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Beyond Fragmentation: Unraveling the Drivers of Yield Divergence in the euro area

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Beyond Fragmentation: Unraveling the Drivers of Yield Divergence in the euro area[1]

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Abstract

This paper provides a novel and high-frequency index of sovereign fragmentation in the euro area. The proposed methodology offers a decomposition of sovereign yields into the common trend, market conditions, and fundamentals-based divergence, which are uncorrelated to fragmentation. Therefore, the fragmentation index constitutes a bottom-line indicator for euro area Central Banks, as measuring disorderly market dynamics in sovereign markets not warranted by fundamentals. In that sense, this paper provides relevant conclusions about the effectiveness of monetary policy interventions, pointing to a significant effect of market stabilization announcements, such as TPI, in reducing sovereign fragmentation. I contribute to the literature as estimating the uncorrelated drivers of euro area yields divergence using a Restricted Principal Components Analysis. The estimated factors are later used to assess the effect of fragmentation, market and fundamentals on country's yields through several economic regimes, pointing to differences across countries and time.

Keywords: Principal Components, Monetary Policy, Quantitative Easing, Sovereign Debt, Financial Crises, Sovereign bond rates
JEL classification: C38,E52, E58, H63, G01 ,G12

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Introduction

Sovereign market fragmentation and the role of the ECB have been gaining importance since 2022 when government bond yields started to rise amid high financial market uncertainty, inflation rise, and the start of monetary policy normalisation. Yields evolution in the euro area have not always gone in the same direction. As stated by Gomez-Puig et al. (2014), before the Great Financial Crisis (GFC), 10-year sovereign yields moved in a narrow range. However, macroeconomic and fiscal imbalances, as well as other sources of risk, that surfaced during and after the GFC, caused euro area yields started to diverge.

A precondition for orderly market functioning is that sovereign bond prices reflect country-specific characteristics and their related risks. However, if market prices are undervalued with compared to the fair price, they could reflect investor's risk aversion. Therefore, sovereign market fragmentation should be defined as the divergencies in euro area yields or credit spreads not related to country fundamentals.

This is, precisely, how fragmentation needs to be evaluated when thinking about a backstop measure to counteract market dysfunction. For instance, the announcement[1] of the Transmission Protection instrument (TPI) in 2022 explicitly mentioned the idea of responding to disorderly market dynamics and the possibility to buy assets in the secondary market if financing conditions are "not warranted by country-specific fundamentals". Moreover, the announcement stated that "PEPP reinvestment flexibility continued to be the first line of defense to counter risks to the transmission mechanism related to the pandemic".

For that reason, controlling for fundamentals is critical (Kakes and Williams, 2023) and needs to be carefully addressed. De Santis (2018) also stated that financial market fragmentation created divergent borrowing costs for governments, firms and households across euro area countries after the GFC and triggered the announcement of the OMT programme. In that sense, it is important to disentangle divergences in euro area sovereign yields driven by country fundamentals, or even, market context, as some authors argue that sovereign spreads also react to financial market conditions (Eijffinger and Pieterse-Bloem, 2022 or Kakes and Williams, 2023). This task could be quite challenging given high correlation observed along sovereign country yields but also between yields, country fundamentals and market conditions.

Therefore, this paper proposes a new measure of fragmentation, which is uncorrelated to fundamental's country differences, common yields evolution and market conditions. More precisely, I estimate the latent factors of euro area sovereign yields, using a restricted Principal Component Analysis, following a similar approach than Motto and Ozen (2021). This way, I can decompose sovereign yields divergence into the risk-free component (common factor), fundamentals divergence arising from economic and fiscal variables (country fundamentals), market conditions (monitored by implied volatility) and fragmentation (gathering information not explained by the other three factors).

The fragmentation index peaked during the sovereign debt crisis but eased following the implementation of Unconventional Monetary Policy (UMP). Fragmentation also emerged in

[1] See Press Release on 21th July 2022:
https://www.ecb.europa.eu/press/pr/date/2022/html/ecb.pr220721~973e6e7273.en.html

2020 during the COVID-19 crisis but has proven to be transitory and reverted quickly, thanks to new ECB tools implemented during this period[2]. In 2022, the index went up but the announcement of the TPI managed to calm the markets. I found that the fragmentation index reacted to market stabilization monetary policy shocks, as derived by Motto and Ozen (2021), meaning the ECB decisions had a crucial role in stabilizing markets. Looking forward, ECB balance sheet normalisation and the end of UMP could pose additional risks on sovereign market functioning and fragmentation. Therefore, it is important to develop and monitor the proposed fragmentation indicator.

The rest of the paper is structured as follows. The next section reviews previous work about fragmentation and sovereign debt markets. Section 3 presents the data to be used and the methodology to compute fragmentation and the rest of the factors. Section 4 shows the results, also including the effects of monetary policy shocks related to market stabilization. Later, section 5 provides some robustness checks and finally, section 6 concludes.

2 Literature review

The paper is related to, at least, three fields of literature. First, it is close to pieces of work that assess euro area sovereign yields and its main drivers, especially the ones related to country fundamentals. Gomez-Puig et al. (2014) and Gibson et al. (2015) found a different impact of country fundamentals to explain sovereign yields between core and peripheral countries. Gomez-Puig et al. (2014) also pointed out that the effect of economic drivers on yields was different before and during the sovereign debt crisis, reflecting a stronger impact for peripheral countries in crisis times. Eijffinger and Pieterse-Bloem (2022) rely on multidimensional factors, using a time-series regression model that accounts for time and region-specific heterogeneities to understand the drivers of sovereign yields. Regarding possible drivers, the authors consider macro fundamentals, market factors, market sentiment and financial linkages. They assess the goodness of fit of each model, including different combinations of data. De Grauwe and Ji (2021) exploit the cross-country dimension and found that, in weaker euro area countries, the macroeconomic variables have a higher loading on sovereign spreads than in stronger countries. My work is close to these papers and my contribution is twofold. First, the methodology provides uncorrelated factors to measure multiple drivers, as in Eijffinger and Pieterse-Bloem (2022). Hence, I offer a solution to the high correlation between country yields, country fundamentals, and market indicators. Second, I assess the impact of the common yields evolution, market conditions, fundamentals as well as fragmentation on sovereign yields in each country and during different periods.

The second field of literature refers to fragmentation and the estimation of quantitative indicators. García de-Andoain et al. (2014) developed a metric of banking fragmentation, which explains borrowing costs based on risk-free rates, credit risk premium, and a country premium, that should be close to zero in the absence of fragmentation. De Santis (2018) also considers country-specific differences to evaluate corporate bonds fragmentation. The authors stated that, during the sovereign debt crisis, fragmentation increase could be attributed to a higher price of credit and macro risk demanded by investors, being higher in some countries. Mayordomo et al. (2015) studied fragmentation in the european interbank market and found that it has been higher, on average, in peripheral countries than in core ones. Kakes and Willem

[2] On 19th March 2020, the ECB announced a new asset purchases programme: Pandemic Emergency Purchase Programme (PEPP), which incorporated flexibility regarding the distribution of asset purchases by countries.

(2023) developed a metric for financial fragmentation in the Euro Area based on higher moments of sovereign spreads related to macro-financial fundamentals, on a monthly basis. They rely on both fixed and time-varying parameters (using rolling window regressions) to get which part of yield divergences could be explained by fundamentals, financial markets volatility or market sentiment. However, they found no effects of monetary policy shocks in reducing fragmentation. ECB (2022) uses a principal component analysis to address sovereign fragmentation on a high-frequency basis. The first principal component is related to a common factor in all euro area countries, which is aligned with risk-free rates, while the second principal component accounts for divergences across countries. Additionally, Motto and Ozen (2021) developed a measure of sovereign market stabilization using intraday data during Governing Council meetings. However, the last two papers do not account for fundamentals. Therefore, I contribute to this strand of literature in two ways. First, I propose a novel methodology to estimate uncorrelated factors driving sovereign yields divergence in the euro area, inspired by the work by Motto and Ozen (2021) and ECB (2022) but accounting for country fundamentals. Second, the methodology employed to estimate sovereign fragmentation could be applied to corporate bonds or money markets.

Thirdly, another field of literature analyses the effects of ECB monetary policy measures on fragmentation and market dysfunction. Eijffinger and Pieterse-Bloem (2022) found that financial market variables and central bank purchases had a significant impact on sovereign spreads. De Santis (2018) pointed out some evidence that fragmentation reverted its trend when ECB president Draghi gave the "whatever it takes" speech in 2012. Mayordomo et al. (2015) studied the short-time effects of ECB announcements on daily interbank fragmentation levels, showing significant effects. Additionally, one can refer to a series of studies that assess ECB monetary policy announcements using high-frequency data to capture unexpected shocks during press conference events. Altavilla et al. (2019) derive three dimensions of monetary policy shocks using changes in euro area yield curve: short-term impact on policy rates, changes in Forward Guidance and Quantitative Easing. Later, Motto and Ozen (2021) include a fourth factor to account for Market Stabilization shocks. Hence, this new dimension offers a quantitative measure for ECB announcements aimed at addressing market segmentation and stabilizing markets. Therefore, this new factor, called Market Stabilization Quantitative Easing can be understood as the surprise driven by each announcement and could be compared with my new measure of fragmentation. My paper contributes to assessing how monetary policy announcements, and precisely the market stabilization quantitative easing (QE) factor by Motto and Ozen (2021), improve market functioning and hence, reduce sovereign market fragmentation.

