Sovereign Debt Dynamics in the Euro-Zone: The Differential Impact of a Common Currency*

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Abstract

How did adopting the Euro influence the evolution of government debt in member states? Employing a matrix completion method, we estimate how key debt drivers would have evolved in early-adopting countries without the common currency. Feeding the resulting counterfactual dynamics of nominal interest rates, inflation, real growth, and primary balances into the government debt law of motion, we generate a counterfactual time series for sovereign debt-to-GDP ratios. Moreover, we quantify each factor's contribution to the gap between actual and counterfactual debt ratios. The results reveal large heterogeneity in the impact of Euro adoption. In most Northern European countries debt ratios where pushed down, in Germany mainly through lower nominal rates, in Ireland via higher growth, and in the Netherlands primarily due to higher inflation. Disinflation, in turn, is the main driver in Southern European countries where we find a strong debt-increasing impact of the Euro—a finding that we associate with the fiscal burden of converting long-term national-currency debt into Euro debt. The union as a whole, despite lower nominal rates, experienced an increase in debt to GDP as adopting the Euro came, in the aggregate, with lower inflation, lower growth, and less favorable primary balances.

JEL Codes: C31, C33, E65, F45, H63, N14.

Keywords: Counterfactual Analysis, Currency Unions, Eurozone, Matrix Completion Method, Sovereign Debt.

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1 Introduction

The launch and adoption of the common currency by the Euro-Zone (EZ) founders marked a significant economic transition, one that has been both praised and criticized. From the inception of the Euro to our days, member countries' sovereign debt levels have been a focus of policy discussions. In particular, the Great Recession, the Euro crisis, and the COVID-19 pandemic have raised questions about the sustainability of sovereign debt within the currency union and the need for collective responses. However, these events also highlighted pronounced differences in debt-to-GDP ratios and attitudes toward fiscal consolidation across EZ countries. While these differences are frequently attributed to long-standing cultural and political factors, this paper seeks to quantify the distinct impact of the common currency's introduction on each member country's sovereign debt dynamics.

We focus on the pivotal moment of the Euro's adoption and evaluate its effect on founder countries' public debt evolution up to 2007. Specifically, how might debt-to-GDP ratios have evolved if the adopting countries had retained their currency and independent monetary policies instead of joining the Euro? To answer this question, we combine structural and non-structural empirical analysis exploiting the government debt law of motion. Using the nuclear norm matrix completion estimator proposed by Athey et al. (2021), we estimate the effects of adopting the single currency on four crucial drivers of government debt: real GDP growth rates, inflation rates, nominal interest rates, and primary balances. Based on the estimated counterfactuals for these four debt drivers and applying the debt law of motion, we can quantify both the overall effect of adopting the single currency on each country's debt-to-GDP ratio over time and the specific contribution of each driver to its trajectory.

Our empirical results reveal substantial heterogeneity in the impact of Euro adoption across the nine early adopters we analyze. For three of the four investigated northern members, Germany, Ireland, and the Netherlands, joining the single currency led to a substantial cumulative reduction in debt-to-GDP ratios, with decreases of approximately 17 percentage points for Ireland and around 10 and 9 percentage points for Germany and the Netherlands, respectively. In contrast, Belgium and all the southern countries experienced a cumulative rise in debt-to-GDP ratios following Euro adoption, with sharp increases of more than 25 percentage points for Italy, Portugal, and Greece and relatively more moderate increments of around 11, 7, and 2 percentage points for Belgium, France, and Spain, respectively.

The contributions of debt drivers in explaining debt dynamics are multifaceted and vary significantly among the EZ founders. For Germany, the inflation rate and nominal interest rate channels consistently pushed the debt-to-GDP ratio downward, with the latter channel being particularly influential. Ireland's debt dynamics were uniquely dominated by real GDP growth, leading to a significant reduction in its debt-to-GDP ratio. The Netherlands experienced a combined influence of real GDP growth and inflation, both exerting downward pressure on debt despite the contrasting effect of the nominal interest rate. Although the substantial debt-decreasing impact of inflation, Belgium's debt-to-GDP ratio increased due to the opposing real GDP growth and primary balance channels. For France, while its debt dynamics reveal the debt-decreasing nominal interest rate as the most salient driver, the other three channels significantly counteract it, leading to an increase in its debt-to-GDP ratio. Greece faced a significant increase in debt to GDP due to the dominant inflation channel, although the real GDP growth and primary balance channels exerted substantial downward pressure in the short term and the nominal interest rate in the long term. Italy's debt dynamics are predominantly influenced by the inflation channel, which exerted upward pressure on its debt-to-GDP ratio despite the nominal interest rate channel's substantial downward force. Additionally, the real GDP growth rate significantly increased the debt ratio, and the primary balance channel also contributed to the long-term increase—leading to the largest absolute change in debt to GDP across members. Portugal's debt-to-GDP ratio rise is driven by the substantial effect of the inflation channel and, to a lesser extent, primary balance impact, with the debt-decreasing nominal interest rate and real GDP growth channels mitigating the increase. For Spain, the inflation channel is the most salient driver, with the debt-decreasing real GDP growth and primary balance channels moderating its debt-increasing impact—leading to the smallest absolute change in debt to GDP across members. Finally, when aggregating the EZ countries according to their real GDP weight, we find that the union as a whole experienced an increase in the debt-to-GDP ratio, despite the debt-decreasing nominal interest channel being the most salient driver at the aggregate level. This rise in the public debt to GDP following the adoption of the Euro can be attributed to the combined effects of disinflation, lower real GDP growth, and less favorable primary balances.

These findings reveal that, across countries, the most salient debt drivers were the inflation rate and nominal interest rate. As, theoretically, changes in expected inflation should be offset by corresponding shifts in nominal interest rates for the real interest rate to stay the same, one might expect the inflation and nominal interest contributions to government debt-to-GDP ratios to largely cancel each other out in our decomposition. However, our findings indicate notable deviations. In Germany and Belgium, both the inflation and nominal interest rate channels work together to exert downward pressure on sovereign debt ratios. In Greece, Portugal, and Italy, while the nominal interest rate channel contributes to reducing debt-to-GDP ratios, it is insufficient to counteract the strong debt-increasing effects of deflation. One possible explanation for these findings is the presence of what we call "legacy debt"—long-term national-currency debt issued when the transition to currency union (or at least its timing) was uncertain. We quantify the impact of legacy debt and find evidence that it significantly accounts for the variation in debt-to-GDP induced by the real interest rate channel—a combination of the inflation and nominal interest rate channels—which in turn accounts for a significant part of the Euro adoption's impact on sovereign debt-to-GDP ratios.

Related Literature. Several studies have explored different aspects of the impact of the Euro's introduction, including on income per capita, consumption smoothing, trade dynamics, and current account balances. Our work contributes to this growing literature by being the first to conduct a counterfactual analysis that quantifies the Euro's effect on sovereign debt-to-GDP ratios. Some economic channels pertinent to our debt analysis have been examined in the literature through counterfactual studies. In particular, Puzzello and Gomis-Porqueras (2018) analyze real GDP per capita, Ferrari and Rogantini Picco (2023) generate GDP counterfactuals, and Dubois et al. (2009) study real industrial production and inflation while imposing restrictions to generate specific counterfactual scenarios. However, our approach notably differs from these studies by utilizing the novel estimator proposed by Athey et al. (2021) to generate counterfactual series for the debt drivers. Athey et al. (2021) demonstrate that their method outperforms, among others, the Synthetic Control Method (SCM), the estimator of choice in the more recent empirical literature generating counterfactuals to assess the impact of the Euro's introduction on some outcomes. Thus, by applying this novel methodology, we additionally offer a complementary assessment of the effects of Euro adoption on real GDP.

Using the SCM, Puzzello and Gomis-Porqueras (2018) estimate the effect of adopting the Euro on the income per capita of six early adopters and relate the estimated gains and losses to economic determinants of the costs and benefits of monetary unions. They find that the income per capita of Belgium, France, Germany, and Italy would have been higher without the Euro, Ireland's income per capita would have been considerably lower, and the Netherlands' income per capita would have been unaffected. These findings align and are largely consistent with our estimates of the Euro's impact on real GDP. Puzzello and Gomis-Porqueras (2018) find that the countries that gained more or lost less from the Euro had more synchronized business cycles, greater trade and migration openness within the union, and less financial integration.

Ferrari and Rogantini Picco (2023) investigate whether adopting the Euro has changed consumption smoothing among EZ member states. The authors employ the SCM to construct a counterfactual dataset of macroeconomic variables and then use an output variance decomposition method to analyze risk sharing through different channels. Ferrari and Rogantini Picco (2023) find that core countries (Austria, Belgium, Finland, France, Germany, Netherlands) did not experience a significant change in consumption smoothing due to the Euro, whereas periphery countries (Greece, Ireland, Italy, Portugal, and Spain) saw a substantial reduction in consumption smoothing, largely due to a lower absorption through private savings.

On trade dynamics, Cerulli et al. (2022) examine the impact of the Euro on the value-added structure of Italian trade flows using the SCM. The authors find that the Euro has accelerated Italy's forward integration in global value chains while slowing down its backward integration, with heterogeneous effects across sectors. Additionally, Hope (2016) studies the extent to which the introduction of the European Monetary Union (EMU) was responsible for the current account imbalances that emerged between member states in the 2000s. The author employs the SCM to create counterfactual current account balances for EMU member states and finds that Austria experienced an improvement in its current account balance, while France, Greece, Italy, and Spain saw significant deterioration.

Finally, using the Global Vector Autoregressive (GVAR) framework Dubois et al. (2009) aim to quantitatively assess the macroeconomic impact of the EMU membership on national outputs (real industrial production) and inflation rates. The authors estimate a GVAR model and then simulate the counterfactuals of what would have happened if the Euro had never been launched by imposing scenario-based restrictions on interest rates and exchange rates. The authors find that the introduction of the Euro led to lower interest rates and higher output in most Euro area countries compared to a scenario with German-type monetary policies. Adopting British monetary preferences, in contrast, would have resulted in higher interest rates, depreciated national exchange rates, and higher output. Overall, the authors find that the single currency did not significantly impact price developments compared to the considered alternative monetary policy regimes.

The remainder of this paper is structured as follows: In Section 2, we detail our empirical approach, including the methodology and data used for the analysis. Section 3 presents the counterfactual dynamics of the key debt drivers and discusses the heterogeneity in their impacts across EZ countries. Section 4 shows the results for public debt dynamics and provides a decomposition to quantify the contributions of each driver. Finally, Section 5 concludes with a discussion of the implications of our findings for policy and future research.

2 Empirical Approach

This section lays out the methodology we employ to account for debt dynamics. It introduces the stock-flow-corrected law of motion for government debt and the empirical approach used to estimate counterfactual outcomes for the four analyzed drivers of government debt. Data sources and sample selection are also discussed.

2.1 Accounting for Debt Dynamics

Our main objective is to estimate the causal effect of adopting the single currency on the government debt-to-GDP ratio. To do so, we combine structural and non-structural empirical analysis exploiting the government debt law of motion, which we lay out next. The concept of debt we refer to in the following is gross public debt at the general government level.[1] Let debt at the end of period t as a ratio to GDP at t be denoted by d_t. The government budget constraint accounts for how i_t, the nominal interest rate paid in period t on the debt stock outstanding at the end of $t-1$,[2] π_t, the net inflation between $t-1$ and t, g_t, the net growth in real GDP between $t-1$ and t, and p_t, the primary balance in period t as a ratio to GDP at t, combine to determine the evolution of the government debt-to-GDP ratio:

$$d_t = \frac{1+i_t}{(1+\pi_t)(1+g_t)} d_{t-1} - p_t \; . \tag{1}$$

When working with empirical data, pronounced discrepancies may arise between the left- and right-hand sides of the government debt law of motion since primary balances and interest payments are flows, i.e. measured over a period, while public debt is a stock, i.e. measured at a specific point in time.[3] In the empirical literature, such discrepancies

[1] The general government sector encompasses all government units and non-market, non-profit institutions predominantly controlled and funded by government entities. This sector includes central, state, and local governments but excludes public corporations or quasi-corporations.

[2] Since, due to data limitations, we cannot account for the complete maturity structure of debt, the notion under consideration is that of an average interest rate. The latter can be retrieved from the interest bill in period t on the debt stock outstanding at the end of $t-1$ as a ratio to GDP at $t-1$, i.e. $b_t = i_t d_{t-1}$, where i_t is the implied average nominal interest rate under consideration.

[3] For instance, discrepancies may originate when a government resorts to off-budget resources, or when it undertakes the recapitalization of a state-owned corporation. Such disparities can also occur when public debt is denominated in foreign currency, and a depreciation in the exchange rate causes a surge in the debt's value relative to GDP, which is denominated in the domestic currency. Empirically, for a sample of significant debt increases in advanced economies over 1980–2010, the International Monetary Fund (2011) finds a stock-flow adjustment contribution of approximately 13 percent of GDP against an average debt increase of 25 percent of GDP. Further, International Monetary Fund (2011) reports that currency valuation changes have had a minimal impact on driving advanced economy debt dynamics from 1980 to 2010, due to the traditionally high share of domestic currency debt in total debt. Rather, as highlighted by Abbas et al. (2011), there seem to be indications that governments took on liabilities while protecting headline fiscal balances from operations that increase debt.

are typically addressed by incorporating an additional term into the equation, known as the stock-flow reconciliation term (also referred to as the unexplained part of public debt), which we will label as sf_t so that (1) becomes:

$$d_t = \frac{1 + i_t}{(1 + \pi_t)(1 + g_t)} d_{t-1} - p_t + sf_t \ . \tag{2}$$

Our approach focuses on firstly estimating the effects of adopting the single currency on four crucial drivers influencing the government debt law of motion (2) by generating counterfactuals for the real GDP growth, inflation rate, nominal interest rate, and primary balance. Doing so allows us to gain a comprehensive understanding of the impact of the Euro adoption on public debt dynamics through the lens of its components: By leveraging the debt law of motion, we can discern both the overall effect of adopting the single currency on public debt over time and the distinct contributions of each driver to its dynamic behavior.

We will not generate a counterfactual for the stock-flow reconciliation term.[4] Instead, in our analysis in Section 4, we will consider this term as a given unchanged factor (equivalently assuming it is unaffected by the treatment) and adjust the counterfactual debt dynamics accordingly.

2.2 Estimation Procedure

Assessing the impact of entering the EZ involves deploying statistical routines to estimate causal effects using observational time-series cross-sectional (TSCS) data. We employ the nuclear norm matrix completion estimator proposed by Athey et al. (2021) to estimate counterfactual outcomes for the debt drivers of EZ members, considering the Euro adoption as a dichotomous treatment. The novel approach proposed by Athey et al. (2021) introduces a class of matrix completion estimators that leverages observed elements from the matrix of control outcomes corresponding to untreated units and periods to impute the missing elements related to treated units and periods. While this is not the only method designed to construct a lower rank approximation of the outcome data matrix using the information of untreated observations to account for potential time-varying confounders (see e.g. Gobillon and Magnac (2016) and Xu (2017)), Athey et al. (2021) notably differs in that they propose regularizing latent factors via the nuclear norm, a computationally more efficient and attractive option to the fixed-rank methods in Bai and Ng (2002) and Xu (2017).

