive action by the policymakers to counteract the negative effect of the financial crisis on the eurozone.

The findings also challenge the conventional understanding that the increase in the debt-GDP ratio in the eurozone was solely driven by the periphery countries (GIPS). Excluding GIPS from the sample reveals that higher debt levels were present across the entire EMU during the pre-crisis period. Moreover, the sensitivity of bond yields to excluding GIPS suggests that markets differentiated between periphery and core EMU countries based on their economic fundamentals. Policymakers may consider these market signals and focus on improving economic fundamentals to regain market confidence and lower borrowing costs.

Future research should delve into the long-term effects of EMU membership on various economic aspects such as trade, investment, productivity, and employment. Another important area of study is how joining the EMU affects the transmission mechanism of monetary policy, particularly how the actions of the ECB impact inflation and output in individual member countries. It would be valuable to investigate whether monetary policy transmission channels are similar or differ across member countries due to varying economic structures and institutional frameworks. Additionally, exploring the effectiveness of fiscal policy within the EMU framework is crucial, given the limited fiscal autonomy of member countries. Future studies should examine how fiscal policies, such as government spending and taxation, influence economic outcomes in member countries, considering the constraints imposed by the EMU. Furthermore, investigating whether joint implementation of fiscal policies at the European level can stimulate economic growth and reduce unemployment in member countries would be an important avenue for research.

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CONFLICT OF INTEREST STATEMENT

The authors declare that they have no relevant or material financial interests.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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ENDNOTE

[1] The EMU member countries consist of Austria, Belgium, Cyprus, Estonia, Finland, France, Germany, Greece, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Portugal, Slovakia, Slovenia, and Spain. The non-member countries encompass Albania, Belarus, Bulgaria, Croatia, Czech Republic, Denmark, Hungary, Iceland, Liechtenstein, Moldova, Monaco, Montenegro, Norway, Poland, Romania, Russia, Sweden, Switzerland, the UK, and Ukraine.

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Additional supporting information can be found online in the Supporting Information section at the end of this article.

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