3 Data and methodology

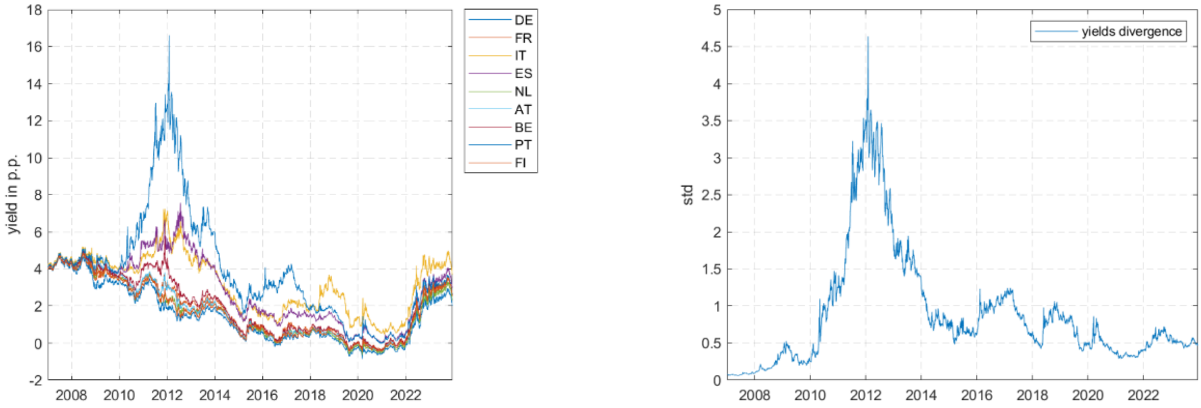
3.1. The data

I construct a dataset based on macro fundamentals for nine[3] euro area countries, market conditions and sovereign bond yields covering the period between 1st January 2007 and December 2023. Sovereign yields (Figure 1) followed a divergent evolution in specific periods, with the sovereign debt crisis being the most relevant. In that sense, some authors like ECB (2022) stated that euro area bond market dynamics could be explained by two factors: one that accounts for co-movements across countries, and the other (divergent factor) which captures segmentation (i.e., yields moving in opposite directions). However, some divergent dynamics could also be related to country characteristics or market conditions.

Similarly to Kakes and William (2023), I use GPD growth and debt-to-GDP change to gather country fundamentals context. I also account for differences in rating scores by Moody's, Fitch and S&P as in Hondroyiannis and Papaoikonomou (2022). The heterogeneous evolution of country fundamentals is collected through the cross-country standard deviation for each country indicator, following Kakes and William (2023). Therefore, higher fundamentals divergence could imply higher differences across countries, which brings higher yields divergence. Figure 2 shows time-varying second moments for each country variable and proves the existence of differences across countries.

[3] Austria, Belgium, Germany, Finland, France, Italy, Netherlands, Portugal, Spain. The selection is done based on yields data availability.

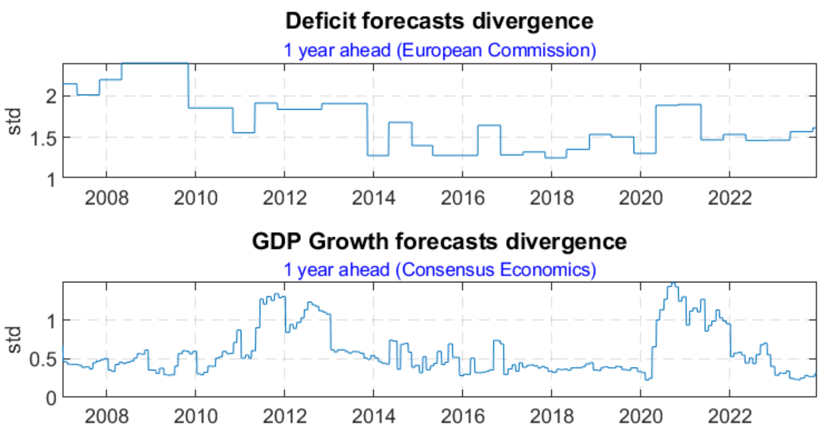
Figure 1: Sovereign bonds yields in the euro area



Source: Bloomberg and own computations. Last observation: 19 December 2023. Yields divergence is computed as the cross-country standard deviation yields $sd_t = \sqrt{\frac{\sum_{n=1}^{N}(y_{i,t}-\overline{y_t})^2}{N-1}}$ *where* $y_{i,t}$ *is the 10-year sovereign yield for country i in period t and N is the number of countries in the sample.*

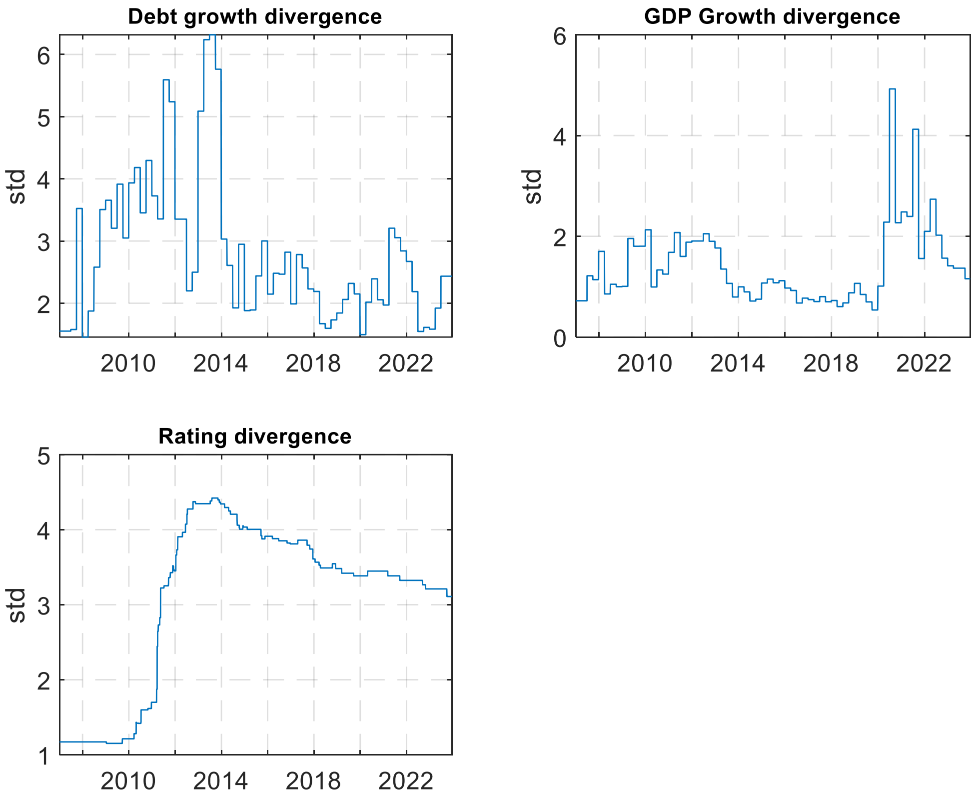
Figure 2: Fundamentals divergence for selected euro area countries

a) Forecasts



Sources: European Commission and Consensus Forecasts. Deficit forecasts for each country are obtained from European Commission Projections produced twice per year (spring and autumn). See: tables labeled "Net lending (+) or net borrowing (-), general government (as a percentage of GDP)". For the whole semester I assume forecasts are maintained as investors would rely on the latest projections. GDP growth is obtained from Consensus Economics, which is updated every month. The divergence is computed as the cross-country standard deviation.

b) Observed data



Sources: SDW, S&P, Moody's and Fitch; own computations. The debt growth represents the change in government debt as a percentage of GDP on a quarterly basis. The rating divergence is computed using the average of the three rating agencies. The divergence for each fundamental variable is computed as the cross-country standard deviation.

I combine observed fundamentals with projections as both can complement each other in several ways. First, some projections are offered on a monthly basis, which improves the frequency of observed data (normally quarterly). Second, one could think investors and hence, sovereign yields respond not only to current data but also to expectations. Third, projections are subject to uncertainty or can be biased, so it is worth comparing them with observed data.

I include the following one-year-ahead forecast variables. Sovereign financial conditions are measured using government deficit forecasts from European Commission Projections, available twice per year (spring and autumn)[4]. GDP growth forecasts account for economic expected developments, which are compiled by Consensus Economics[5] and available on a monthly frequency. Similarly, I monitor observed data on government debt growth[6], GDP growth and headline inflation using ECB statistical data warehouse databases. Finally, country specific characteristics are combined with rating scores.

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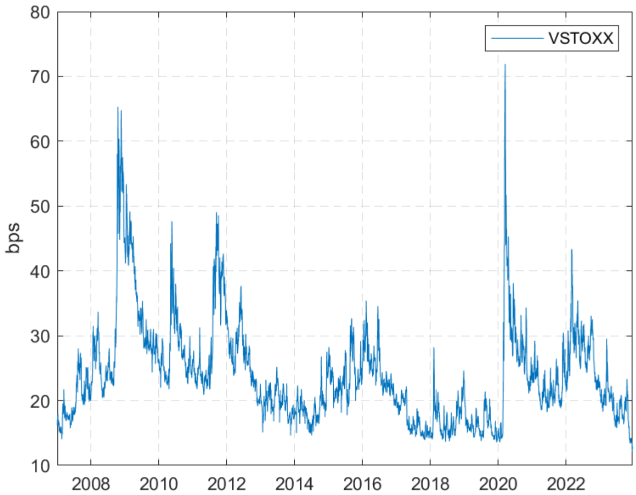
[4] Those forecasts are available here: *https://economy-finance.ec.europa.eu/economic-forecast-and-surveys/economic-forecasts_en*

[5] Consensus Economics surveys over 250 prominent financial and economic forecasters estimates of different variables including future growth interest rates or exchange rates, among others.

[6] *Government debt growth differs from the deficit/surplus value by the Deficit-debt-adjustment (DDA). For more information, see: https://www.ecb.europa.eu/pub/pdf/scpsps/ecb.sp29.en.pdf.*

As stated by several authors (Eijffinger and Pieterse-Bloem, 2022), financial market conditions also matter in understanding the evolution of sovereign yields. Therefore, I include the VSTOXX (Figure 3) as a proxy for financial market risk.