As noted by Athey et al. (2021), for causal inference in TSCS data settings with exposure to binary treatments, two methodologies have emerged. The unconfoundedness liter-

[4]Relatedly, it would be unappealing to generate counterfactual outcomes for public debt directly.

ature, exemplified by works such as Rosenbaum and Rubin (1983) and Imbens and Rubin (2015), entails imputing missing potential control outcomes for treated units by leveraging observed control outcomes from units with akin values in preceding periods. Conversely, the synthetic control literature, represented by Abadie and Gardeazabal (2003), Abadie et al. (2010), Abadie et al. (2015), Doudchenko and Imbens (2016), Ben-Michael et al. (2021), Arkhangelsky et al. (2021), Abadie (2021) and others, imputes missing control outcomes for treated units through weighted averages of control unit outcomes, where weights are chosen to align lagged control outcomes with those of treated units. These approaches diverge conceptually in terms of the correlation patterns they exploit for imputing missing potential outcomes: The unconfoundedness approach presupposes stable temporal patterns across units, while the synthetic control approach assumes stability in patterns across units over time. Empirically, these methods find application in disparate settings based on variations in missing data structures or assignment mechanisms.

Athey et al. (2021) integrate insights from the econometric literature on factor models and interactive fixed effects (Bai and Ng, 2002, Bai, 2003 and Xu, 2017), and the matrix completion literature (Candès and Recht, 2009 and Candès and Plan, 2010, among others) to devise an innovative method for imputing missing potential outcomes. Their approach, distinct from unconfoundedness and synthetic control methods, can be seen as a synthesis of both. Athey et al. (2021) demonstrate that the synthetic control and unconfoundedness approaches, along with their method, can be represented as a matrix completion method based on matrix factorization, sharing a common objective function utilizing the Fröbenius norm. While unconfoundedness and synthetic control introduce restrictions on factors in matrix factorization, Athey et al. (2021) employ regularization without imposing specific restrictions. Furthermore, the authors generalize findings from the matrix completion literature to accommodate time series dependency structures in the patterns of missing data. When applied to two actual datasets, Athey et al. (2021) show that their nuclear norm matrix completion estimator outperforms unconfoundedness-based and synthetic control estimators.

The setup is as follows. Consider a balanced panel with N units observed over T periods. Denote W_{it} the treatment status: In period t, unit i is exposed or not to a binary treatment, with $W_{it} = 1$ indicating that the unit is exposed to the treatment and $W_{it} = 0$ otherwise. In each period t each unit i is characterized by two potential outcomes, $Y_{it}(0)$ when $W_{it} = 0$ and $Y_{it}(1)$ when $W_{it} = 1$. We observe for each unit and period the pair (W_{it}, Y_{it}) where the realized outcome is $Y_{it} = Y_{it}(W_{it})$. The focus is on imputing the missing entries in the $Y(0)$ matrix for treated units with $W_{it} = 1$, or relatedly $\alpha_{it} = Y_{it}(1) - Y_{it}(0)$.

For any positive integer n, the notation $[n]$ refers to the set $\{1, \ldots, n\}$. Define $\mathcal{M}$ to be the set of pairs of indices (i, t), $i \in [N]$, $t \in [T]$, corresponding to the missing entries in $Y(0)$ with $W_{it} = 1$ and $\mathcal{O}$ to be the set of pairs of indices corresponding to the observed entries in $Y(0)$ with $W_{it} = 0$. Then, in general, the data can be thought of as consisting of two $N \times T$ matrices, one incomplete and one complete:

$$Y(0) = \begin{pmatrix} Y_{11}(0) & Y_{12}(0) & ? & \cdots & Y_{1T}(0) \\ ? & ? & Y_{23}(0) & \cdots & ? \\ Y_{31}(0) & ? & Y_{33}(0) & \cdots & ? \\ \vdots & \vdots & \vdots & \ddots & ? \\ Y_{N1}(0) & ? & Y_{N3}(0) & \cdots & ? \end{pmatrix}$$

and

$$W = \begin{pmatrix} 0 & 0 & 1 & \cdots & 0 \\ 1 & 1 & 0 & \cdots & 1 \\ 0 & 1 & 0 & \cdots & 1 \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ 0 & 1 & 0 & \cdots & 1 \end{pmatrix},$$

where

$$W_{it} = \begin{cases} 1 & \text{if } (i,t) \in \mathcal{M}, \\ 0 & \text{if } (i,t) \in \mathcal{O}, \end{cases}$$

is an indicator for the event that the corresponding component $Y_{it}(0)$ is missing. The focus is then on imputing the missing values in $Y(0)$. As the missingness arises from treatment assignments, in our application of the Euro adoption on early adopters, the missing data will take a specific structure. In particular, our data is characterized by the block structure, with a subset of the units adopting an irreversible treatment at a particular point in time $T_0 + 1$.

Allowing for unit-specific, time-specific, and unit-time-specific covariates, the model specification and estimation are as follows. For unit i, we observe a vector of unit-specific covariates denoted by X_i, and X denotes the $N \times P$ matrix of covariates with the i-th row equal to $X_i^\top$. Similarly, Z_t denotes the time-specific covariates for period t, with Z denoting the $T \times Q$ matrix with the t-th row equal to $Z_t^\top$. In addition, we allow for a unit-time specific $J \times 1$ vector of covariates V_{it}. Then, the model we consider is

$$Y_{it}(0) = L_{it}^* + \sum_{p=1}^{P} \sum_{q=1}^{Q} X_{ip} H_{pq}^* Z_{qt} + \gamma_i^* + \delta_t^* + V_{it}^\top \beta^* + \varepsilon_{it},$$

where ε_{it} is random noise. We are interested in estimating the unknown parameters L^*, H^*, γ^*, δ^*, and β^*. This model allows for traditional econometric fixed effects for the units (γ_i^*) and time effects (δ_t^*). It also allows for fixed covariates (with time-varying coefficients), time covariates (with individual coefficients), and time-varying individual covariates.

With many parameters, we need regularization such that we shrink L and H toward zero. To regularize H, the Lasso-type element-wise l_1 norm is used, defined as $\|H\|_{1,e} = \sum_{p=1}^{P}\sum_{q=1}^{Q}|H_{pq}|$. To regularize L, note that given the full singular value decomposition $L_{N\times T} = S_{N\times N}\Sigma_{N\times T}R_{T\times T}$ where S, R unitary, Σ is rectangular diagonal with entries $\sigma_i(L)$ that are the singular values. Rank of L is the number of non-zero $\sigma_i(L)$. There are different ways to regularize L. The nuclear norm implements $\|L\|_* = \sum_{i=1}^{\min(N,T)}\sigma_i(L)$. Thus, the Matrix-Completion with Nuclear Norm Minimization estimator uses the nuclear norm to estimate H^*, L^*, δ^*, γ^*, and β^* by solving the following convex program:

$$\min_{H,L,\delta,\gamma,\beta}\left[\sum_{(i,t)\in\mathcal{O}}\frac{1}{|\mathcal{O}|}(Y_{it}(0) - L_{it} - \sum_{p=1}^{P}\sum_{q=1}^{Q}X_{ip}H_{pq}Z_{qt} - \gamma_i - \delta_t - V_{it}\beta)^2 + \lambda_L\|L\|_* + \lambda_H\|H\|_{1,e}\right],$$

where λ_L and λ_H are chosen through cross-validation. In words, producing estimates for quantities of interest can be seen as a two-step process. First, on the subset of untreated observations $\mathcal{O}$, fit a model of $Y_{it}(0)$, obtaining estimates for H^*, L^*, δ^*, γ^*, and β^*. Second, using these estimates, predict the counterfactual outcome $\hat{Y}_{it}(0)$ for each treated observation, i.e. for all $(i,t)\in\mathcal{M}$, and relatedly estimate the individualistic treatment effects $\hat{\alpha}_{it}$ for each treated observation $(i,t)\in\mathcal{M}$.

2.3 Sample and Data

2.3.1 Treated and Control Countries

For each investigated debt driver, we conduct counterfactual estimations on nine Eurozone countries: Belgium, France, Germany, Greece, Ireland, Italy, the Netherlands, Portugal, and Spain.[5] In our analysis, we select untreated countries exclusively from the OECD economies to enhance similarity with the treated units. This choice is grounded in the idea that untreated units should be influenced by similar structural processes as those affecting the treated unit. When creating a counterfactual for advanced economies, there is a potential for bias when including developing countries as untreated units. Opting for

[5]Of the twelve early adopters in which Euro banknotes and coins were introduced at the beginning of 2002, our analysis does not include Austria, Finland, and Luxembourg. In particular, we exclude the latter due to data limitations. Austria and Finland are currently not included due to concerns around disentangling the integration effect related to joining the European Union in 1995 from the impact due to Euro adoption.

a smaller control pool only composed of OECD economies prioritizes greater similarities with treated units, even if it may result in a somewhat diminished pre-treatment fit. This simple idea shares commonalities with what matching techniques implement: attempting to reduce bias by creating a sample of units that received the treatment that is comparable on all observed covariates to a sample of units that did not receive the treatment, so as to mitigate confounding issues by having units with similar propensity scores in both treatment and control.

The sample of untreated units used to analyze real GDP consists of ten countries: Australia, Canada, Denmark, New Zealand, Norway, Sweden, Switzerland, Turkey, the United Kingdom, and the United States. For the analysis of the inflation rate, nominal interest rate, and primary balance, we cannot maintain Turkey in the sample due to data limitations, bringing the set of untreated units down to nine countries.

2.3.2 Sample Timeframe

We utilize annual country-level data spanning from 1961 to 2007. Importantly, we exclude periods associated with the global financial recession, the European sovereign debt crises, and their aftermath. This exclusion is based on the rationale that these crises could have led to structural changes in the most affected economies, thereby compromising the representativeness of counterfactual dynamics.

Although the official announcement of the creation of the Euro occurred in 1998, with the currency being launched virtually on 1 January 1999, most EZ countries had already started implementing measures to meet the Maastricht requirements prior to this date. To account for these anticipation effects, we designate 1996 as the treatment date, similarly to Puzzello and Gomis-Porqueras (2018). This allows us to define a pre-intervention period of 35 years for all EZ members in our sample. Given that the last post-treatment year in our dataset is 2007, the post-intervention period extends for 12 years. This timeframe is considered sufficient to capture both the short-term and long-term effects of the treatment, thereby providing a comprehensive evaluation of the dynamics following the Euro's adoption.

2.3.3 Data

The outcome variables under consideration are real GDP growth, inflation rate, nominal interest rate, and primary balance. The real GDP data are sourced from the Penn World Tables version 10.0 (PWT 10.0; Feenstra et al., 2015), specifically utilizing the Output-side real GDP (ORGDP) at current PPPs, measured in millions of 2017 US dollars. Following the methodologies of Born et al. (2019) and Gabriel and Pessoa (2020), we include covariates that represent the shares in ORGDP of the following components:

(i) household consumption at current PPPs, (ii) gross capital formation at current PPPs, (iii) government consumption at current PPPs, (iv) merchandise exports at current PPPs, and (v) merchandise imports at current PPPs. Additionally, we include a human capital index based on years of schooling and returns to education. All these covariates are also drawn from PWT 10.0. Inflation rate data, as measured by the consumer price index, are obtained from the IMF International Financial Statistics. The covariates used in relation to inflation include the implied interest rate from interest bills and the output gap, the latter of which is calculated using a one-sided HP filter applied to real GDP. Data for the implied interest rate are sourced from the IMF Public Finances in Modern History (PFMH) dataset (International Monetary Fund, 2023), while the output gap is derived from real GDP data in PWT 10.0. Primary balance data are also sourced from the IMF PFMH dataset. In addition to the inflation rate, covariates used in the analysis of primary balance include government revenues (as a percentage of GDP), government expenditures (as a percentage of GDP), and gross public debt (as a percentage of GDP), all of which are obtained from the IMF PFMH dataset. Finally, the data for the nominal interest rate are sourced from the IMF PFMH dataset, with covariates including the inflation rate, primary government expenditures, government revenues, interest bills, and the output gap.

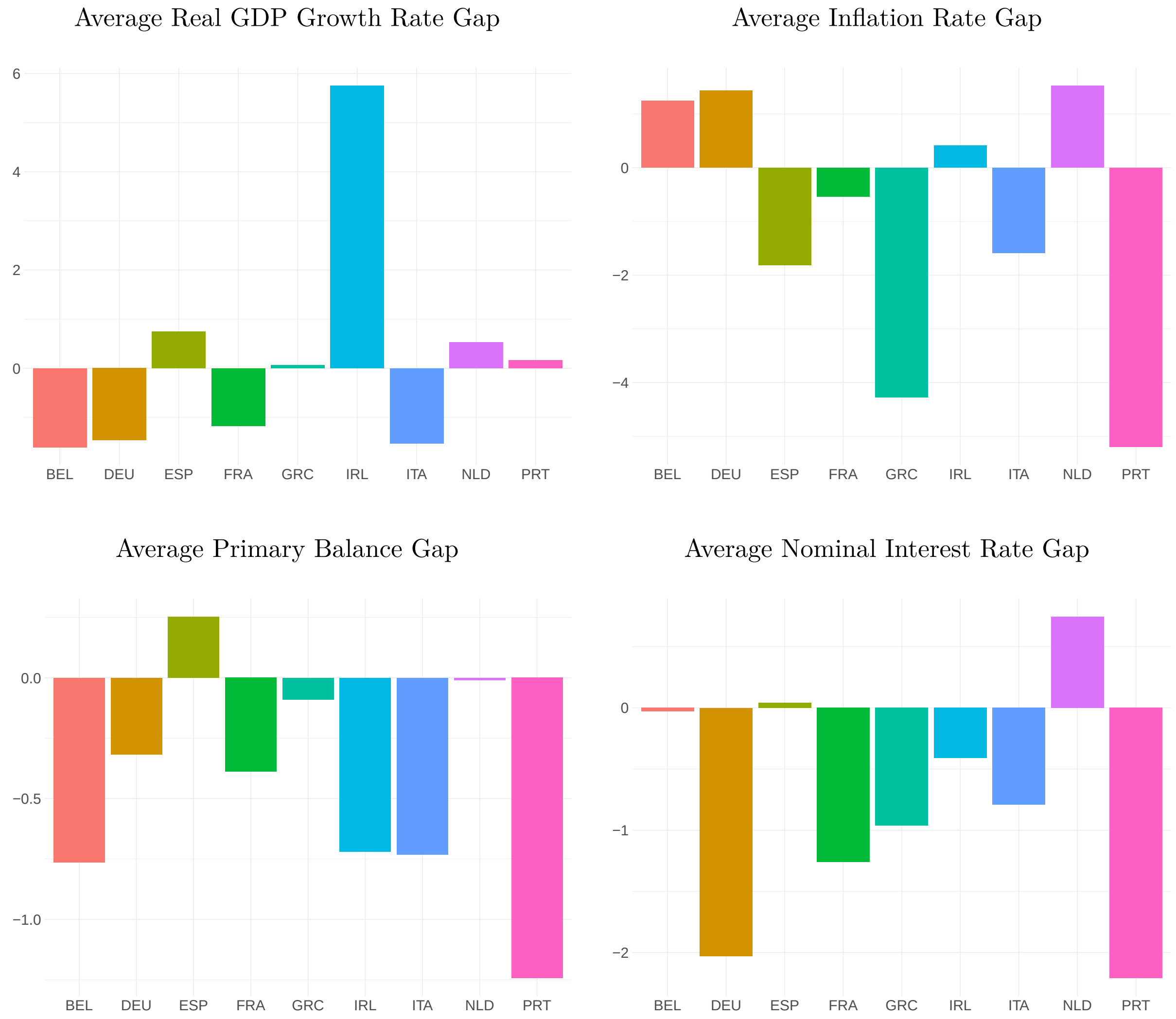
3 Counterfactual Dynamics of Debt Drivers

In this section, we assess the impact of joining the currency union on the factors influencing public debt by comparing the actual time series of debt drivers for each examined EZ member with the estimated counterfactual time series.