Figure 3: VSTOXX



Source: Bloomberg. Last observation: December 2023

Once I have country individual data for each indicator, and following Kakes and William (2023), I compute cross-country daily standard deviation following equation 1, where the subscript t refers to time and $f_{i,t,k}$ denotes each of the k variables for country i in period t.

$$Fundamental\ variable\ divergence_{t,k} = \sqrt{\frac{\sum_{n=1}^{N}(f_{i,t,k}-\overline{f_{k,t}})^2}{N-1}} \quad (1)$$

Using high-frequency data (on a daily basis) is attractive for several reasons. First, it provides up-to-date information on market conditions, especially during crises when high fluctuations are observed. Second, it allows for the estimation of a high-frequency indicator for sovereign fragmentation, whose evolution can be evaluated alongside relevant events, such as monetary policy press conferences. Third, daily frequency offers the opportunity to assess the impact of various factors on yield divergence across different economic regimes using subsamples.

I obtain 10-year sovereign yields from Bloomberg on a daily basis. For lower frequency data (i.e. quarterly and monthly observations), I assume that the relevant information assessed by financial markets corresponds to the latest (observed or projected) data. Accordingly, the k fundamental value of each variable during the quarter (q) or month (m) is obtained as in equation 2. Cut-off dates correspond to survey dates for forecasts and calendar periods for observed data.

$$f_{i,t,k}\{t\epsilon m\} = f_{i,m,k} \text{ for months,}$$
$$f_{i,t,k}\{t\epsilon q\} = f_{i,q,k} \quad \text{for quarters} \quad (2)$$

$where\ q = \{1, \dots, Q\}\ and\ m = \{1, \dots, M\}$, being Q the set of quarters and M, the months.

Once the dataset of euro area bond yields is arranged, one needs to consider which methodology to use. In general, literature addressing the drivers of sovereign yields identifies a dependent variable (i.e., bond yields) and independent variables: fundamentals, market conditions, and economic characteristics, among others. However, a data description offers interesting insights (Table A1, Annex). First of all, the correlation among euro area yields is higher than 70% in all cases but some heterogeneities arise across countries. For instance, Italy and Spain seem to be moving closer (correlation equal to 95%), while the correlation is lower when compared to Germany. Secondly, the correlation between Portugal and the rest of the countries stays around 60%, being closer to Italy and Spain (higher than 80%). Moreover, there is a strong interrelation between yields and the economic fundamentals or rating qualifications, especially for the countries that had been more affected by the sovereign debt crisis. This connection also exists across country fundamentals. Finally, VSTOXX is also closely related to yields and country-specific characteristics. Consequently, estimates of country yields drivers based on these variables could be subject to multicollinearity. PCA analysis can overcome this issue by providing a reduction of the dataset that captures the uncorrelated factors.

3.2. Assessing stationarity

A Principal Component Analysis (PCA) requires a preceding stationary analysis. Table 1 presents the results of the Augmented Dickey-Fuller test for stationarity of each variable on a daily basis.

Table 1: Augmented Dickey-Fuller test for variables measured as cross-country standard deviation (divergence)

Variable	ADF test (daily data)
Rating - cross-country divergence	-2.18** (0.03)
GDP growth observed - cross-country divergence	-3.81*** (0.00)
Debt growth observed - cross-country divergence	-2.64** (0.00)
GDP growth forecast - cross-country divergence	-3.00*** (0.00)
deficit forecast - cross-country divergence	-2.36** (0.02)
VSTOXX - cross-country divergence	-5.43*** (0.00)
sovereign yields - cross-country divergence	-1.76* (0.07)

Test statistic ***,**,* denote rejection at 1%,5% and 10% significance level. The alternative hypothesis is stationarity. For each variable, I compute the cross-country divergence as stated in equation 1.

The results point out that all the variables are stationary, at least, at the 10% significance level[7].

Therefore, I can assert that euro area yields, fundamentals divergence and market conditions can be described by four factors, categorized as: a) common factor, b) fundamentals divergence, c) market conditions and d) fragmentation. The dataset is summarized in equation 3.

$$X_{t,j}=\begin{bmatrix} Y_{t=1,country\ j=1} & \cdots & Y_{t=1,country\ j=10} & std\ \Delta Debt_{\ t=1} & std\ GDP_{\ t=1} & std\ Rating_{\ t=1} & std\ def.for_{\ t=1} & std\ Growth\ for_{\ t=1} & VSTOXX_{\ t=1} \\ \vdots & \ddots & & & & \vdots & & & \\ Y_{t=T,country\ j=1} & \cdots & Y_{t=T,country\ j=10} & std\ \Delta Debt_{\ t=T} & std\ GDP_{\ t=T} & std\ Rating_{\ t=T} & std\ def.for_{\ t=T} & std\ Growth\ for_{\ t=T} & VSTOXX_{\ t=T} \end{bmatrix} \quad (3)$$

Where $Y_{t,\ country}$ denotes the 10-year sovereign yield in country j at time t, $std\ \Delta Debt_{\ t}$ is the cross-country standard deviation of government debt growth over GDP at time t, $std\ GDP_t$ is the cross-country standard deviation of GDP growth at time t, $std\ Rating_t$ is the cross country standard deviation of rating scores at time t, $std\ def.\ for_t$ is the standard deviation of deficit forecasts, $std\ Growth\ for_t$ is the standard deviation of growth forecasts at time t and $VSTOXX_t$ denotes implied market volatility at time t.

To obtain the latent factors, I first estimate the four unrestricted principal components of dataset X described in equation 3, where the first step is normalizing all the variables. The obtained components can be understood as the four factors having a large impact on the dataset, and they can explain together 91% of the total variation in the dataset. Mathematically, the initial unrestricted PCA can be written as in equation 4.

$$X = FA + \varepsilon \qquad (4)$$

Where F is the matrix $(T \times k)$ of initial factors being T the number of periods and k the factors. A is the matrix $(k \times j\ )$ of latent factors, where the element $A_{k,j}$ represents the loading of factor k in variable j , and ε is the residual.

3.3. The restricted PCA

The unrestricted PCA estimation is done in such a way as to maximize the variation in X, but does not offer an economic meaning of the factors. So, I follow a similar approach to Swanson (2021), Altavilla et al. (2019) and Motto, Ozen (2021) to estimate a rotated factor matrix that fits exactly the data but imposes some economic restrictions to make them interpretable. More precisely, I want to study the divergent evolution of sovereign yields across euro area but accounting for fundamentals and market conditions. The decision to follow such approach is aligned with a broadly accepted definition of market fragmentation, which should reflect interest rate divergence that is not explained by fundamentals.

Technically, I am looking for a matrix of latent factors $\tilde{F} \equiv FU$, and factor loadings $\tilde{A} \equiv U'A$, where F and A are the initial factors and loadings, respectively. Therefore, the main objective is estimating a rotation matrix U $(k \times k)$, where k is equal to the four factors. Its estimation requires imposing the following restrictions, which can be mathematically represented as in equations 5.1 to 5.4.:

I. The loadings of the fragmentation factor on Italian and German bond have the opposite sign (equation 5.1),

[7] I also assess the total number of factors to be included, checking the rank of the dataset. Results are provided in Table A2 (Annex) and confirm the existence of 4 factors.

II. The loadings of the fundamentals factor on country variables are positive (equation 5.2),
III. The common factor does not load on country variables (equation 5.3) and
IV. Factors are orthogonal (equation 5.4).

$(U_{,4}{}'\, A_{,Germany\ 10-y}).(U_{,4}{}'A_{,Italy\ 10-y}) < 0$ (5.1)
$(U_{,2}{}'\, A_{,country\ variables}) > 0$ (5.2),
$(U_{,1}{}'\, A_{,country\ variables}) = 0$ (5.3),
$U_{,1}{}'\, U_{,1}=1,\ U_{,2}{}'\, U_{,2}=1,\ U_{,3}{}'\, U_{,3}=1,\ U_{,4}{}'\, U_{,4}=1,$
$U_{,1}{}'\, U_{,2}=0,\ U_{,1}{}'\, U_{,3}=0,\ U_{,1}{}'\, U_{,4}=0,$
$U_{,2}{}'\, U_{,3}=0,\ U_{,2}{}'\, U_{,4}=0,$
$U_{,3}{}'\, U_{,4}= 0$ (5.4)

where country variables are: $std\ \Delta Debt_t$, $std\ GDP_t$, $std\ Rating_t$, $std\ def.for_t$, $std\ Growth\ for_t$ *and*
$U_{,1}$ *is the first column of rotation matrix related to the common factor,*
$U_{,2}$ *refers to fundamentals,* $U_{,3}$ *is related to Market and the*
last column $U_{,4}$ *refers to Fragmentation.*
Each element of the U matrix is denoted as $U_{i,j}$ *where i represents the row and j, the column.* $A_{k,j}$ *is the matrix of loadings where k denotes each variable, j each variable and t each time observation.*

Similarly to Motto Ozen (2021), I minimise the variance of each factor related to some variables. Those requirements aim to make each factor as close as possible to the dimension they represent and reduce possible disturbances from other variables. First, I pursue to minimise the variance of the common and fundamentals factor related to market conditions (VSTOXX). Second, I minimise the variance of the market factor related to sovereign yields and fundamentals variables. Third, the fragmentation factor variance related to country variables and VSTOXX should be the minimum as possible.

To sum up, the factor identification requires solving the optimization problem as in equation 6.

$$U^* = \arg min\{U_{i,j}\}\ (F_{,VSTOXX}\, U_{,1})^2 + (F_{,VSTOXX}\, U_{,2})^2 + (F_{,j=1:(k-1)}\, U_{,3})^2 + (F_{,j=11:K}\, U_{,4})^2$$
$$\text{Subject to Eq. 5.1, 5.2, 5.3, 5.4,} \qquad (6)$$

Where *j=1:9 denotes the yields, j=10:14* the country variables and, *j=15* the *VSTOXX.* $F_{t,k}$ is the matrix of factors.

4 Results

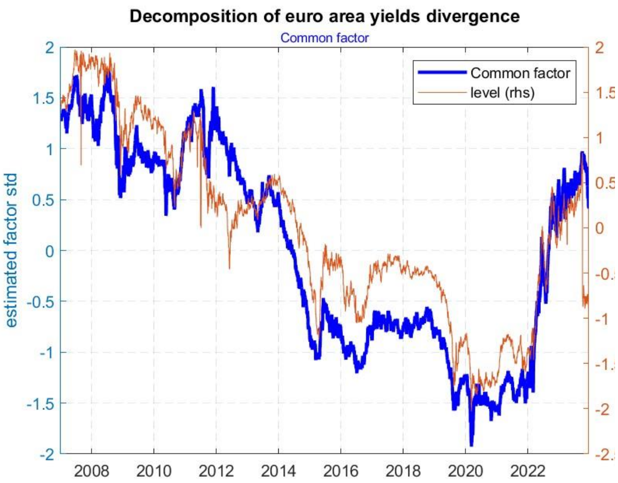
4.1. The latent factors

Figure 4 shows the estimated factors explaining together the evolution of sovereign yields, market conditions, and country fundamental divergences. The obtained factors are normalised and, hence, positive (negative) numbers correspond to higher (lower) than historical values and vice versa.

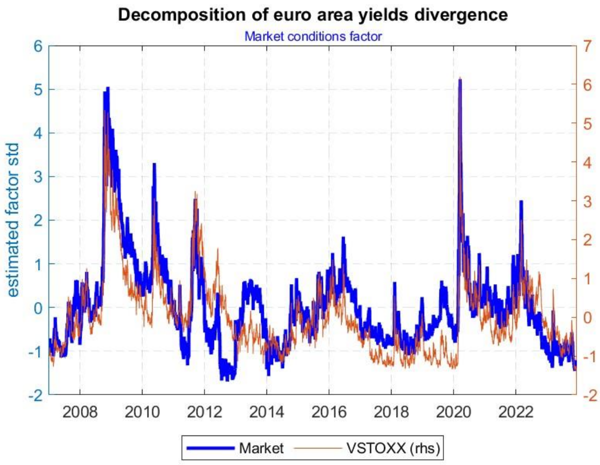
As expected, the common factor (Figure 4a) is very close to long-term monetary policy expectations[8]. Indeed, the common factor goes down during periods of accommodative monetary policy while it increases in tightening periods.

Figure 4: The latent factors

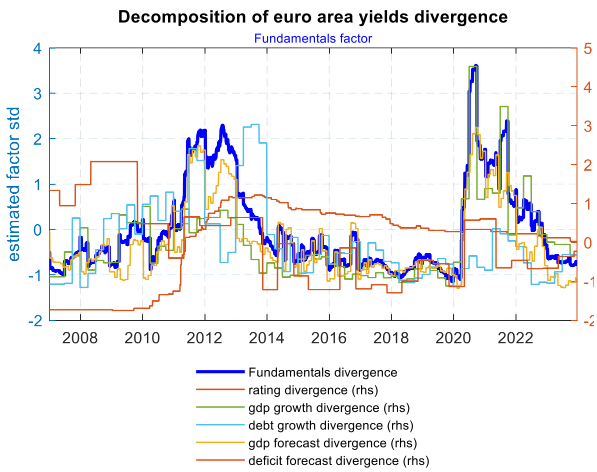
a) Common factor



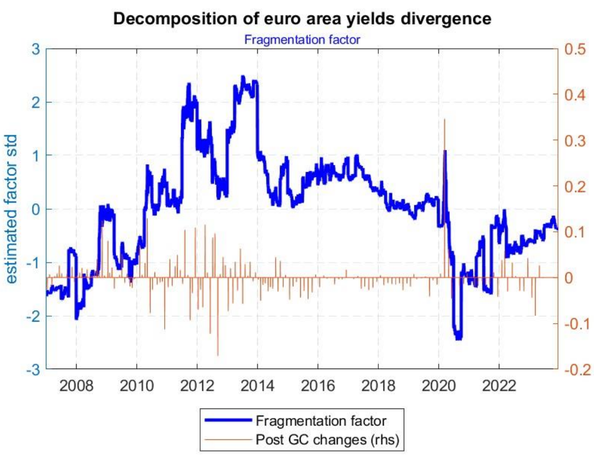
b) Market factor



c) Fundamentals divergence



d) Fragmentation factor



Source: author's computation. Level is included as a reference for long-term monetary policy expectations, even if it is not included in the model. Factors are normalised, so that they show standard deviations from its historical mean value. Positive (negative) numbers point to higher (lower) than historic values. Panel d) the post GC changes show daily changes in the fragmentation index during ECB Governing Council meetings. Last data: December 2023.

[8] I compute the expected long-term level of risk-free rates, using the forward curve obtained from OIS rates and based on the Nelson–Siegel model.

The market factor (Figure 4b) mainly loads on market volatility (VSTOXX). This index moves in parallel to crisis events, being the most significant the GFC and COVID-19. Market conditions deteriorated, on a lesser extent, during the sovereign debt crisis.

Additionally, the fundamentals factor (Figure 4c) combines five variables used to monitor country divergences across the euro area. Among the included indicators, GDP growth divergences, using both projections and observed values are the main loadings of the fundamentals index (see Table A3b). It is worth mentioning, that the factor peaked during crisis periods but on a different magnitude than the market factor. The highest value was reached just after the inception of the pandemic and lasted until mid-2022 driven by differences in GDP growth (both in observed and projected terms). The second spike can be identified during the sovereign debt crisis, clearly affected by differences in GDP forecasts for Euro Area countries. It is also interesting that, during these periods, the fundamentals factor was above historic values, but it significantly went down in 2022.

Finally, regarding the fragmentation factor (Figure 4d), the highest values were observed during the sovereign debt crisis until the introduction of unconventional monetary policy in 2014. Therefore, one could think ECB interventions (e.g., SMP, OMT, APP) partly alleviated market dysfunction dynamics. I provided more details of such analysis in section 4.3. The second highest value can be noticed in March 2020, coinciding with an increasing trend in sovereign yields amid pandemic concerns. In fact, on 12th March 2020, markets were disappointed as they would expect a “whatever it takes” intervention by the ECB president (Motto, Ozen 2021) pointing to the highest daily increase in the fragmentation factor. Markets calmed down some days after when the introduction of the PEPP programme offered some flexibility (i.e., no constraints related to ECB capital[9]) along asset purchases, which narrowed sovereign yields.

The restrictions imposed for the fragmentation factor require opposite movements along the Italian and the German 10-year bond. This restriction is reflected in positive loadings for the fragmentation factor in Portugal, Spain and Italy, while estimates pointed to negative loadings for the rest of the countries (Table A3a). Therefore, the fragmentation index is able to identify those countries where spreads spiked during a fragmentation episode.

Moreover, part of the notable reduction in the fragmentation index in 2020 can be attributed to a spike in economic fundamentals. Some fundamentals indicators (GPD observed growth and GDP forecast growth) load negatively in the fragmentation index. Hence, economic growth differences should scale down the fragmentation index, as divergent movements along core and periphery yields should be related to economic conditions. On the opposite side, debt growth and rating divergences, to a lesser extent, load positively on the fragmentation index. Those results suggest some important findings. Economic differences (i.e., GDP growth) can be a better proxy for fundamental differences along countries than other indicators, while debt and rating have interconnections with both fundamentals and fragmentation. Intuitively, one can think that rating differences between countries normally increase when sovereign yields start to diverge reinforcing country risk concerns. Similarly, increasing yields harm fiscal positions by imposing higher debt costs on countries. Consequently, debt growth and rating divergences

[9] The former Asset Purchases Programme (APP) limited asset purchases to country’s capital key, restricting the volumes that can be bought by the Eurosystem.

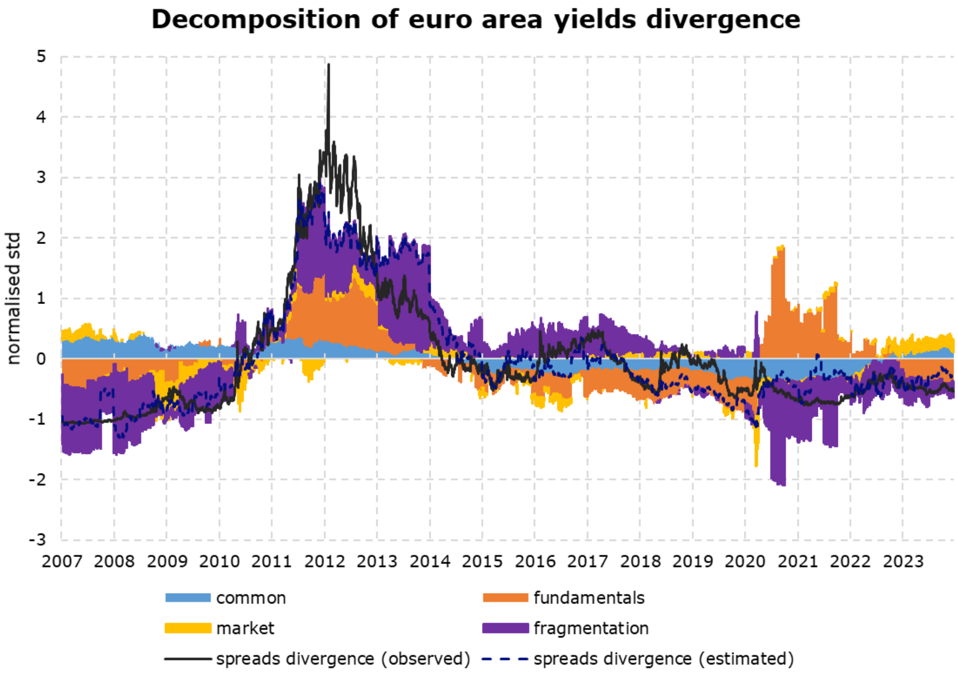
would also exacerbate fragmentation fears. The obtained results align with the idea of fragmentation as self-reinforcing spread-widening dynamics (ECB, 2022).