Before delving into a detailed discussion of the results of each channel's dynamics, we provide a broad overview of the impact on all debt drivers. Figure 1 presents the average yearly treatment effect for the real GDP growth rate, inflation rate, nominal interest rate, and primary balance across the analyzed EZ members, revealing significant heterogeneity already in average outcomes.

In terms of real GDP growth, Ireland stands out with the largest positive average effect, while Spain and the Netherlands also exhibit gains, albeit to a much lesser extent. Greece and Portugal record modest positive effects, whereas Belgium, Germany, France, and Italy experience declines. Turning to inflation, Portugal undergoes the most pronounced average decline, followed by Greece, Spain, Italy, and France. In contrast, the northern members see inflation rise on average, with Ireland registering the smallest increase, the Netherlands the highest, and Germany and Belgium falling not too far off the Netherlands. For the primary balance, Portugal again records the largest deterioration,

Figure 1: Debt Drivers' Average Post-treatment Gap.

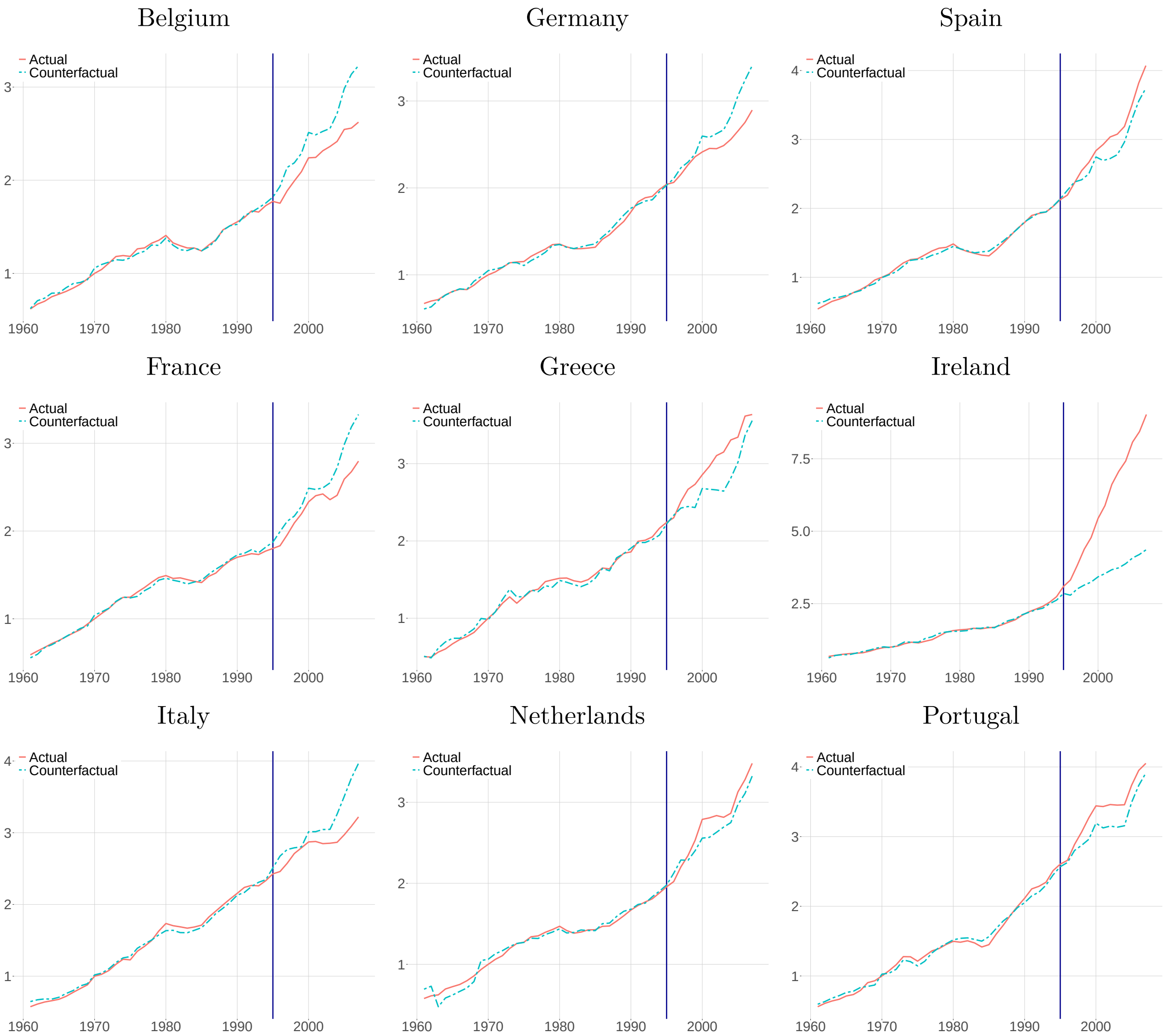


This figure presents the average yearly post-treatment gap in the real GDP growth rate, inflation rate, primary balance, and nominal interest rate for the nine EZ members, measured in percentage points.

followed by Belgium, Italy, Ireland, France, Germany and Greece. Only Spain sees an average improvement in its primary balance. Finally, concerning the nominal interest rate, Portugal experiences the steepest decline, closely followed by Germany. France, Greece, Italy, and Ireland also register negative average treatment effects, while the Netherlands stands out as the only country with a substantial average increase in the nominal interest rate.

In the following, to evaluate the significance of the estimated effects, we adopt the suggestion of Athey et al. (2021) and use resampling methods to assess statistical fluctuations of the imputed matrix. We select K subsets $\mathcal{O}_k \subset \mathcal{O}$ and obtain the estimators $\hat{H}(k)$, $\hat{L}(k)$, $\hat{\delta}(k)$, $\hat{\gamma}(k)$, and $\hat{\beta}(k)$ for each subset $\mathcal{O}_k$. Then, for every entry (i,t) in the matrix, one can utilize the statistical fluctuations of the collection $\{\hat{H}(k)_{it}, \hat{L}(k)_{it}, \hat{\delta}(k)_{it}, \hat{\gamma}(k)_{it}, \hat{\beta}(k)_{it}\}_{k\in[K]}$

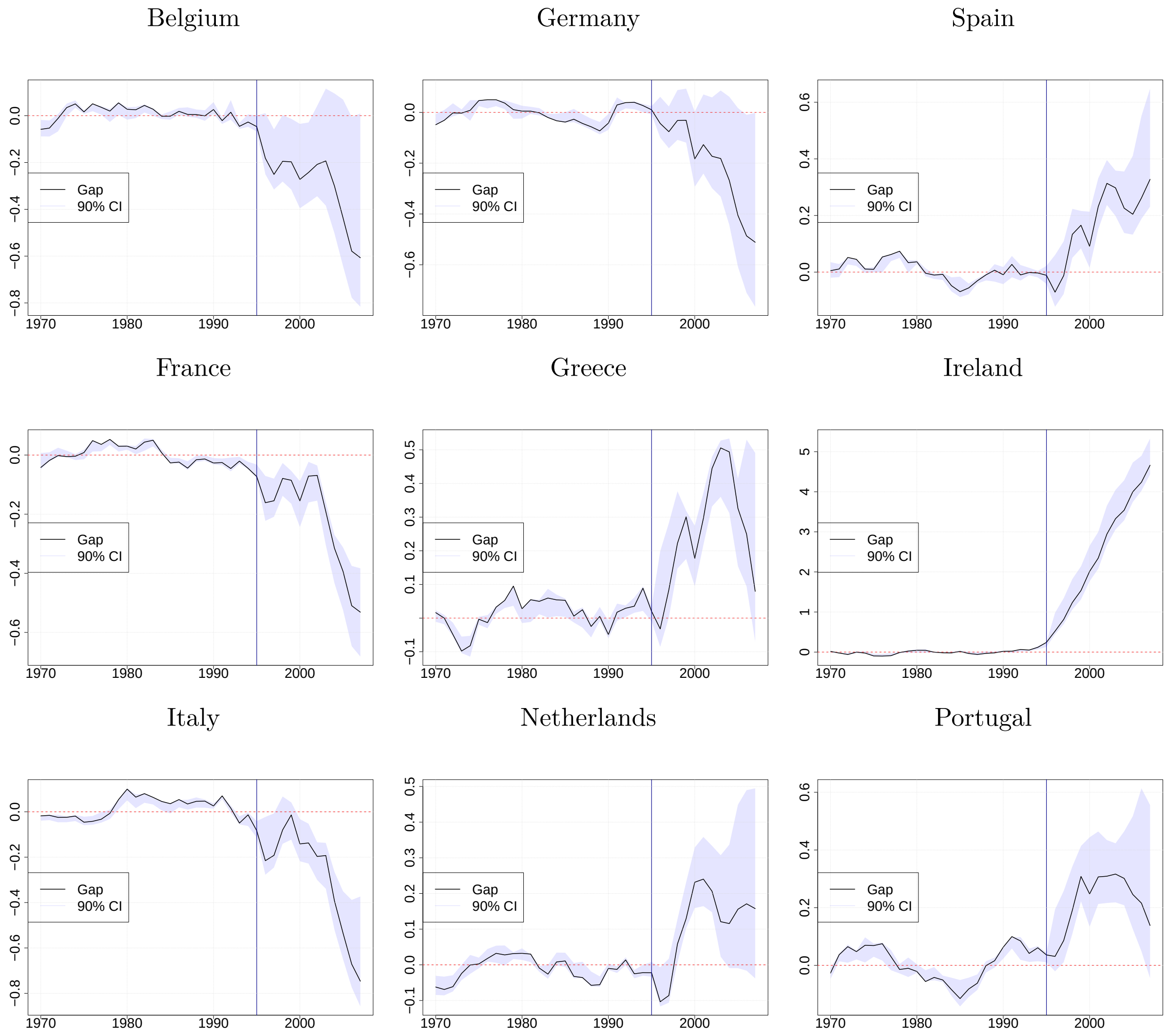
Figure 2: Real GDP Dynamics.



In each subplot, the normalized real GDP counterfactual time series is represented by the blue dashed line, while the actual time series is depicted by the solid red line. The vertical line denotes 1995, the year preceding the treatment. The analysis covers the period from 1961 to 2007 for each country.

to construct a confidence interval. This approach draws parallels with the utilization of permutation methods in the synthetic control literature (Abadie et al., 2010, and Abadie et al. (2015)). More specifically, we re-estimate the counterfactual scenario by systematically excluding one untreated country at a time. For each exclusion, we also generate counterfactual scenarios by iteratively omitting pre-treatment observations from 1961 to 1969. This process results in a total of $K = 100$ subsets for the analysis of real GDP and $K = 90$ subsets for the other debt drivers. We then compute the 5th and 95th percentiles at each point in time for the constructed distribution of K counterfactuals and report the 90% confidence interval.

Figure 3: Real GDP Gaps Significance.



In each subplot, the solid black line illustrates the normalized real GDP gap time series, depicting the difference between the actual and counterfactual series. The light blue shaded area corresponds to the 90% confidence interval. The vertical line denotes 1995, the year before the treatment. The analysis spans from 1970 to 2007 for each country.

3.1 Real GDP Dynamics

Figure 2 illustrates the observed real GDP series, which is normalized to unity in 1970, for each EZ country (solid red line) alongside its estimated counterfactual counterpart (dashed blue line) spanning from 1961 to 2007. The counterfactual real GDP of each EZ member closely mirrors the actual series until 1995, as is also more readily evident from the pre-Euro gaps depicted in Figure 3, which also displays the 90% confidence interval.

As illustrated in both Figure 2 and Figure 3, the real GDP trajectories of all EZ members diverge significantly from their counterfactual paths in the post-treatment period, with heterogeneity in the shape and magnitude of short and long-term dynamics.

Notwithstanding variations in when divergences between actual and counterfactual paths accelerated the most, the gap dynamics of Belgium, Germany, France, and Italy exhibit a significant and persistent decline in their real GDP. Specifically, in terms of the average post-treatment gaps in real GDP growth rates, Belgium is the most adversely affected, followed by Germany and Italy, which show similar effects, while France experiences the least negative impact. In contrast, Spain's real GDP gap dynamics in the short and long terms reflects an enduring positive impact of Euro adoption. Greece, the Netherlands, and Portugal also experienced significant short-term increases in their real GDP. However, the real GDP gap for these countries follows a hump-shaped trajectory, indicating that the long-term impact of Euro adoption on their real GDP was less pronounced compared to that of Spain. Lastly, Ireland shows the most substantial increase in real GDP among all positively affected EZ countries, making it the clear beneficiary in terms of real GDP growth from the Euro adoption.