One of the objectives of this paper is to understand euro area yields divergence. Therefore, I employ the estimated latent factors to explain yield differences[10], computed as the cross-country standard deviation, following Kakes and Williams (2023). I then estimate OLS regressions as in equation 7, where the dependent variable is the standard deviation of euro area yields and the independent variables are the four latent factors. One of the main advantages of this strategy is using orthogonal explanatory variables and hence, being able to disentangle fragmentation from fundamentals, common, and market factors and assess the contribution of each factor to yields divergence.

$$STD\ yields_t = \beta^{common} Common\ factor + \beta^{fundamentals} fundamentals\ factor + \beta^{market} Market\ Factor + \beta^{fragmentation} Fragmentation\ Factor + u_t \quad (7)$$

Where $STD\ yields_t$ refers to cross-country bond yield divergence, computed as presented in equation 1 and $Common\ factor$, $fundamentals\ factor$, $Market\ Factor$ and $Fragmentation\ Factor$ refer to the four factors estimated and shown in figure 4.

Figure 5: Decomposition of euro area sovereign yields divergence



Source: author's computation. Note that values are normalised, meaning that positive values reflect higher than average values, but do not necessarily point to positive fragmentation.

Contributions are computed as the estimated coefficient multiplied by the value of the factor at each point in time. Figure 5 shows the decomposition of yields divergences and Table 2 contains the estimated coefficients. As expected, I found both fragmentation and fundamentals account

[10] An alternative measure of yields divergence is the estimation of a two-factor principal component analysis, where the second component will illustrate differences across countries (see for instance ECB, 2022) and the first component is related to the common evolution. I compare both estimates, which provide very similar results and are included in Figure A6 (Annex).

for the highest proportion of yields divergence. During the sovereign debt crisis, both factors showed high historical values, driving a noteworthy increase in yields divergence. Conversely, the period around the COVID-19 crisis differed from the sovereign crisis: the peak in the fragmentation index was transitory and reverted after a rapid and accommodative monetary policy intervention. Fundamental differences also emerged, reflecting differences among countries regarding economic growth and fiscal conditions.

Divergences in euro area yields increased again in the first part of 2022, triggered by financial market uncertainty and geopolitical risks, and were mostly explained by the increase in the fragmentation index. They were partially attenuated later by the Transmission Protection Instrument (TPI) announcement, which managed to stabilize the markets.

Table 2: Estimated effect of each factor on yields divergence

	model 1	model 2	model 3
Common	0.26***	0.18***	0.24***
	(0.00)	*(0.00)*	*(0.00)*
Fundamentals	0.65***	0.43***	0.52***
	(0.00)	*(0.00)*	*(0.00)*
Market	-0.09***	0.05***	0.19***
	(0.00)	*(0.00)*	*(0.00)*
Fragmentation	0.57***	0.72***	0.7***
	(0.00)	*(0.00)*	*(0.00)*
Adjusted R-squared	85.35%	73.32%	87.27%
# Observations	4 366	4 366	4 366

Test statistic ***,**,* denote rejection at 1%,5% and 10% significance level. P-values in parenthesis

Model 1: only observed fundamentals with rating; Model 2: observed fundamentals without rating; Model 3: observed and forecast fundamentals with rating (final model).

4.2. The effect of each factor on country yields

I apply a similar analysis than Motto Ozen who, after providing estimates for the factors related to Monetary Policy shocks (MPS), assesses the impact of each factor on country yields. Therefore, OLS regressions for each country are estimated following equation 8.

$$10\ year\ yield_{c,t} = \beta^{common,c} Common_t + \beta^{fundamentals,c} fundamentals_t + \beta^{market,c} Market_t + \beta^{fragmentation,c} Fragmentation_t + u_{t,c} \qquad (8)$$

Where the sub index c denotes each of the countries included in the sample, and t the time. $u_{t,c}$ denotes the error.

Table 3: Estimated effects of estimated factors on 10-year sovereign yields

	DE	FR	IT	ES	NL	AT	BE	PT	FI
Common	0.94***	0.98***	0.94***	0.94***	0.96***	0.96***	0.99***	0.74***	0.95***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Fundamentals	-0.18***	-0.1***	0.1***	0.17***	-0.15***	-0.12***	-0.03***	0.34***	-0.16***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Market	-0.11***	-0.1***	0.00	-0.01*	-0.14***	-0.14***	-0.12***	0.03***	-0.14***
	(0.00)	(0.00)	(0.34)	(0.08)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Fragmentation	-0.22***	-0.14***	0.16***	0.23***	-0.19***	-0.17***	-0.07***	0.49***	-0.21***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Adjusted R-squared	98.56%	99.29%	92.18%	96.40%	98.99%	99.24%	99.07%	90.64%	98.77%
# Observations	4366	4366	4366	4366	4366	4366	4366	4366	4366

Test statistic ***,**,* denote rejection at 1%,5% and 10% significance level. P-values in parenthesis

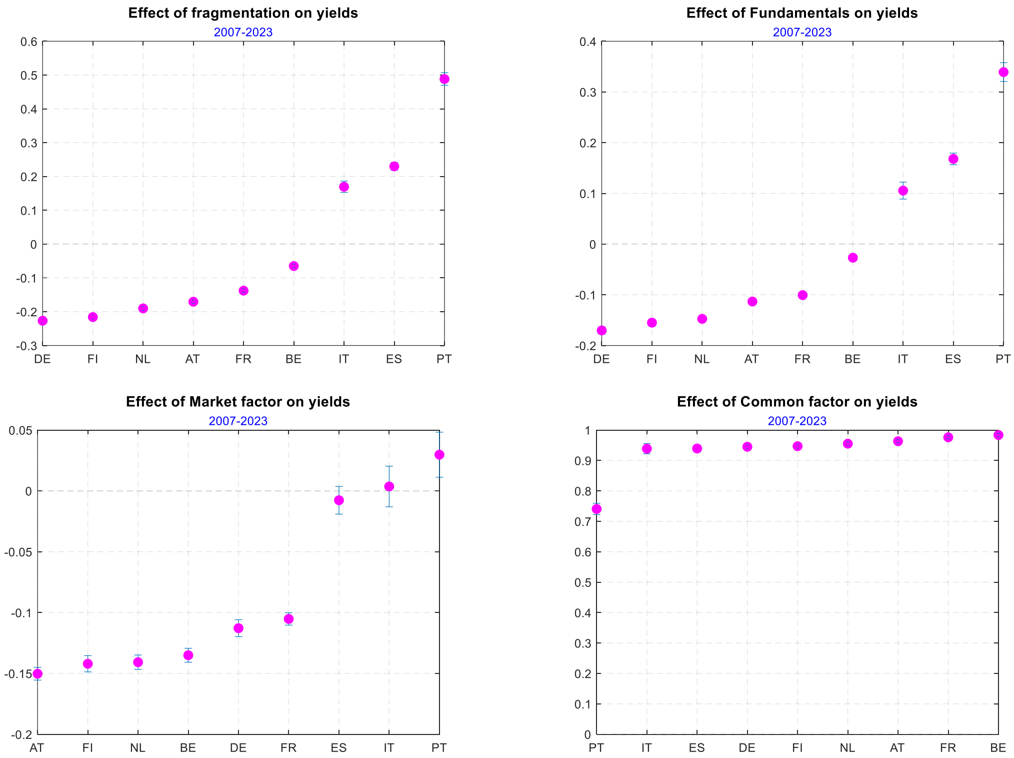
Table 3 and Figure 6 provide the results of these regressions. The high values observed for the coefficient of the common factor suggest a common trend driving euro area yields exists, but its relevance is lower in peripherical countries. Additionally, one can see that this common factor is able to explain most part of country yields evolution for the overall sample (see Figure 7, which shows the relative contribution of each factor[11]).

The comparison of the other coefficients suggests the existence of two groups of countries. In some countries, yields increase when economic or fiscal divergences emerge, market conditions worsen or fragmentation increases, while others 'benefitted' from those tensions. These conclusions can be derived from the coefficients for fundamentals, market, and fragmentation factors where the opposite sign is obtained for the group of core and periphery countries. Therefore, when economic or fiscal differences arise, yields of the periphery countries tend to increase while they go down for the rest of the countries. Similarly, when market conditions worsen, flight-to-quality pursues investors to look for safer assets, and hence, yields of both groups of countries move in the opposite direction. The role fragmentation has on sovereign yields is as expected: a higher index puts upward pressure on those countries normally considered as more fragile (or having higher credit spreads). Moreover and, more importantly, it reflects divergences in euro area yields not related[12] to economic and/or country's fiscal differences.

[11] Given orthogonality among the latent factors, I introduced the factors one by one to gather the additional contribution of each one.

[12] The fact that the four estimated factors are orthogonal allows me to disentangle each of the effects.