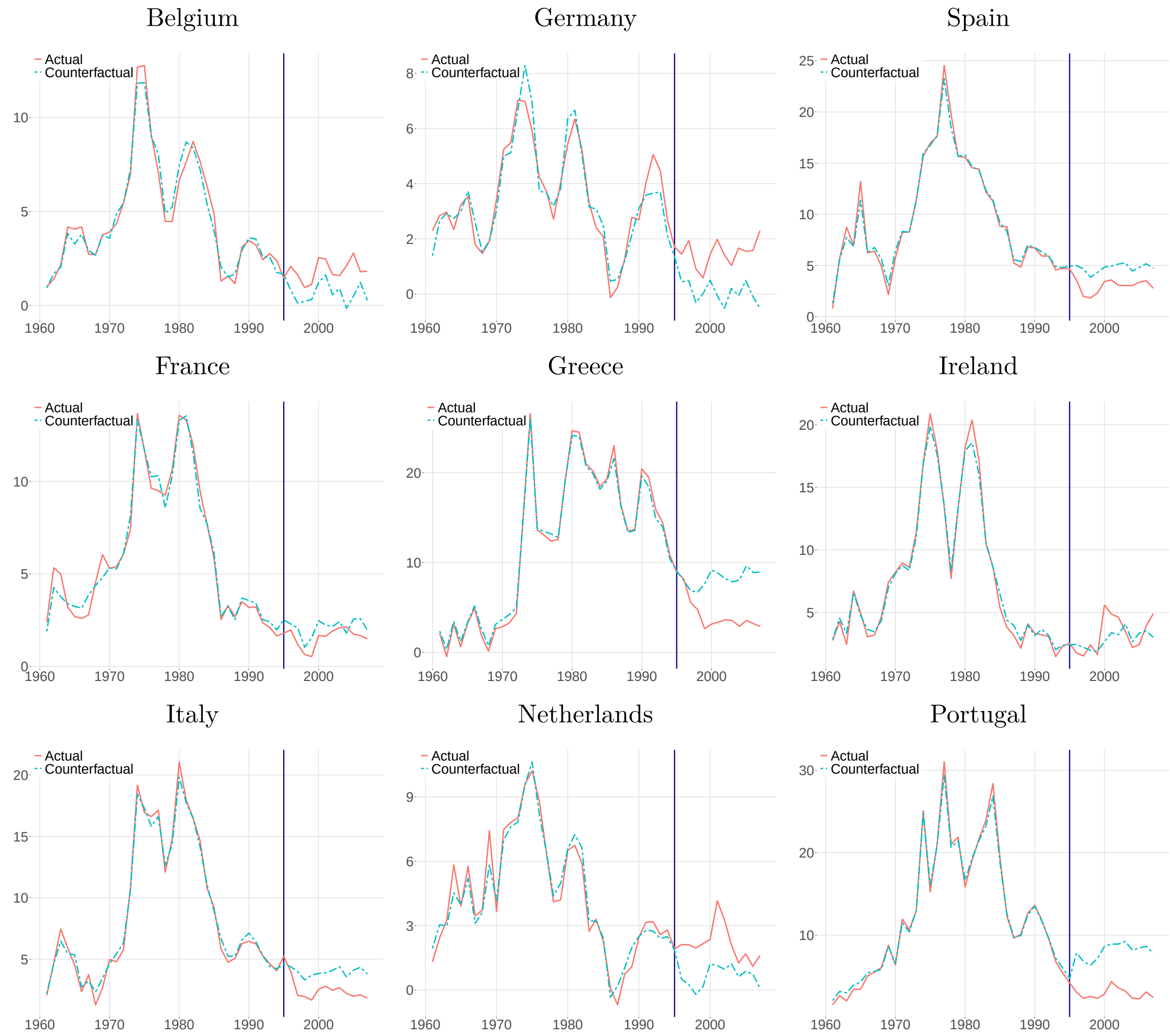
Overall, the dynamics of real GDP across the Eurozone reveal a heterogeneous impact following the introduction of the Euro. Along with Ireland and the Netherlands, the peripheral southern European countries—Spain, Greece, and Portugal—experienced a positive effect on real GDP, indicating that Euro adoption translated into economic growth gains for these nations. Conversely, along with Belgium, the larger core Eurozone economies of Germany, France, and Italy faced significant negative deviations, revealing that Euro adoption had a dampening effect on their economic growth.

3.2 Inflation Rate Dynamics

Figure 4 presents the observed inflation rate series for each EZ country (solid red line) alongside the estimated counterfactual series (dashed blue line) over the period from 1961 to 2007. The counterfactual inflation rates generally align well with the actual series until 1995, though some discrepancies are noticeable during the inflation spikes of the 60s, 70s, and 80s, where the counterfactual is not as accurate in capturing these extreme fluctuations. The corresponding inflation rate gaps and their confidence intervals are detailed in Figure 5.

Collectively, Figures 4 and 5 demonstrate that the inflation trajectories of nearly all EZ members begin to diverge significantly from their counterfactual paths shortly after the treatment. The point estimates for Spain, France, Greece, Italy, and Portugal are negative throughout the post-treatment, except for one year for France, revealing that the adoption of the Euro exerted significant and persistent deflationary pressure on these economies. In contrast, Belgium, Germany, Ireland, and the Netherlands experienced a significant and enduring inflationary effect from the Euro adoption. Despite these categorizations, there is notable heterogeneity in the dynamics and magnitude of these effects across countries.

Figure 4: Inflation Rate Dynamics.

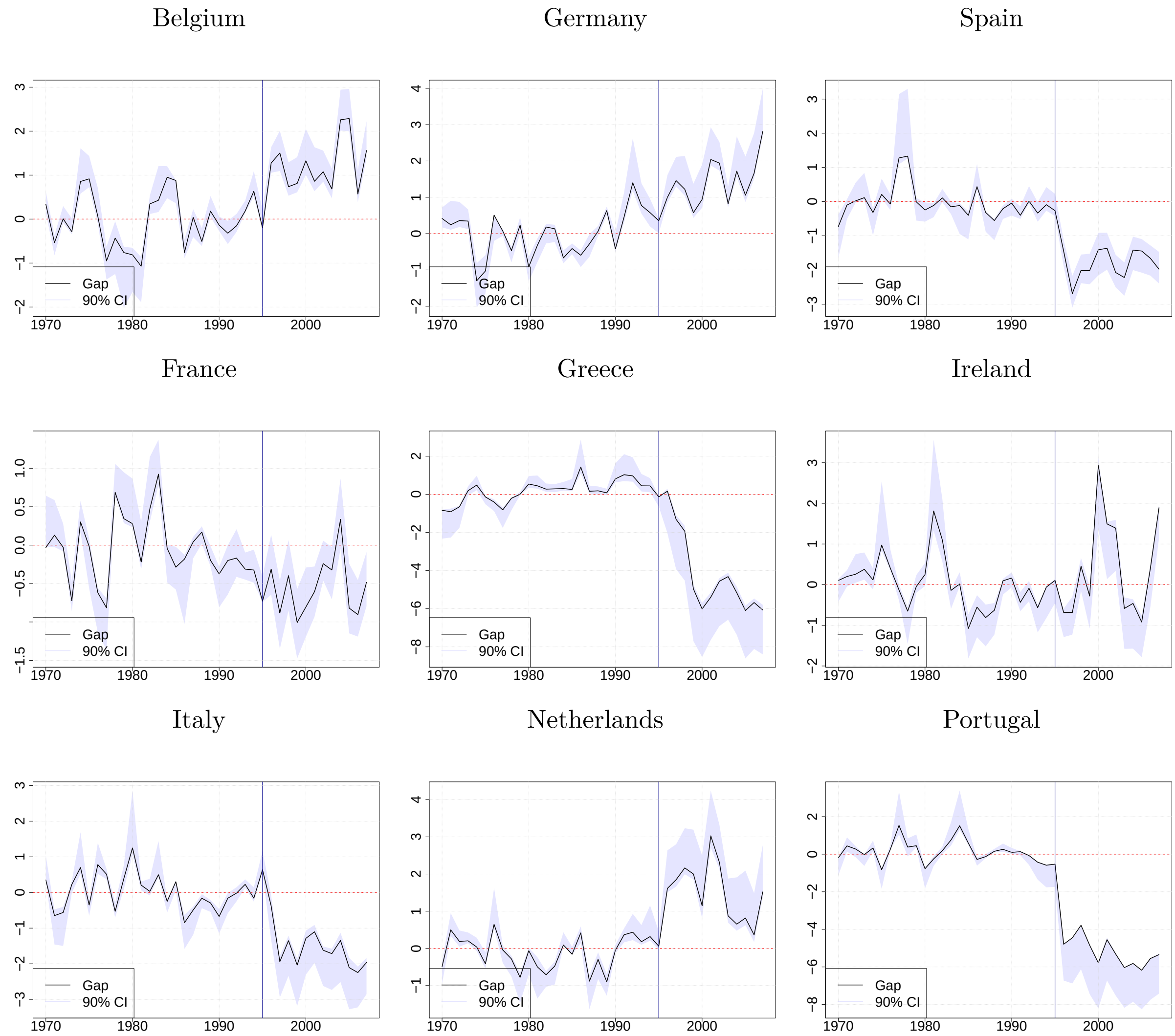


In each subplot, the (%) inflation rate counterfactual time series is represented by the blue dashed line, while the actual time series is depicted by the solid red line. The vertical line denotes 1995, the year preceding the treatment. The analysis covers the period from 1961 to 2007 for each country.

By the end of the post-treatment period, Greece exhibits the most substantial decline in inflation, with a decrease of approximately 6 percentage points, followed by Portugal, Spain, Italy, and France. Among the countries with an inflationary effect, Germany shows the largest long-term positive gap, with an increase of nearly 3 percentage points, followed by Ireland, Belgium, and the Netherlands.

Overall, the northern EZ members—Belgium, Germany, Ireland, and the Netherlands—experienced significant inflationary pressure following the adoption of the Euro. In contrast, the southern countries—Spain, France, Greece, Italy, and Portugal—faced substantial deflationary effects.

Figure 5: Inflation Rate Gaps Significance.



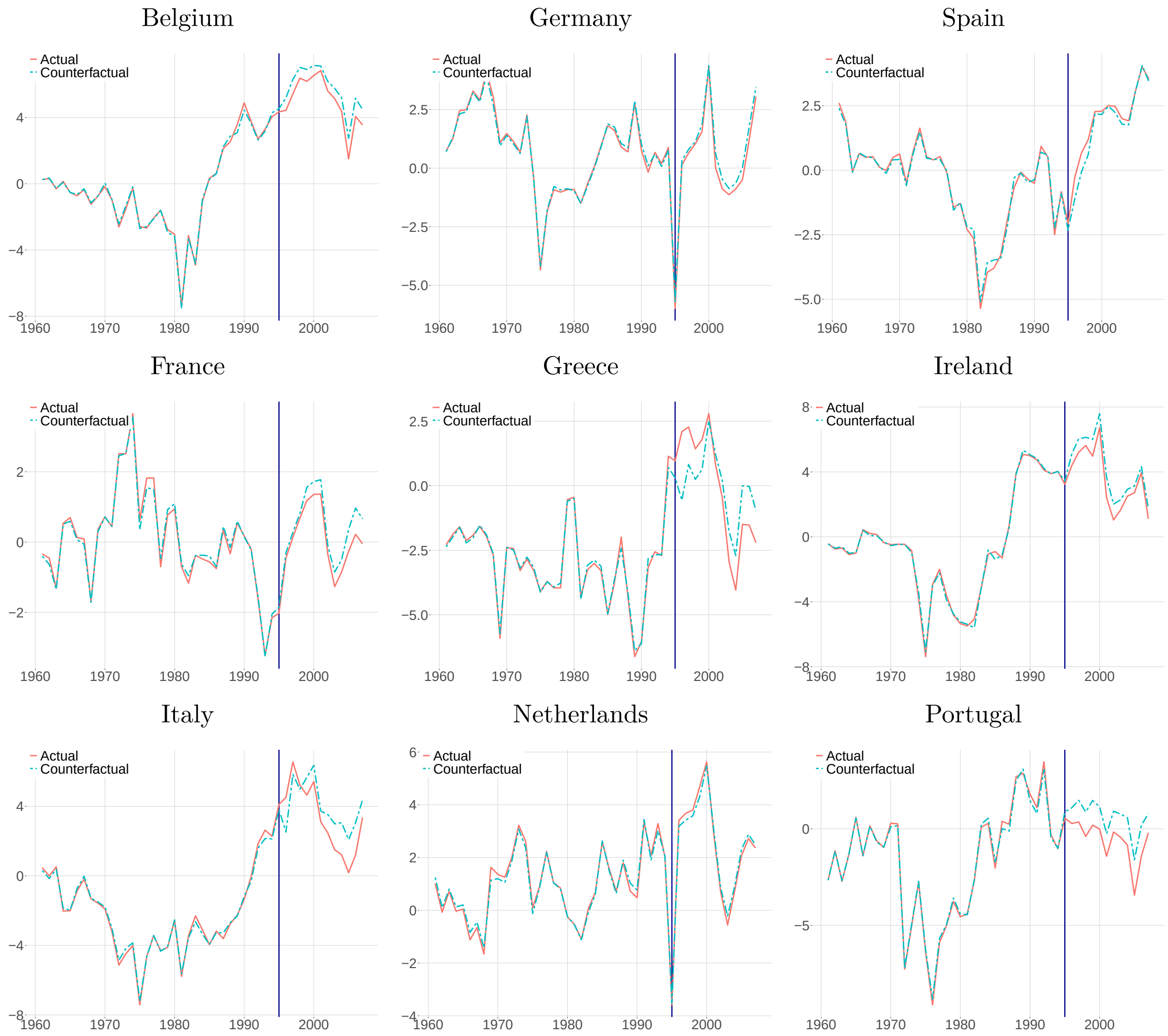
In each subplot, the solid black line illustrates the inflation rate gap, depicting the difference between the actual and counterfactual series. The light blue shaded area corresponds to the 90% confidence interval. The vertical line denotes 1995, the year before the treatment. The analysis spans from 1970 to 2007 for each country.

3.3 Primary Balance Dynamics

Covering the years 1961 to 2007, Figure 6 illustrates the observed primary balance (% of GDP) series for each EZ country (solid red line) alongside its estimated counterfactual (dashed blue line). The counterfactual primary balance of each EZ member closely tracks the actual series in the pretreatment period, as also evident from the pre-euro gaps depicted in Figure 7.

Figure 6 and Figure 7 show that the point-estimate in 2007 is negative for the large majority of EZ members, indicating that the Euro adoption led to higher (lower) primary deficits (surpluses), or deficits instead of surpluses in the long-term for several countries.

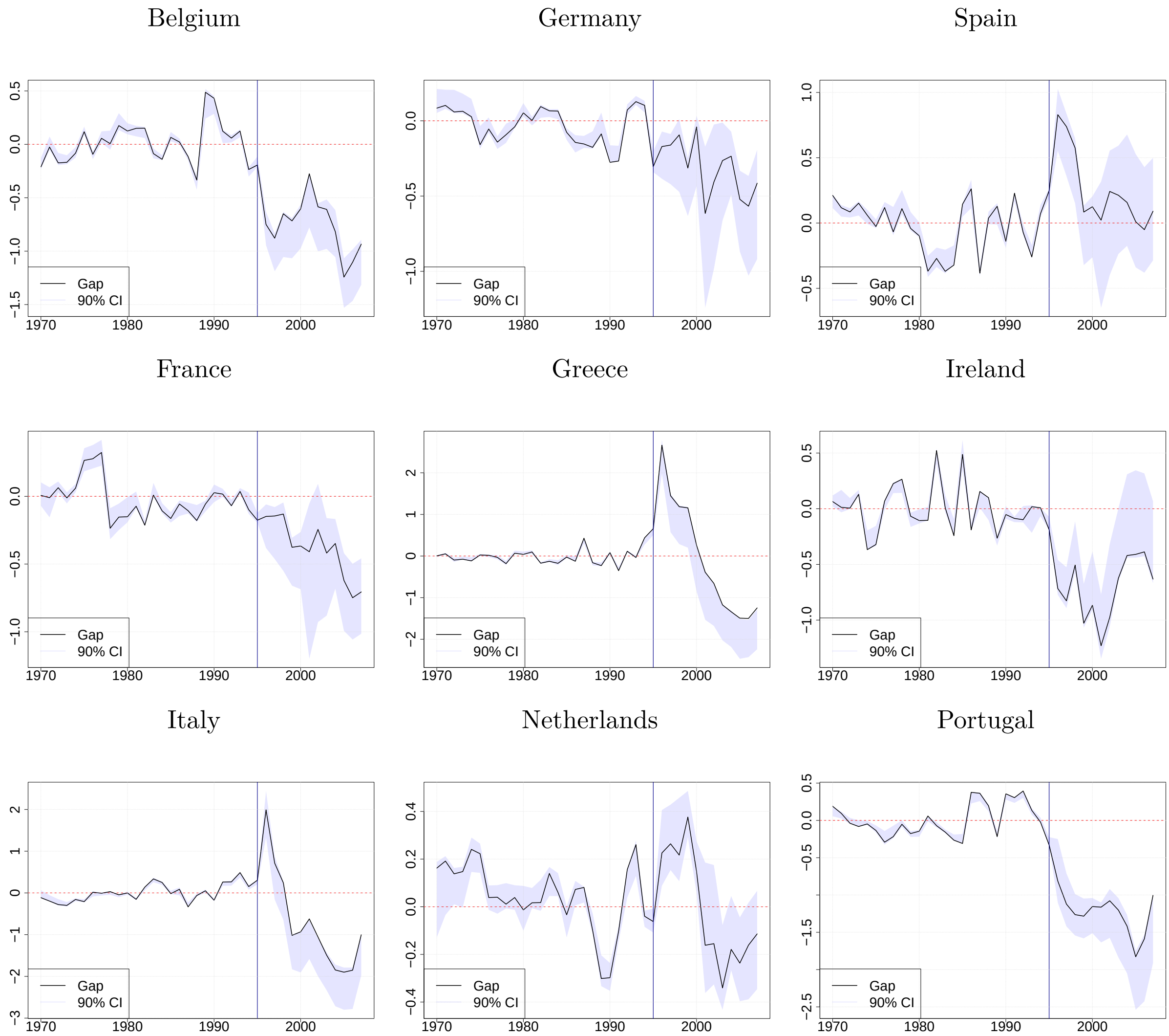
Figure 6: Primary Balance Dynamics.



In each subplot, the primary balance (% of GDP) counterfactual time series is represented by the blue dashed line, while the actual time series is depicted by the solid red line. The vertical line denotes 1995, the year preceding the treatment. The analysis covers the period from 1961 to 2007 for each country.

For the other members, the point estimate in 2007 cannot be distinguished from zero. In particular, although the long-term effect for Spain, Ireland, and the Netherlands is not statistically significant, the short-term impact is positive for both Spain and the Netherlands, with peak gaps of about 0.8 and 0.4 percentage points, respectively, and negative for Ireland, reaching a gap of about -1.2 percentage points in 2001. Further, there are notable heterogeneous dynamics also for countries displaying a long-term negative effect: Greece and Italy's series show a short-term positive impact on primary balances, with the largest gaps estimated at around 2.6 and 2 percentage points, respectively, implying that in the short-term they were even more fiscally disciplined (running larger surpluses than in the counterfactual) than they would have been if they had not joined the Euro.

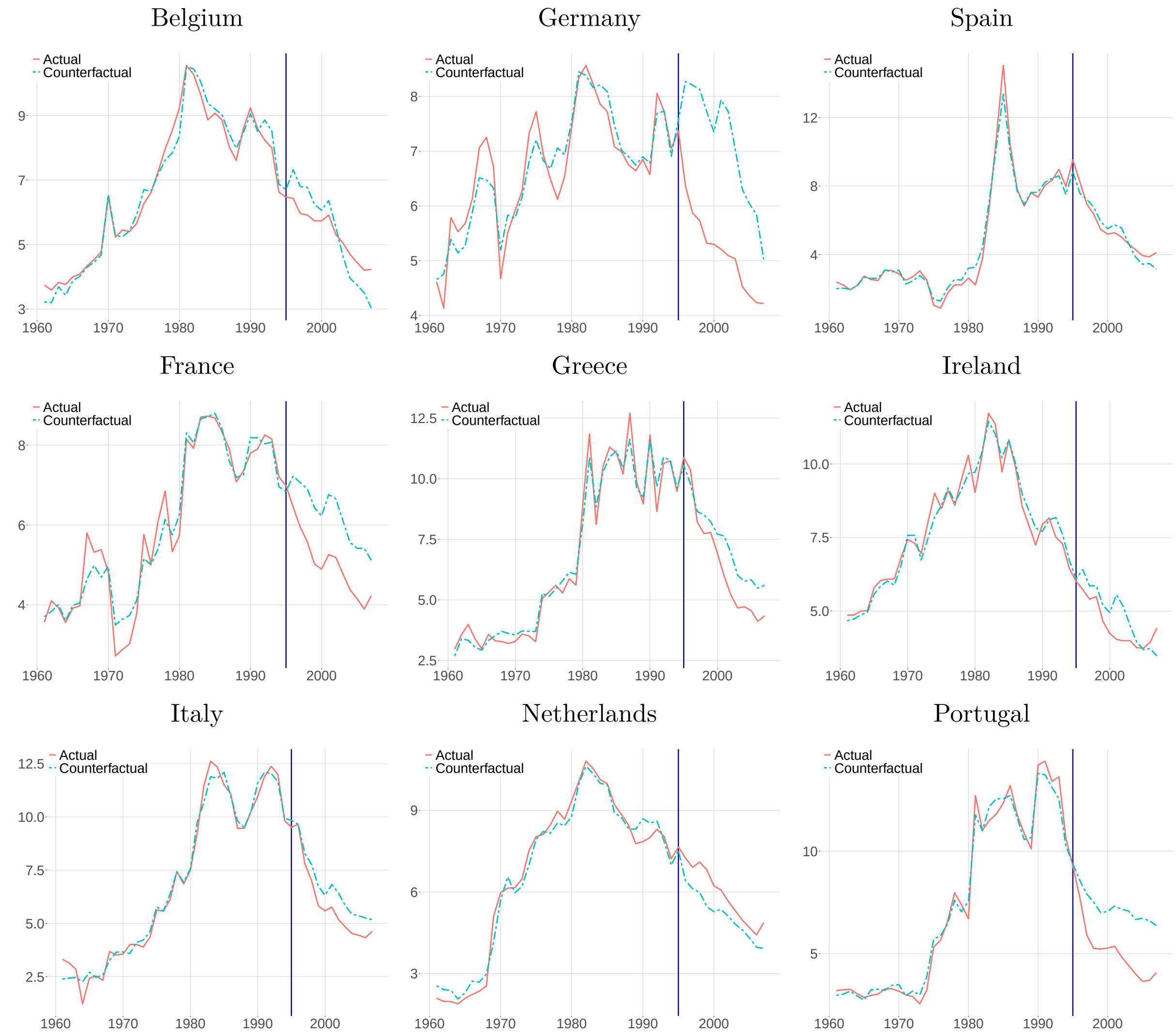
Figure 7: Primary Balance Gaps Significance.



In each subplot, the solid black line illustrates the primary balance gap, depicting the difference between the actual and counterfactual series. The light blue shaded area corresponds to the 90% confidence interval. The vertical line denotes 1995, the year before the treatment. The analysis spans from 1970 to 2007 for each country.

Nevertheless, the gap series of both members switched to just negative later, in 1999 for Italy and 2001 for Greece. At the end of the post-treatment period, the estimated negative gap for Greece is the largest in absolute terms, followed by Portugal, Italy, Belgium, France, and Germany.

Figure 8: Nominal Interest Rate Dynamics.



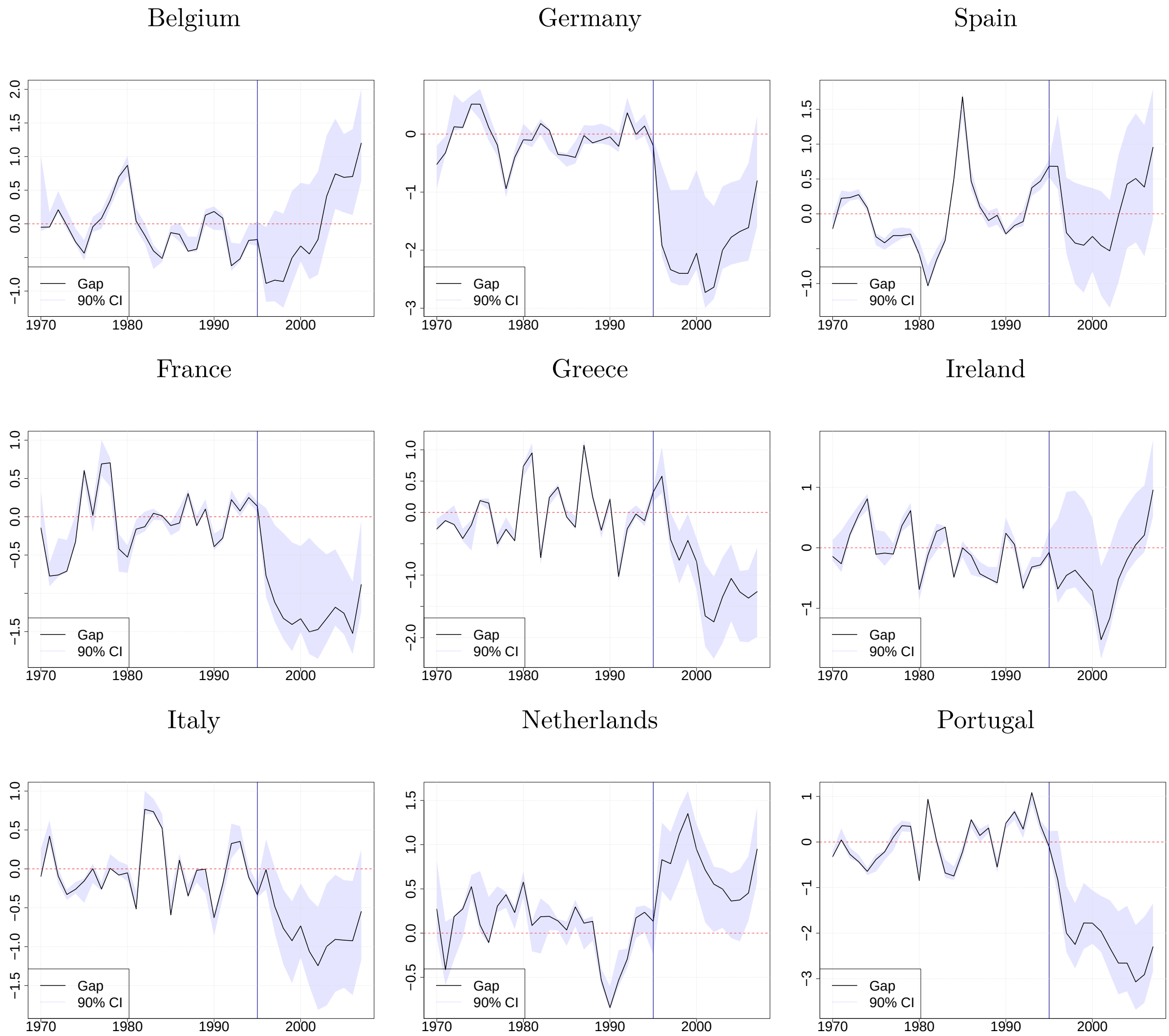
In each subplot, the (%) nominal interest rate counterfactual time series is represented by the blue dashed line, while the actual time series is depicted by the solid red line. The vertical line denotes 1995, the year preceding the treatment. The analysis covers the period from 1961 to 2007 for each country.

3.4 Nominal Interest Rate Dynamics

Figure 8 shows the (average) nominal interest rate on public debt for each EZ country (solid red line) alongside its estimated counterfactual (dashed blue line) for the years between 1961 and 2007, with the pre-Euro and post-Euro gaps depicted in Figure 9.

Figure 8 and Figure 9 show heterogeneity across countries in the point estimates for both short-term and long-term horizons. For the core economies Germany, France, and Italy, as well as the peripheral countries Greece, Ireland, and Portugal, the initial effect is negative, indicating that the Euro adoption significantly reduced the nominal financing cost of debt for most EZ members in the short to medium term. For France,

Figure 9: Nominal Interest Rate Gaps Significance.



In each subplot, the solid black line illustrates the nominal interest rate gap, depicting the difference between the actual and counterfactual series. The light blue shaded area corresponds to the 90% confidence interval. The vertical line denotes 1995, the year before the treatment. The analysis spans from 1970 to 2007 for each country.

Greece, and Portugal, the long-term effect on their debt's nominal interest rate remains significantly negative. For Germany and Italy, the effect diminishes around the end of the post-treatment, while it even reverses for Ireland. With respect to the other members, the adoption of the Euro led to an increase in the nominal financing cost of debt for both Belgium and the Netherlands, whereas for Spain, the medium to long-term impact is largely insignificant. An interesting observation is that Germany experienced the second-largest drop in the nominal interest rate following Euro adoption, with a gap of about −2.7 percentage points. For comparison, the other two core economies, France and Italy, experienced a drop of about −1.5 and −1.2 percentage points, respectively. Only Portugal had a more negative point estimate, with a decrease in the nominal interest rate of about 3 percentage points.

3.5 Identification

Generally, making causal claims when using TSCS data warrants caution. To address this, we implement the identification diagnostic tools suggested by Liu et al. (2024). Specifically, we conduct a test in which, as explained by the authors, some periods of observations just before the treatment begins are left out for the treated units. The remaining untreated observations are used to estimate the untreated outcomes for those left-out periods. The idea is that if the identifying assumptions hold, the average differences between the observed and estimated outcomes in these periods should be near zero. Liu et al. (2024) refer to this inspection as a placebo test, as we calculate an artificial treatment effect by removing observations in the specified range for model fitting and then test whether the estimated artificial effect in this range is significantly different from zero.