Figure 6: The effect of latent factors on country yields



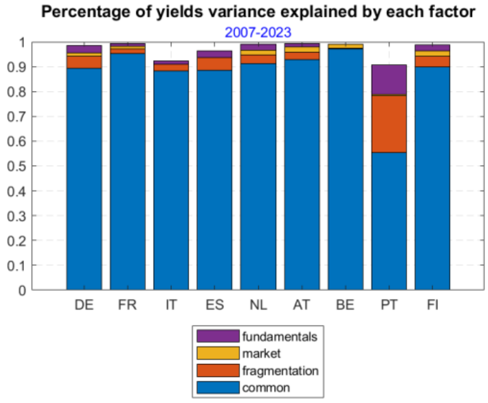
Source: author's computations. Note: estimated coefficients based on equation 8. Bars show 95% confidence intervals

Additionally, I assess if those effects vary along different time regimes, as stated by Eijffinger and Pieterse-Bloem (2022). Figure 7 confirms how the relative contribution of each factor has not been homogeneous over time. More precisely, I found that the effect of market conditions is more relevant in periods of stress, such as the sovereign debt crisis and Covid-19. Moreover, one can see that in the sovereign debt crisis, the fragmentation factor has been playing a relevant role in driving sovereign yields up[13]. Finally, it is worth mentioning that after the implementation of the Unconventional Monetary Policy, the common evolution has been the most important factor driving Euro Area government bonds, promoting financial integration.

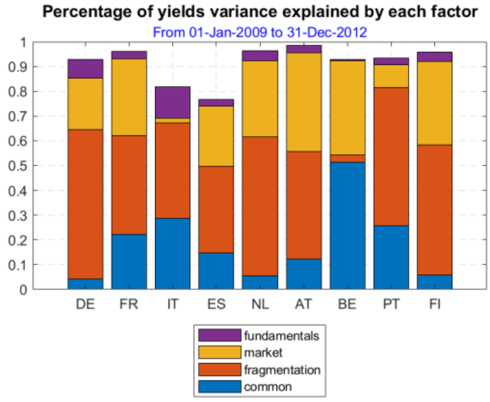
[13] The impact of the fragmentation factor has been particularly high in Portugal. Figure 1, which shows sovereign yields in the euro area as well as yields dispersion, suggests that Portuguese yields have been driving divergence during most of the sample and, at least, until 2020. This is also reflected in Portuguese yields having the largest loading on fragmentation (Figure A3a). Additionally, it can also be observed that Portugal has the lowest percentage of variance explained by the four estimated factors. One can think other drivers such as political uncertainty, not included here, could affect yields evolution.

Figure 7: Relative contribution of each factor on country yields using different subsamples

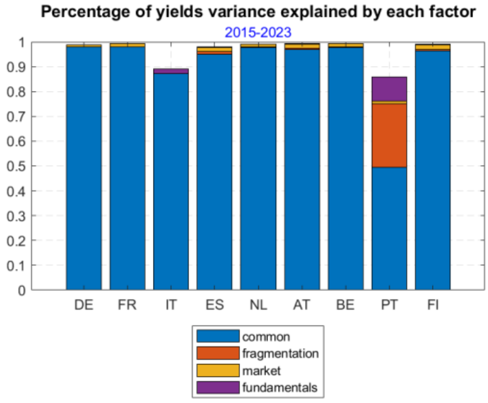
a) all sample



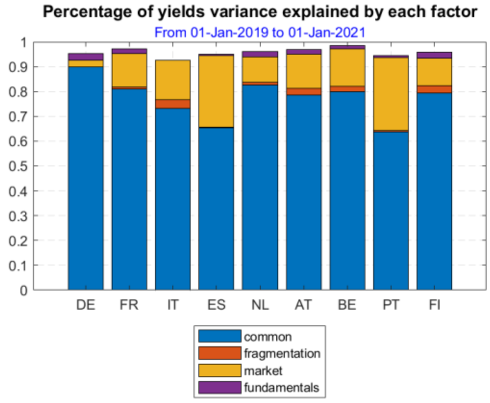
b) Sovereign debt crisis



c) *After implementation of APP*



d) *COVID-19 crisis*



Source: author's computations.

4.3. Relationship with Monetary Policy and Market Stabilization QE

I took advantage of the novel measure developed by Motto Ozen (2021) which provides four dimensions of monetary policy shocks, referred: short-term shock, Forward Guidance, Quantitative Easing (QE) and, Market Stabilization QE. The latest dimension is the main contribution with respect to Altavilla et al. (2019) and focuses on yields movements across euro area countries. These shocks gather unexpected information in a very short time window and then, are not influenced by country characteristics or market conditions[14]. The new Market Stabilization QE shock could be related to announcements aimed to address market functioning (e.g., the announcement on 2 September 2012 of the details of the OMT programme) or targeting market segments flexibly (refer for instance to 4 June 2020, when PEPP[15] was expanded and the Market Stabilization Shock was significantly accommodative)[16].

[14] Hence, there are two main differences between MPS and the fragmentation index: i) MPS is obtained using intraday data only during governing council decision meetings while the fragmentation index uses daily data for the overall sample; ii) MPS does not consider country fundamentals data while fragmentation index does. For that reason, I argue that estimated factors could react to MPS and, one could expect the fragmentation index to be reduced once the ECB announces some Market Stabilization measures.

[15] PEPP programme, as compared to conventional APP, introduced the idea of flexibility along the distribution of asset purchases by countries, which could benefit countries with higher yields.

[16] Replication of MPS following Motto and Ozen (2021) can be found in Figure A7.

I follow a similar approach than Kakes and William (2023) to estimate the impact of Monetary Policy Shocks (MPS) in the estimated factors (i.e., the common, fundamentals, market, and fragmentation dimensions). I only assess the impact of Conventional QE and Market Stabilization QE shocks, as the other two (short-term and forward guidance) are not relevant to my study[17]. Conventional QE mostly gathers changes in risk-free long-term yields (based on overnight index swaps, OIS) and Market Stabilization QE is defined to capture opposite movements between the long-term risk-free rate (OIS) and the Italian sovereign bond[18]. Therefore, my hypotheses regarding the effects of MPS on the latent factors are the following:

I. The Market Stabilization QE shocks should have a positive and significant impact on the Fragmentation factor, but not on the Common factor,
II. Conventional QE shocks should be relevant for the common sovereign yields evolution (i.e., the common factor) but not for the Fragmentation (or Fundamentals) factor,
III. Market conditions, mostly reflecting VSTOXX might be impacted by monetary policy shocks indirectly, but should not be affected by any of the MPS dimensions,
IV. Finally, I test whether Market Stabilization QE shocks could reduce fundamentals divergences. One could think about a second-round effect: announcements aiming to stabilize markets can manage to reduce sovereign yield (therefore, affecting debt and deficit dynamics).

Local projections based on Jordà (2005) are estimated to test each of the above-mentioned hypotheses. The model is specified in equation 9. I do it for each of the four dimensions or latent factors (i.e., common, fundamentals, market and fragmentation factor) on daily first differences. For each equation, I run some robustness tests, including the rest of the factors as controls in section 5, pointing to similar results.

$$Latent\ factor_{t+h} = \alpha_t + \varphi_h MP_t + \epsilon_{t+h} \qquad (9)$$

Where MP_t refers to either Market stabilization QE or Conventional QE shock and h to the horizon ahead period (up to 20). I restrict the sample for the period 2010-2023, as there were no significant shocks before.

Figure 8a confirms the hypothesis I, II and IV. The impulse responses to a Market Stabilization (ME) QE shock are significant on the first horizon ahead for the fragmentation factor and to a lower extent, to the fundamentals factor. More precisely, the estimates suggest that a one standard deviation accommodative (tightening) shock reduces (increments) the fragmentation index by 0.5 standard deviations and decreases (increases) the fundamentals index by 0.2 standard deviations. However, as expected, responses to ME QE shocks are not making a significant impact on the common and the market factors.

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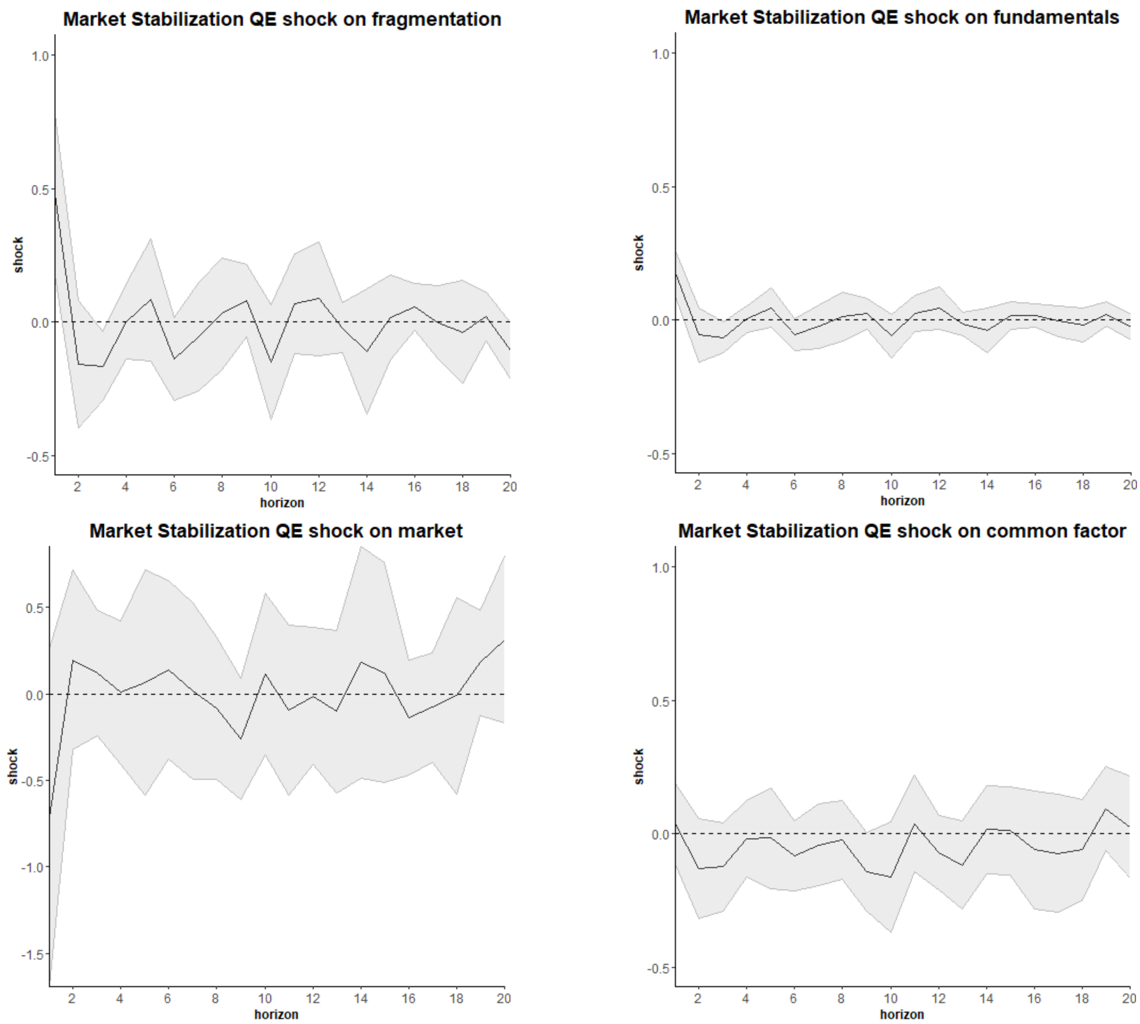
[17] The short-term shock refers to the impact of announcements on the short-term rates while the Forward Guidance mostly accounts for changes in 2-year OIS. This is, therefore, out of my scope, as this paper assesses long-term yields.