More formally, we let the treatment start $S = 3$ periods earlier than the defined onset for each EZ member and apply the matrix completion estimator to obtain estimates of the average treatment effects on the treated (ATT) at s periods from the treatment's onset, i.e. for $s = -(S-1), \ldots, -1, 0$. If the identifying assumptions hold, we should expect the magnitude of these artificial ATT estimates to be close to zero. In Table 1 we report the results of the placebo tests for the four debt drivers, showing the p-values for the tests against the null hypothesis of no difference. As seen in Table 1, the large p-values for all the placebo tests indicate that we cannot reject the null of no-differences for any of the debt drivers already at the 10% level.

Additionally, we implement Liu et al. (2024)'s no pretrend test. As the authors explain, the latter is an extended version of the placebo test. The idea behind this extension addresses the concern that if a potential time-varying confounder is cyclical or does not appear immediately before the treatment's onset, the placebo test may fail to detect it. Thus, Liu et al. (2024) propose a more global test to check for the absence of a pretrend. In particular, an approach suggested by the authors is to jointly test a set of null hypotheses that the average of residuals for any pretreatment period is zero, that is, $ATT_s = 0$ for all $s \leq 0$ using a goodness-of-fit test (a variant of the F test). In Table 1 we report the results of the pretrend tests for the four debt drivers, showing the p-values for the tests against the null hypothesis of no difference. The large p-values for all the pre-trend F-tests show that we cannot reject the null of no pretreatment differential trends for any of the debt drivers already at the 10% level.

Table 1: Placebo and Pretrend tests for the debt drivers.

Debt Driver	Placebo p-value	Pretrend p-value
Real GDP	0.580	0.898
Inflation Rate	0.394	0.807
Primary Balance	0.128	0.868
Nominal Interest Rate	0.624	0.794

For each debt driver, the table reports the p-values of the placebo and pretrend tests. For all debt drivers, we cannot reject the null for both the placebo and pretrend tests already at the 10% level.

4 Debt Counterfactual and Decomposition

With the estimated counterfactual series for the four analyzed debt drivers, we can now generate the counterfactual public debt time series via the government budget constraint. To assess the impact of joining the currency union on the evolution of sovereign debt, we will compare the actual time series of the government debt-to-GDP ratio for each examined EZ member with the simulated counterfactual series. Further, we will decompose each country's debt dynamics to quantify each debt driver's contribution to the difference between actual and counterfactual paths of public debt.

4.1 Counterfactual Debt Dynamics

For a given country j at time t, let the counterfactual real GDP growth rate be $\hat{g}_{j,t}$, the counterfactual inflation rate be $\hat{\pi}_{j,t}$, the counterfactual (average) nominal interest rate on debt be $\hat{i}_{j,t}$, and the counterfactual primary balance be $\hat{p}_{j,t}$. Then, for each EZ member j and year $t = T_0 + 1, \ldots, T$, we generate the counterfactual debt series $\hat{d}_{j,t}$ for the post-treatment period using

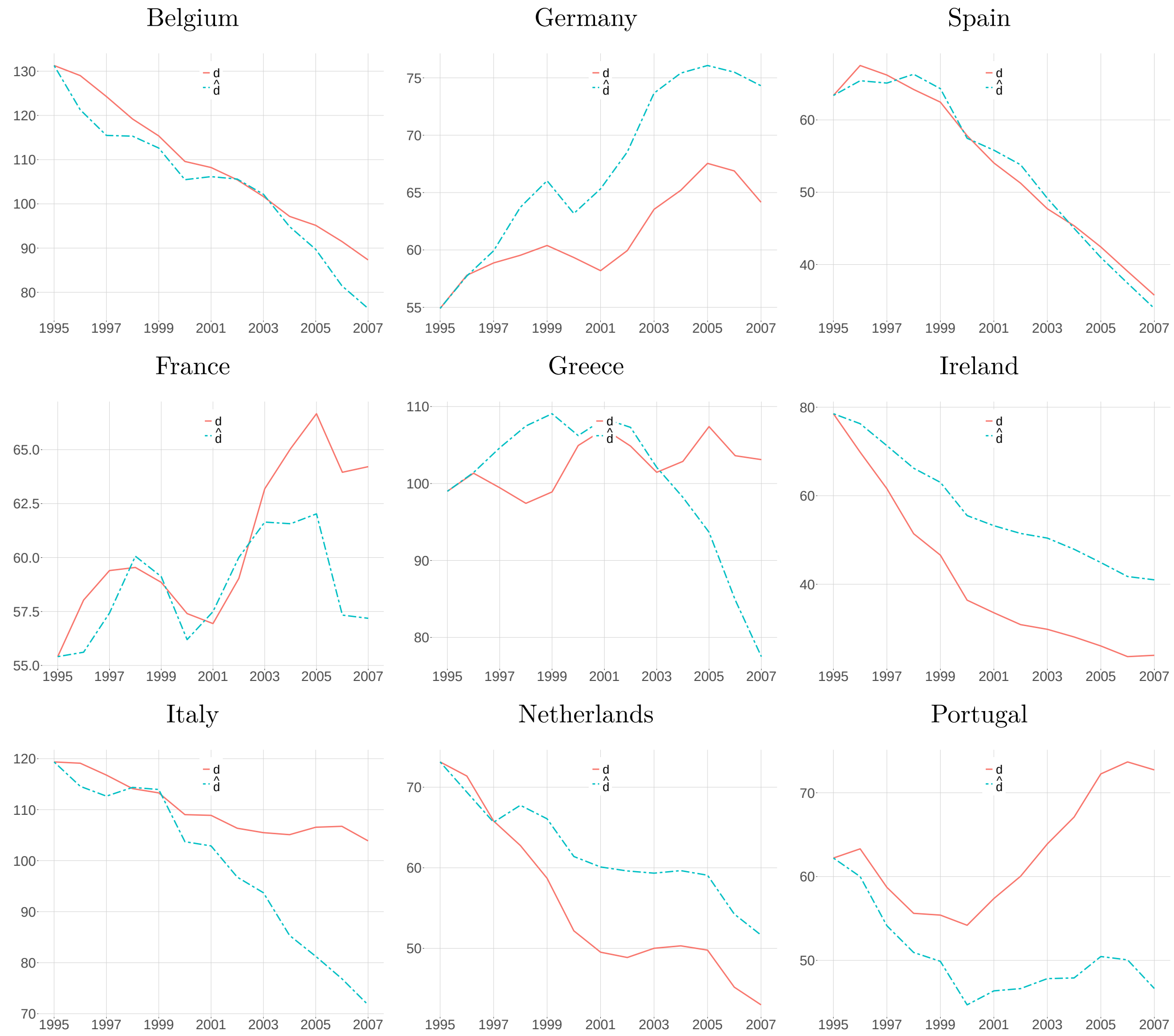
$$\hat{d}_{j,t} = \frac{1 + \hat{i}_{j,t}}{(1 + \hat{\pi}_{j,t})\,(1 + \hat{g}_{j,t})}\hat{d}_{j,t-1} + \hat{p}_{j,t} + sf_{j,t},$$

where recollect that $sf_{j,t}$ represents the term for the actual stock-flow reconcilation series.

Figure 10 illustrates the observed debt-to-GDP ratio series for each EZ country (solid red line) alongside the generated counterfactual (dashed blue line) from 1995, for which year the two series will start at the same level by construction, to 2007.

Overall, joining the single currency led to a significant reduction in the public debt to GDP of three northern members, a relatively moderate increase for one peripherical southern country, and a substantial expansion in the debt to GDP of four southern members and one northern country. Further, the dynamics of countries' debt-to-GDP ratio

Figure 10: Actual and Counterfactual debt dynamics for each country.



In each subplot, the (%) debt-to-GDP ratio counterfactual time series is represented by the dashed blue line, while the actual time series is depicted by the solid red line. The starting year for both lines is 1995, the year preceding the treatment. The analysis covers the period from 1995 to 2007 for each country.

gap underscores large heterogeneity in the materialization of the effect. In particular, for Germany, Ireland, and the Netherlands, starting early in the post-treatment, the observed debt-to-GDP ratio consistently falls below the counterfactual series, with the divergence growing more pronounced towards the end of the post-treatment. As reported in Table 2, by 2007, the negative gap becomes substantial for all countries, with the observed debt-to-GDP ratio being lower than the counterfactual one by approximately 17 percentage points for Ireland, 10 and 9 percentage points for Germany and the Netherlands, respectively. Adopting the Euro put some downward pressure on Spain's public debt-to-GDP ratio early on. However, the actual debt to GDP overtook the counterfactual one from 2004 onward and ended at about a 2 percentage points higher level, indicating that the

Table 2: Cumulative Debt Gaps.

BEL	DEU	ESP	FRA	GRC	IRL	ITA	NLD	PRT	WEZ
+10.97	-10.15	+1.83	+7.03	+25.59	-17.05	+32.15	-8.66	+26.08	+5.52

This table reports, in percentage points, the difference between actual and counterfactual debt in 2007 for each country and the EZ as a whole.

initial debt-decreasing effect did not prove long-lasting. Finally, coming to the countries experiencing a debt increase from the introduction of the Euro, Belgium, France, and Greece's counterfactual debt-to-GDP ratios started being consistently and substantially below their actual series only after 2003—which is due to the counteracting impact of different debt drivers, as we will see in the next section—while marked and enduring effects for Italy and Portugal materialized already starting in 2000. Notably, Greece's public debt experienced downward pressure shortly after treatment, with the largest negative gap at about -10 percentage points, making the substantial positive cumulative effect even more remarkable. As seen in Table 2, in 2007, the observed debt-to-GDP ratio is higher than the counterfactual one by a staggering 32 percentage points for Italy, approximately 26 percentage points for Portugal, 25 percentage points for Greece, 11 percentage points for Belgium, and about 7 percentage points for France. Finally, when aggregating the EZ countries according to their real GDP weight, we find that the union as a whole experienced an increase in the debt-to-GDP ratio of roughly 6 percentage points.

4.2 Debt Dynamics Decomposition

To more comprehensively understand the effect of adopting the single currency on the evolution of public debt, we decompose each country's debt dynamics to single out the contribution of each debt driver. Specifically, for each examined EZ member j and year $t = T_0 + 1, \ldots, T$, we generate the time series of the debt-to-GDP ratio for four different counterfactual scenarios using the debt law of motion. First, let $\hat{d}^{\pi}_{j,t}$ be the debt-to-GDP ratio inflation-counterfactual time series: the series for which only the inflation rate is set to counterfactual compared to the actual debt-to-GDP series, such that for the other three drivers their actual time series are used. Then,

$$\hat{d}^{\pi}_{j,t} = \frac{1 + i_{j,t}}{(1 + \hat{\pi}_{j,t})\,(1 + g_{j,t})} \hat{d}^{\pi}_{j,t-1} + p_{j,t} + sf_{j,t}.$$

Second, let $\hat{d}^{g}_{j,t}$ be the debt-to-GDP ratio GDP-growth-counterfactual time series: the series for which only the real GDP growth rate is set to counterfactual compared to the actual debt-to-GDP series. Then,

$$\hat{d}^{g}_{j,t} = \frac{1 + i_{j,t}}{(1 + \pi_{j,t})(1 + \hat{g}_{j,t})} \hat{d}^{g}_{j,t-1} + p_{j,t} + sf_{j,t}.$$

Third, let $\hat{d}^{p}_{j,t}$ be the debt-to-GDP ratio primary-balance-counterfactual time series: the series for which only the primary balance is set to counterfactual compared to the actual debt-to-GDP series. Then,

$$\hat{d}^{p}_{j,t} = \frac{1 + i_{j,t}}{(1 + \pi_{j,t})(1 + g_{j,t})} \hat{d}^{p}_{j,t-1} + \hat{p}_{j,t} + sf_{j,t}.$$

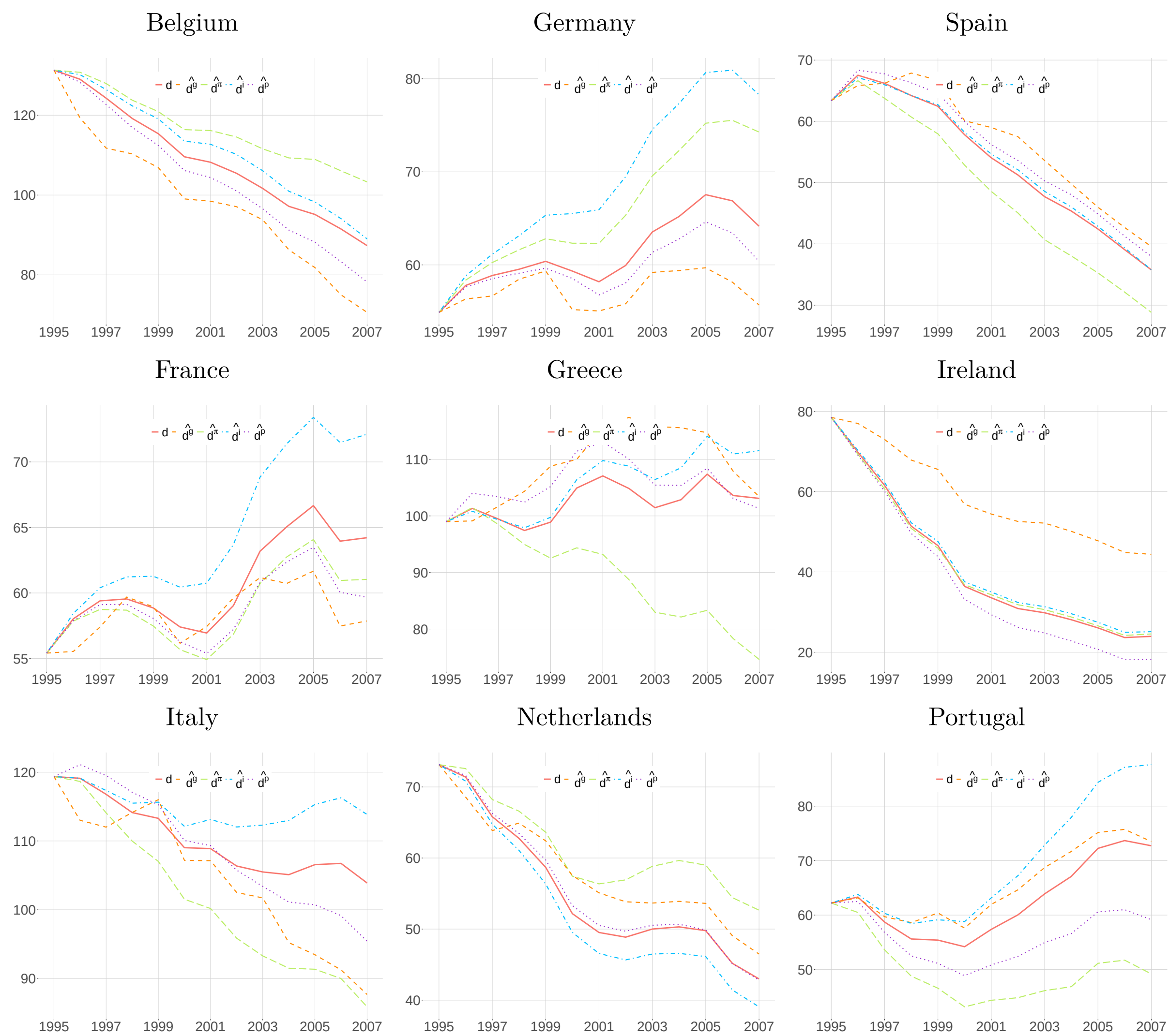
Fourth, let $\hat{d}^{i}_{j,t}$ be the debt-to-GDP ratio interest-rate-counterfactual time series: the series for which only the nominal interest rate is set to counterfactual compared to the actual debt-to-GDP series. Then,

$$\hat{d}^{i}_{j,t} = \frac{1 + \hat{i}_{j,t}}{(1 + \pi_{j,t})(1 + g_{j,t})} \hat{d}^{i}_{j,t-1} + p_{j,t} + sf_{j,t}.$$

Figure 11 illustrates the observed debt-to-GDP ratio series for each EZ country $d_{j,t}$ (solid red line) alongside the four debt-to-GDP counterfactuals: $\hat{d}^{\pi}_{j,t}$ (long-dashed green line), $\hat{d}^{g}_{j,t}$ (short-dashed orange line), $\hat{d}^{p}_{j,t}$ (dotted purple line), and $\hat{d}^{i}_{j,t}$ (dot-dashed blue line). As before, the analysis spans from 1995 to 2007. The difference $d_{j,t} - \hat{d}^{x}_{j,t}$ quantifies the effect of adopting the Euro on country j's debt dynamics exclusively via the x channel. In Figure 12, we report the cumulative quantitative contribution of each debt driver to the difference between actual and counterfactual debt in 2007 for each EZ country and the 2007-GDP weighted average of the considered EZ countries.

Following Figure 11, we discuss each country in order. Belgium's debt to GDP dynamics are, both in the short-term and long-term, rationalized by the dominance of the debt-increasing real GDP growth rate and primary balance channels over the debt-decreasing inflation rate and nominal interest rate channels, leading to a positive debt-to-GDP ratio gap almost throughout the considered timespan. The opposing cumulative impacts of the inflation and real GDP growth rates, the most sizable channels, nearly cancel each other out, leaving the primary balance channel to explain the rise in debt to GDP, as it can also be appreciated in Figure 12. For Germany, the two most relevant debt drivers are the nominal interest rate and inflation rate channels throughout the post-treatment period, consistently pushing the effect of the Euro accession in one direction: a decrease in government debt. Although the other two debt drivers work in the opposite direction, they

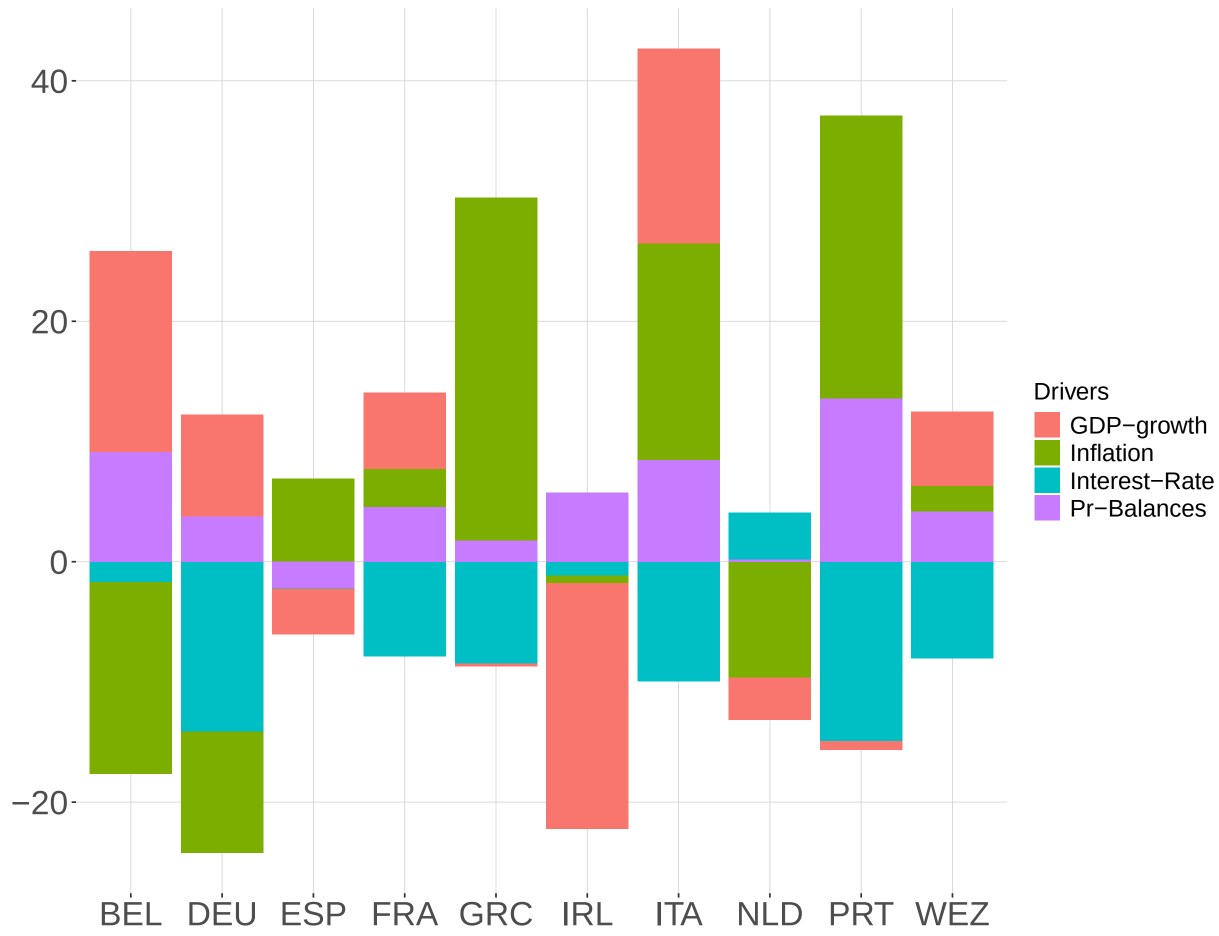
Figure 11: The debt drivers' contributions to each country's debt dynamics.



In each subplot, we illustrate the time series of the (%) debt-to-GDP ratio using various counterfactual scenarios. The solid red line represents the actual debt-to-GDP ratio over time. The long-dashed green line displays the debt-to-GDP ratio inflation-counterfactual time series, where only the inflation rate is set to counterfactual compared to the actual debt-to-GDP series, thus using for the other three factors their respective actual time series. Similarly, the short-dashed orange line shows the debt-to-GDP ratio GDP-growth-counterfactual time series, setting to counterfactual only the real GDP growth rate. The dotted purple line depicts the debt-to-GDP ratio primary-balance-counterfactual time series, modifying to counterfactual solely the primary balance. Lastly, the dot-dashed blue line exhibits the debt-to-GDP ratio interest-rate-counterfactual time series, changing to counterfactual only the nominal interest rate. All lines commence in 1995, the year before the treatment, and extend until 2007.

are not large enough to even match the debt-decreasing effect of the nominal interest rate, the most salient channel in understanding Germany's debt dynamics as seen in Figure 12. For Spain, the most relevant debt driver is the inflation rate, with the opposing real GDP growth rate following second in importance. The latter and the primary balance channel work opposite to the debt-increasing effect of the inflation channel but are not sufficiently large throughout the post-treatment to prevent a positive debt-to-GDP ratio gap in 2007, as shown in Figure 12. France's debt dynamics highlight the nominal interest rate as the most salient debt driver. However, the other three channels are all sizable and work against it, rationalizing a debt-increasing effect of the Euro adoption. Greece's inflation channel is the most significant overall, ultimately defining a large debt-increasing effect of joining the EZ. Nevertheless, as the real GDP growth rate and the primary balance channels, the latter initially supporting the former significantly, dominate in the first years, the Euro adoption has a short-term debt-decreasing effect. However, the latter is transient. The debt-decreasing impact of the nominal interest rate grows over the years, but cannot match the inflation channel, which induces a large cumulative debt-increasing effect as seen in Figure 12. Ireland is a one-channel story: the real GDP growth rate drives the large debt-decreasing effect of adopting the Euro. Figure 12 shows that Ireland is the only country for which the real GDP growth rate channel is at least three times as large, in absolute value, compared to the second most relevant debt driver. The short-term trajectory of Italy's public debt dynamics can be explained by the influence of the primary balance channel, followed by the nominal interest rate channel, working toward a potential debt-decreasing effect, which, however, is nullified by the opposing real GDP growth rate channel first and the inflation rate channel later. In the long-term, while the nominal interest rate channel exerts a substantial downward force on debt dynamics, the inflation channel becomes the predominant driver, exerting upward pressure on debt. The cumulative effect of the real GDP growth rate channel contributes substantially to a debt increase, and to a lesser extent, the primary balance channel also plays a significant role, as can be seen in Figure 12. Consequently, the impact of Italy's Euro adoption on its debt is a substantial and persistent increase, with inflation being the primary factor driving this surge. The Netherlands' debt-to-GDP ratio dynamics feature the inflation channel as the most dominant mechanism throughout the post-treatment. Although the debt-increasing nominal interest rate mechanism grows in relevance over time, Figures 11 and 12 show that the real GDP growth rate channel dominates it in the short term and is almost as substantial in the long term, leaving the inflation channel to rationalize the cumulative debt-decreasing impact of joining the EZ. For Portugal, three of the debt drivers are capable of inducing substantial debt variation. Figure 12 shows that the inflation channel holds the primary position among debt drivers, followed by the opposing nominal interest rate channel. Collectively, the inflation and primary balance effects jointly exceed the nominal interest rate and real GDP growth impacts throughout the timespan, resulting in a persistent and substantial increase in Portugal's public debt to GDP following the adoption of the Euro. Finally, we find that the EZ as a whole experienced an increase in the debt-to-GDP ratio despite the debt-decreasing nominal interest rate channel being the

Figure 12: Debt drivers' contributions to cumulative debt gaps.



Each bar illustrates the components' importance, in percentage points, in driving the cumulative debt gap for each country and the EZ as a whole. Each bar is divided into four segments: The red segment is the contribution of the real GDP growth rate channel, the green segment is the contribution of the inflation rate channel, the purple segment is the contribution of the primary balance channel, and the blue segment is the contribution of the nominal interest rate channel.

most salient driver at the aggregate level. The rise in the public debt to GDP following the adoption of the Euro can be attributed to the combined effects of inflation, real GDP growth, and primary balance channels, all exerting upward pressure on government debt at the aggregate level, as seen in Figure 12.

Altogether, the most salient drivers in understanding EZ countries' debt dynamics are the inflation rate and nominal interest rate channels. The inflation rate emerges as a significant driver, either reducing the debt-to-GDP ratio, as seen in Germany and the Netherlands, or increasing it, as observed in Spain, Greece, Italy, and Portugal. The nominal interest rate channel also plays a crucial role, particularly in Germany, where it significantly influences debt dynamics. Additionally, the real GDP growth rate is impactful, most notably in Ireland, exerting downward pressure on peripheral countries' debt. As these findings highlight the dominant influence of inflation and nominal interest rates on public debt to GDP dynamics, the next section extends the analysis by combining these two debt drivers. We will then assess the debt dynamics of EZ members through the lens of the real interest rate and relate its impact to the intrinsically linked fiscal burden of converting long-term national-currency debt into Euro debt.

4.3 Real Interest Rate and Legacy Debt

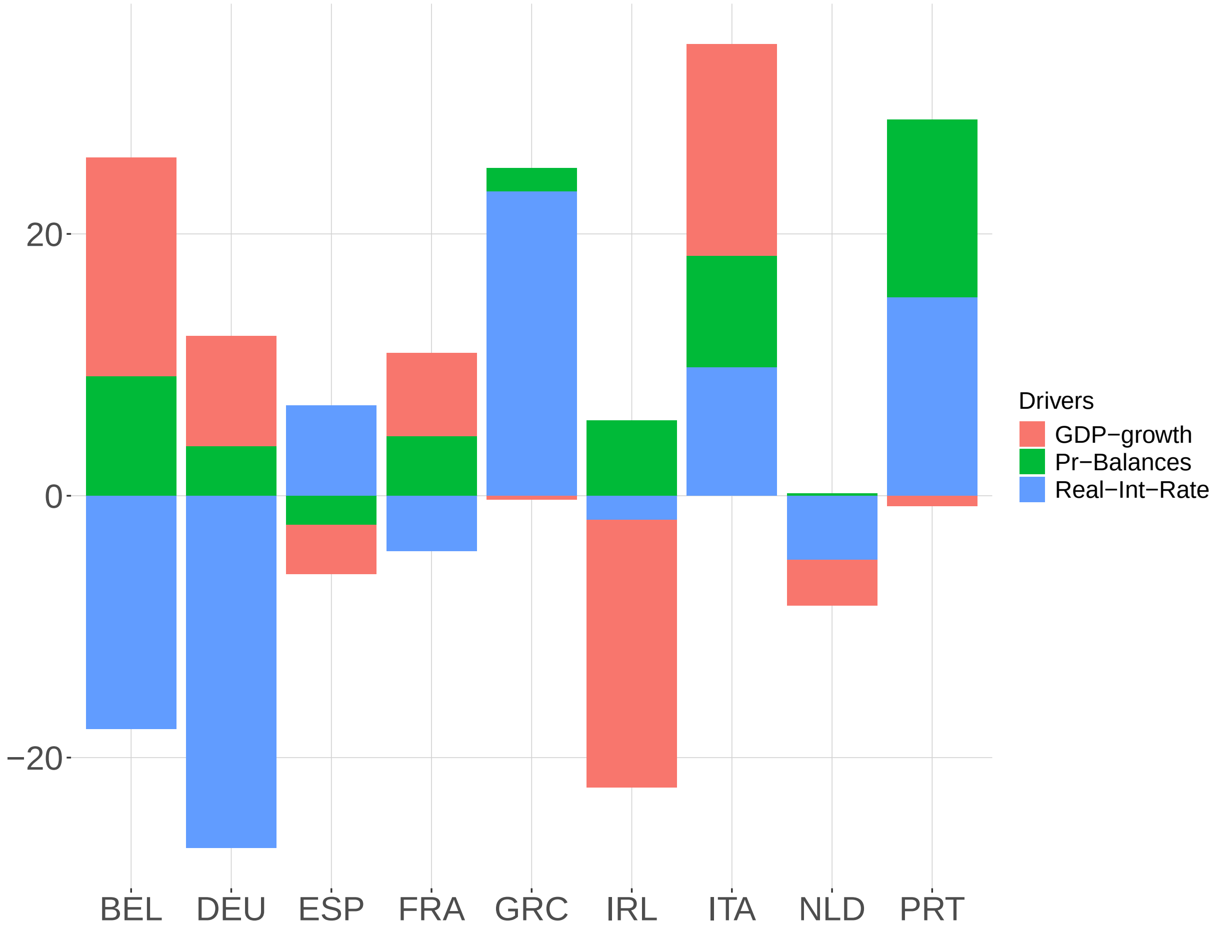
Since a change in expected inflation of a given magnitude requires a similar-sized shift in the nominal interest rate for the real interest rate to stay the same, one might expect the inflation and nominal interest contributions to government debt to largely cancel each other out in our decomposition. However, this is not the case: there are two notable exceptions. First, for Germany and, to a lesser extent, Belgium, the cumulative impact of both channels is to reduce the debt-to-GDP ratio. Second, for Greece, Portugal, and Italy, the nominal interest rate channel contributes to reducing debt but is not large enough to counteract the strong debt-increasing deflationary effect. To further understand these outcomes, when constructing the decomposition of the debt-to-GDP dynamics, we now combine the inflation and nominal-rate channels into a single channel, the real interest rate channel. Figure 13 displays the quantitative importance of this combined channel compared to the real GDP growth and primary balance channels. The real interest rate channel has a salient debt-reducing cumulative impact in the first set of countries (Germany and Belgium) and a debt-increasing cumulative impact in the second group (Greece, Portugal, and Italy).