[18] The Italian bond is used as a reference for countries negatively affected by market stress conditions, given that Italian credit spreads widened significantly during those episodes. The analysis by Motto and Ozen (2021) includes four Euro Area countries: Germany, France, Italy and Spain, where some robustness checks were applied by changing the opposite movement restrictions to Spain vs OIS. Additionally, the authors found Market Stabilization QE also loads negatively on Spanish sovereigns.

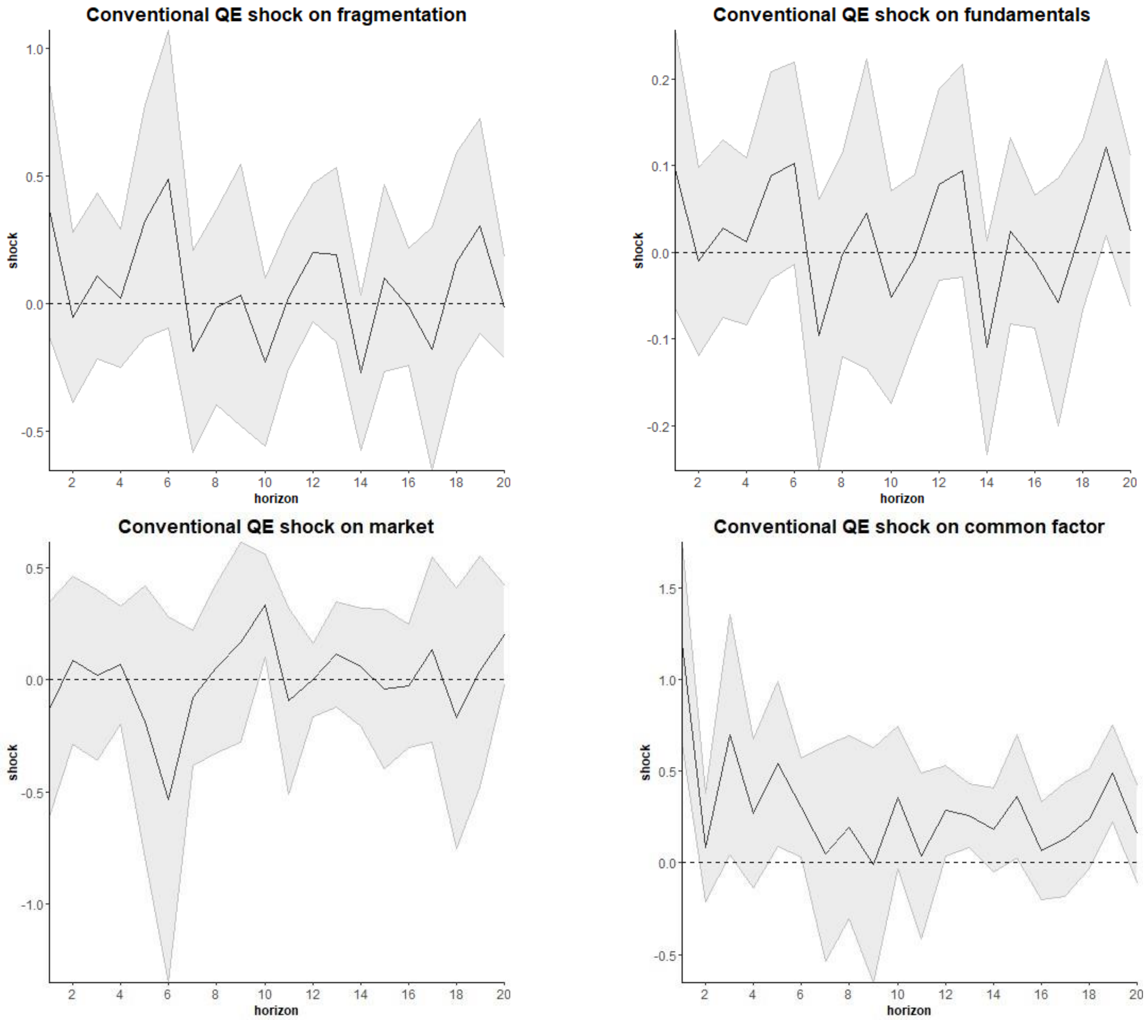
Figure 8b illustrates a similar exercise but looks at the impulse response functions of the four latent factors to a Conventional QE shock. The charts confirm the second hypothesis of a significant response in the common sovereign factor to conventional QE shocks. The intuition behind this is the following: the estimated common factor reflects long-term sovereign yields general dynamics, being close to risk-free rates. Conventional quantitative easing targets a general reduction of (long-term) sovereign yields as it absorbs part of its duration risk, which resulted in a drastic reduction of bond yields after the implementation of such monetary policy measures. To summarize, my estimates show that accommodative ECB announcements can help reduce sovereign fragmentation and therefore, play a relevant role in stabilizing markets.

Figure 8: Impulse responses to a one standard deviation Monetary Policy Shock (MPS) using local projections

a) Responses to a Market Stabilization shock



b) Responses to a Conventional QE shock



Source: own computations using market-stabilization and conventional QE shocks as represented in Figure A7 in Annex.

5 Robustness

I do several robustness analyses based on potential endogeneity and the comparison of results using different specifications.

Estimated effects of the latent factors on yields divergence and country yields (Tables 2 and 3 in section 4) could be subject to endogeneity concerns, especially regarding the fundamentals factors. For instance, country's debt growth or ratings are affected by yields evolution. For that reason, I propose a two-stage least square (2SLS) approach and the use of lagged factors[19] as instrumental variables. That way, in the first stage I can test the null hypothesis of weak instruments and, in the second stage, I obtain the estimated effects of such instruments on country yields. The results are summarized in Table 4 and confirm instruments are good

[19] I use lag 5, which can be related to last week values.

enough and there are no endogeneity issues. I later compare (Table 5) the estimated coefficients using both OLS regressions and 2SLS, which pointed to very similar results.

Table 4: Weak instruments and Wu-Hausman tests for endogeneity (daily frequency)

	Weak instruments (common)	Weak instruments (fundamentals)	Weak instruments (fragmentation)	Weak instruments (market)	Wu-Hausman
DE	154,345.21***	34,413.28***	27,443.11***	9,066.05***	5.72***
FR	154,345.21***	34,413.28***	27,443.11***	9,066.05***	12.54***
IT	154,345.21***	34,413.28***	27,443.11***	9,066.05***	11.45***
ES	154,345.21***	34,413.28***	27,443.11***	9,066.05***	13.26***
NL	154,345.21***	34,413.28***	27,443.11***	9,066.05***	2.49***
AT	154,345.21***	34,413.28***	27,443.11***	9,066.05***	9.02***
BE	154,345.21***	34,413.28***	27,443.11***	9,066.05***	7.07***
PT	154,345.21***	34,413.28***	27,443.11***	9,066.05***	9.37***
FI	154,345.21***	34,413.28***	27,443.11***	9,066.05***	6.39***
sd yields	154,345.21***	34,413.28***	27,443.11***	9,066.05***	8.39***

Test statistic ***,**,* denote rejection at 1%,5% and 10% significance level. The null hypothesis is weak instruments and endogeneity (Wu-Hausman test).