Then, why could nominal interest payments net of inflation be lower (higher) in countries like Germany (Italy) due to adopting the Euro? One reason could be that some of the debt on which interest is paid was issued when Euro adoption (or at least its timing) was not (anticipated as) certain. We refer to this portion of the debt as "legacy debt". To quantify the implications of this debt portion, we define the legacy debt effect for country j as

$$-d_{j,T_0} \times m_{j,T_0} \times \frac{\sum_{i=1}^{\lfloor m_{j,T_0} \rceil} (\pi_{j,T_0+i} - \hat{\pi}_{j,T_0+i})}{\lfloor m_{j,T_0} \rceil}, \tag{3}$$

where d is the end-of-period debt-to-GDP ratio, T_0 is the year before the treatment year, m is the average maturity of debt, π is the observed inflation rate and $\hat{\pi}$ the counterfactual one. Using this metric based on inflation gaps, we quantify the impact on the debt-to-GDP ratio that one would expect from the legacy debt channel on theoretical grounds: The product of the debt-to-GDP ratio and average debt maturity, both measured before

Figure 13: Debt drivers' contributions to cumulative debt gaps.

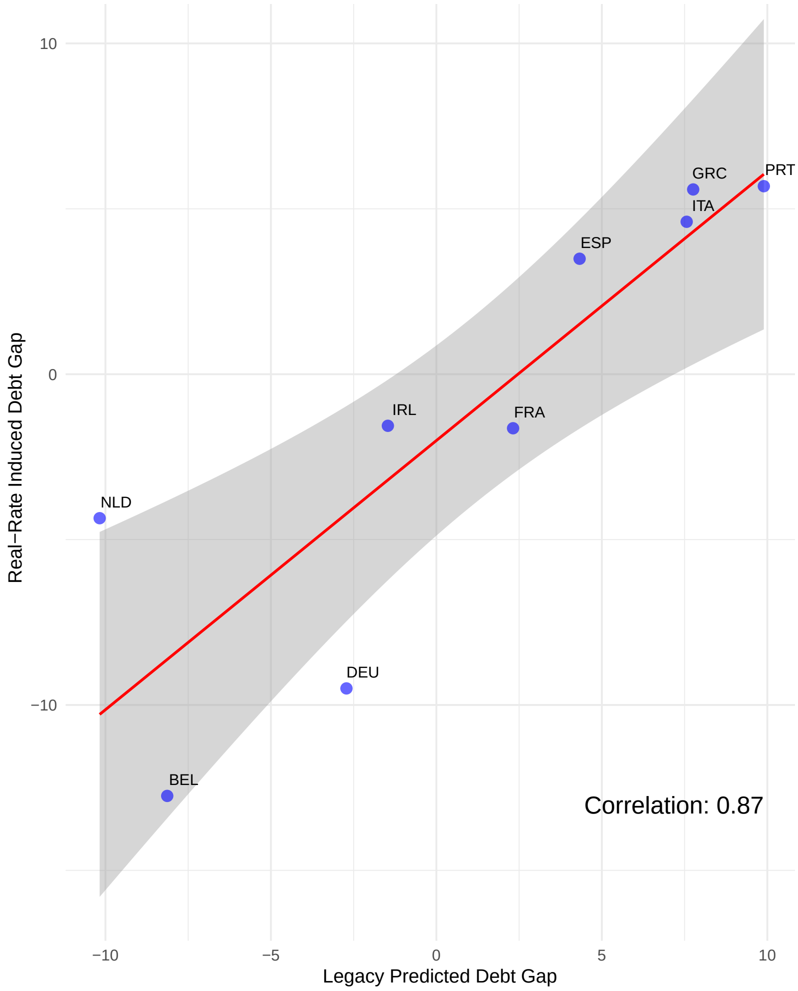


Each bar illustrates the components' importance, in pp, in driving the cumulative debt gap for each country. Each bar is divided into three segments: The red segment is the contribution of the real GDP growth rate channel, the green segment is the contribution of the primary balance rate channel, and the blue segment is the contribution of the real interest rate channel.

treatment, multiplied by the average inflation gap over the time horizon given by the debt's average maturity. In Figure 14, we plot for each EZ member the impact of the legacy debt mechanism against the time-horizon-corresponding real-rate induced debt gap, which is the difference at time $T_0 + \lfloor m_{j,T_0} \rceil$ between the actual debt-to-GDP ratio and the debt-to-GDP ratio real-rate-counterfactual, i.e. $d_{j,T_0+\lfloor m_{j,T_0} \rceil} - \hat{d}^{rr}_{j,T_0+\lfloor m_{j,T_0} \rceil}$. The correlation is 0.87, and the slope of the regression line is 0.81, indicating that the legacy-debt channel significantly explains the real-rate channel, which in turn accounts for a large part of the Euro adoption's impact on debt-to-GDP ratios, as seen in Figure 13.

However, the legacy-debt channel does not fully explain the real-rate channel, particularly for Germany. It is likely that adopting the Euro had a direct impact on the real interest rate, especially pronounced for the largest economy in the monetary union, which

Figure 14: The real rate induced debt gap vis-á-vis the legacy debt mechanism.



This plot relates the real interest rate contribution to the difference between actual and counterfactual debt and the change in debt attributable to the legacy-debt mechanism. In particular, on the x-axis the legacy effect for country j is computed as in (3), and on the y-axis the difference at time $T_0 + \lfloor m_{j,T_0} \rceil$ between the actual debt-to-GDP ratio and the debt-to-GDP ratio real-rate-counterfactual is reported.

also had a reputation for frugal fiscal and monetary policy. Germany seems to have benefited from issuing debt in Euros, likely making German government debt more attractive to investors from other EZ countries. Future research should explore this channel further.

Finally, our findings on the relevance of legacy debt can be linked to and further understood through the complementary results of Equiza-Goñi (2016) on the significance of debt maturity for optimal debt management. This study investigates how the maturity structure of government debt influences the dynamics of sovereign debt-to-GDP ratios in six Euro Area countries (Belgium, Finland, France, Germany, Italy, and Spain). Notably, Equiza-Goñi (2016) conducts a counterfactual simulation altering the timing of public debt maturity extensions in Italy and Spain during the 1990s. The study reveals that if Spain had maintained the longer maturity structure from the end of 1998 during the period 1995-1998, its debt-to-GDP ratio would have been significantly higher. Similarly, Equiza-Goñi (2016) finds that postponing Italy's debt maturity extension from 1994 to 1998 would have resulted in smaller capital gains for debt holders, thereby reducing Italy's debt-to-GDP ratio.

5 Conclusion

In this paper, we set out to quantify the impact of adopting the Euro on the sovereign debt-to-GDP ratios of nine early adopters. By employing a novel counterfactual estimation approach, we examine the evolution of key debt drivers—real GDP growth, inflation, nominal interest rates, and primary balances—and assess their contributions to the changes in public debt.

Our findings reveal significant heterogeneity in the effects of Euro adoption on public debt-to-GDP ratios across the examined countries. For three of the four northern EZ members—Germany, Ireland, and the Netherlands—the adoption of the Euro resulted in a substantial reduction in debt-to-GDP ratios, driven primarily by favorable inflation and nominal interest rate dynamics, as well as robust GDP growth in the case of Ireland. In contrast, one northern member and all the southern countries—Belgium, Spain, France, Greece, Italy, and Portugal—experienced increases in debt ratios, largely driven by intense disinflationary pressures not sufficiently offset by lower nominal rates, along with adverse or not favorable enough GDP growth. In addition, our aggregate analysis reveals that the EZ as a whole experienced an increase in government debt to GDP following the adoption of the Euro. This increase is attributed to the combined upward pressure from inflation, real GDP growth, and primary balance channels despite the salient debt-reducing impact of lower nominal interest rates. Our study highlights the crucial role of the inflation and nominal interest rate channels and how the combined real rate effect significantly contributed to the divergence in the sovereign debt-to-GDP ratios of northern and southern countries. We associate this result with the fiscal burden from legacy debt and provide evidence that it substantially explains the variation in debt to GDP induced by the real interest rate channel.

This paper underscores that a significant portion of the divergence in sovereign debt to GDP across EZ countries is a consequence of Euro adoption. This insight is critical when assessing today's debt ratios and serves as a cautionary note for countries considering joining a currency union or forming a new one. Addressing legacy debt and mitigating asymmetric impacts on debt drivers are essential for fostering convergence among member countries. Future research should further investigate the factors influencing real interest rate dynamics and their broader implications.

References

Abadie, Alberto (2021). "Using Synthetic Controls: Feasibility, Data Requirements, and Methodological Aspects". *Journal of Economic Literature 59* (2), 391–425.

Abadie, Alberto, Alexis Diamond, and Jens Hainmueller (2010). "Synthetic Control Methods for Comparative Case Studies: Estimating the Effect of California's Tobacco Control Program". *Journal of the American Statistical Association 105*, 493–505.

——— (2015). "Comparative Politics and the Synthetic Control Method". *American Journal of Political Science 59*, 495–510.

Abadie, Alberto and Javier Gardeazabal (2003). "The Economic Costs of Conflict: A Case Study of the Basque Country". *American Economic Review 93*, 113–132.

Abbas, S. M. Ali, Nazim Belhocine, Asmaa El-Ganainy, and Mark Horton (2011). "Historical Patterns and Dynamics of Public Debt—Evidence From a New Database". *IMF Economic Review 59*.

Arkhangelsky, Dmitry, Susan Athey, David A. Hirshberg, Guido W. Imbens, and Stefan Wager (2021). "Synthetic Difference-in-Differences". *American Economic Review 111* (12), 4088–4118.

Athey, Susan, Mohsen Bayati, Nikolay Doudchenko, Guido Imbens, and Khashayar Khosravi (2021). "Matrix Completion Methods for Causal Panel Data Models". *Journal of the American Statistical Association 116*, 1716–1730.

Bai, Jushan (2003). "Inferential Theory for Factor Models of Large Dimensions". *Econometrica 71*, 135–171.

Bai, Jushan and Serena Ng (2002). "Determining the Number of Factors in Approximate Factor Models". *Econometrica 70*, 191–221.

Ben-Michael, Eli, Avi Feller, and Jesse Rothstein (2021). "The Augmented Synthetic Control Method". *Journal of the American Statistical Association 116* (536), 1789–1803.

Born, Benjamin, Gernot J. Müller, Moritz Schularick, and Petr Sedlácek (2019). "The Costs of Economic Nationalism: Evidence from the Brexit Experiment". *The Economic Journal 129*, 2722–2744.

Candès, Emmanuel J. and Yaniv Plan (2010). "Matrix Completion With Noise". *Proceedings of the IEEE 98*, 925–936.

Candès, Emmanuel J. and Benjamin Recht (2009). "Exact Matrix Completion via Convex Optimization". *Foundations of Computational Mathematics 9*, 717.

Cerulli, G., S. Nenci, L. Salvatici, and A. Zinilli (2022). "Estimating the Effect of the EMU on Current Account Balances: A Synthetic Control Approach". *European Journal of Political Economy 8*, 373–407.

Doudchenko, Nikolay and Guido W. Imbens (2016). "Balancing, Regression, Difference-in-Differences and Synthetic Control Methods: A Synthesis". Tech. rep. National Bureau of Economic Research.

Dubois, E., J. Haricourt, and V. Mignon (2009). "What if the Euro Had Never Been Launched? A Counterfactual Analysis of the Macroeconomic Impact of Euro Membership". *Economic Bulletin 3*, 2241–2255.

Equiza-Goñi, Juan (2016). "Government Debt Maturity and Debt Dynamics in Euro Area Countries". *Journal of Macroeconomics 49*, 292–311.

Feenstra, Robert C., Robert Inklaar, and Marcel P. Timmer (2015). "The Next Generation of the Penn World Table". *American Economic Review 105* (10), 3150–3182.

Ferrari, A. and A. Rogantini Picco (2023). “Risk Sharing and the Adoption of the Euro”. *Journal of International Economics 141*.

Gabriel, Ricardo Duque and Ana Sofia Pessoa (2020). *Adopting the Euro: a synthetic control approach*. MPRA Paper 99391.

Gobillon, L. and T. Magnac (2016). “Regional Policy Evaluation: Interactive Fixed Effects and Synthetic Controls”. *Review of Economics and Statistics 98*, 535–551.

Hope, D. (2016). “Estimating the Effect of the EMU on Current Account Balances: A Synthetic Control Approach”. *European Journal of Political Economy 44*, 20–40.

Imbens, Guido W. and Donald B. Rubin (2015). *Causal Inference in Statistics, Social, and Biomedical Sciences*. New York: Cambridge University Press.

International Monetary Fund (2011). “The Fiscal Monitor”. *IMF Fiscal Affairs Department*.

——— (2023). *Public Finances in Modern History Database*. URL: https://www.imf.org/external/datamapper/datasets/FPP.

Liu, Licheng, Ye Wang, and Yiqing Xu (2024). “A Practical Guide to Counterfactual Estimators for Causal Inference with Time-Series Cross-Sectional Data”. *American Journal of Political Science 68* (1), 160–176.

Puzzello, L. and P. Gomis-Porqueras (2018). “Winners and Losers from the Euro”. *European Economic Review 108*, 129–152.

Rosenbaum, Paul R. and Donald B. Rubin (1983). “The Central Role of the Propensity Score in Observational Studies for Causal Effects”. *Biometrika 70*, 41–55.

Xu, Yiqing (2017). “Generalized Synthetic Control Method: Causal Inference With Interactive Fixed Effects Models”. *Political Analysis 25*, 57–76.