Table 5: Country regressions using 2SLS and OLS
(Instrumental variables are the 5th lag of each factor)

	Germany 10-y		France 10-y		Italy 10-y		Spain 10-y		Netherlands 10-y	
	OLS	2SLS	OLS	2SLS	OLS	2SLS	OLS	2SLS	OLS	2SLS
common	0.945***	0.945***	0.977***	0.976***	0.940***	0.941***	0.941***	0.941***	0.956***	0.955***
	(0.002)	(0.002)	(0.001)	(0.001)	(0.004)	(0.004)	(0.003)	(0.003)	(0.002)	(0.002)
fundamentals	-0.176***	-0.175***	-0.104***	-0.104***	0.105***	0.103***	0.168***	0.167***	-0.151***	-0.151***
	(0.002)	(0.002)	(0.001)	(0.001)	(0.004)	(0.004)	(0.003)	(0.003)	(0.002)	(0.002)
fragmentation	-0.222***	-0.223***	-0.137***	-0.137***	0.162***	0.163***	0.224***	0.225***	-0.187***	-0.187***
	(0.002)	(0.002)	(0.001)	(0.001)	(0.004)	(0.004)	(0.003)	(0.003)	(0.002)	(0.002)
market	-0.113***	-0.111***	-0.098***	-0.097***	0.027***	0.031***	0.015***	0.019***	-0.138***	-0.138***
	(0.002)	(0.002)	(0.001)	(0.001)	(0.004)	(0.004)	(0.003)	(0.003)	(0.002)	(0.002)
Observations	4,366	4,361	4,366	4,361	4,366	4,361	4,366	4,361	4,366	4,361
Adjusted R2	0.986	0.986	0.993	0.993	0.922	0.922	0.964	0.964	0.990	0.990

	Austria 10-y		Belgium 10-y		Portugal 10-y		Finland 10-y		std 10-y	
	OLS	2SLS	OLS	2SLS	OLS	2SLS	OLS	2SLS	OLS	2SLS
common	0.964***	0.964***	0.985***	0.985***	0.743***	0.744***	0.947***	0.947***	0.242***	0.242***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.005)	(0.005)	(0.002)	(0.002)	(0.006)	(0.006)
fundamentals	-0.116***	-0.116***	-0.028***	-0.029***	0.345***	0.341***	-0.159***	-0.159***	0.520***	0.519***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.005)	(0.005)	(0.002)	(0.002)	(0.006)	(0.006)
fragmentation	-0.169***	-0.169***	-0.065***	-0.065***	0.481***	0.484***	-0.214***	-0.215***	0.696***	0.696***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.005)	(0.005)	(0.002)	(0.002)	(0.006)	(0.006)
market	-0.144***	-0.145***	-0.124***	-0.124***	0.060***	0.060***	-0.138***	-0.138***	0.191***	0.192***
	(0.001)	(0.001)	(0.001)	(0.002)	(0.005)	(0.005)	(0.002)	(0.002)	(0.006)	(0.006)
Observations	4,366	4,361	4,366	4,361	4,366	4,361	4,366	4,361	4,366	4,361
Adjusted R2	0.992	0.992	0.991	0.991	0.907	0.907	0.988	0.988	0.849	0.849

Test statistic ***,**,* denote rejection at 1%,5% and 10% significance level. P-values in parenthesis

Moreover, in section 4.3, I checked the responses of latent factors to MP shocks (i.e., Conventional and Market Stabilization QE). I also estimate an alternative local projection specification, inspired by Kakes and Williams, (2023) that accounts for the influence of the other factors, as shown in equation 10.

$$\Delta Latent\ factor_{t+h} = \alpha_t + \varphi_h MP_t + \beta^j Factor_t^{j \neq F \in \{1,2,3,4\}} + \gamma^j Factor_{t-1}^{j \neq F \in \{1,2,3,4\}} + \epsilon_{t+h} \quad (10)$$

Where MP_t is either Market stabilization QE or Conventional QE shock, and the latent factors F includes the common, market, fundamentals, and market factor as daily first differences. $Factor_t^{j \neq F \in \{1,2,3,4\}}$ denotes the matrix of the other factors. Figure A4 (Annex) provides the results, which are aligned with the ones obtained in section 4.3 and illustrated in Figure 8.

Moreover, I compare the estimated latent factors using different models. The results are shown in Figure A5 (Annex) and confirm that similar conclusions can be derived. Therefore, analogous patterns are observed.

6 Conclusions

I provide a new, high-frequency index to measure sovereign market fragmentation in the euro area, excluding other sources of yield divergence arising from either fundamentals or market conditions. The estimates are based on a restricted PCA, which permits gathering four latent factors of euro area yields: common factor, fundamentals divergence, market conditions, and fragmentation.

Accordingly, the proposed fragmentation index constitutes a crucial indicator for monetary policy, that could be monitored by National Central Banks (NCBs). This work is aligned with the main objective of some backstop measures, such as the TPI. Hence, it purely obeys the mandate of measuring disorderly market dynamics related to sovereign yields divergences not warranted by fundamentals. In that sense, an increase in the fragmentation factor would raise concerns about the effective transmission of monetary policy.

The results suggest fragmentation and fundamentals played the most relevant role in explaining yields divergences during the sovereign debt crisis. It lasted for some time, until the implementation of unconventional monetary policy in 2015. Conversely, during the COVID-19 crisis, the fragmentation index rose very rapidly but during a very short period of time, thanks to rapid ECB intervention. Another important finding relates to the opposite effect of fragmentation, fundamentals and market factors on sovereign yields along periphery and core countries, but also during different economic regimes. On the one hand, the common factor has been the main contributor to sovereign yields along the euro area for the full period and especially, after the implementation of Unconventional Monetary Policy. On the other hand, fragmentation has been the main driver of yields during the Sovereign Debt crisis episode while market conditions have been relevant in the COVID-19 crisis.

Finally, this paper also provides relevant conclusions about the role of ECB in stabilizing markets. I employ monetary policy shocks by Motto and Ozen (2021) as a quantitative indicator of ECB announcements, specifically those related to Quantitative Easing (QE) and Market Stabilization QE. The results point to a significant effect of Market Stabilization QE on fragmentation and, to a lesser extent, on fundamentals while QE announcements only affect the common factor. This is consistent with the idea of the common factor as a risk-free rate measure for long-term sovereign yields.

Currently, the fragmentation index stays at low historical levels but it is crucial to monitor its evolution to mitigate the adverse effects of self-reinforcing dynamics observed in past financial crises. Moreover, in the context of monetary policy normalisation, it is extremely relevant to ensure market functioning and the good transmission of monetary policy.

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Annex: Additional tables and figures

Table A1: Correlation between fundamentals, sovereign yields and VSTOXX

	DE	FR	IT	ES	NL	AT	BE	PT	FI	gdp growth divergence	debt growth divergence	rating divergence	gdp growth forecast divergence	deficit forecast divergence	HICP forecast divergence	VSTOXX
DE	1.00															
FR	0.99	1.00														
IT	0.81	0.88	1.00													
ES	0.80	0.86	0.95	1.00												
NL	1.00	0.99	0.83	0.82	1.00											
AT	0.99	1.00	0.86	0.84	1.00	1.00										
BE	0.96	0.99	0.91	0.90	0.98	0.99	1.00									
PT	0.51	0.61	0.82	0.87	0.54	0.58	0.69	1.00								
FI	0.99	0.99	0.83	0.81	1.00	1.00	0.97	0.52	1.00							
gdp growth divergence	-0.11	-0.09	-0.06	-0.03	-0.10	-0.08	-0.06	-0.01	-0.09	1.00						
debt growth divergence	0.19	0.24	0.37	0.46	0.22	0.23	0.31	0.54	0.19	0.09	1.00					
rating divergence	0.03	0.13	0.48	0.54	0.06	0.10	0.23	0.78	0.04	-0.02	0.03	1.00				
gdp growth forecast divergence	-0.20	-0.15	0.04	0.11	-0.19	-0.16	-0.07	0.30	-0.20	0.62	0.28	0.22	1.00			
deficit forecast divergence	0.67	0.66	0.54	0.55	0.68	0.67	0.66	0.36	0.67	0.20	0.29	-0.67	0.20	1.00		
HICP forecast divergence	-0.03	-0.02	0.09	-0.02	-0.03	-0.02	-0.03	-0.09	0.00	-0.09	-0.15	0.19	0.00	-0.10	1.00	
VSTOXX	0.23	0.27	0.28	0.28	0.27	0.31	0.33	0.28	0.28	0.28	0.25	-0.34	0.23	0.44	-0.12	1.00

<0.2	0.2-0.4	0.4-0.7	> 0.7

Source: Bloomberg, SDW, Consensus Economics, European Commission, and own computations.

Table A2: Tests for number of cointegrated factors using different data combinations

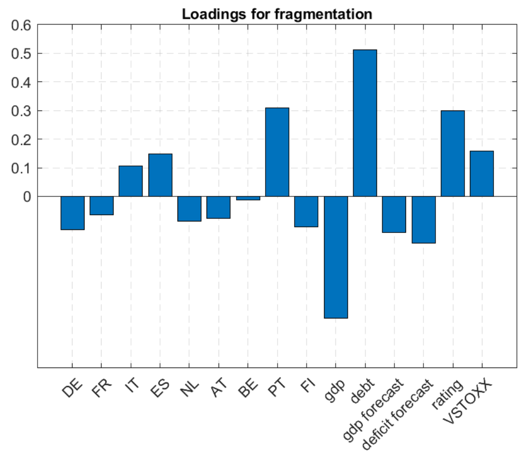
	Model 1	Model 2	Model 3
r <= 4	19.29**	4.33	25.87***
r <= 3	34.34***	17.6*	48.41***
r <= 2	57.65***	34.04***	93.32**
r <= 1	103.15***	58.4***	145.3***
r = 0	167***	98.96***	223.05***

Test statistic ***,**,* denote rejection at 1%,5% and 10% significance level.
Model 1: only observed fundamentals with rating.
Model 2: observed fundamentals without rating.
Model 3: observed and forecast fundamentals with rating (final model).

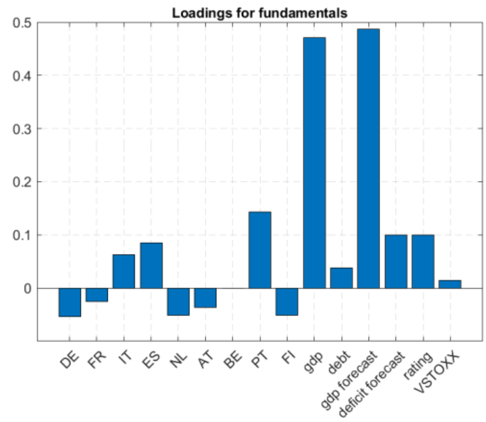
Note: I apply the Johansen Cointegration test, which gives the number of cointegrated vectors, i.e., multiple linear combination of time series; r≤n tests for the existence of n number of factors (or linear combinations), where n should be lower than k (total number of variables in the PCA).

Figure A3: Rotated loadings for fragmentation and fundamentals factor

a) fragmentation



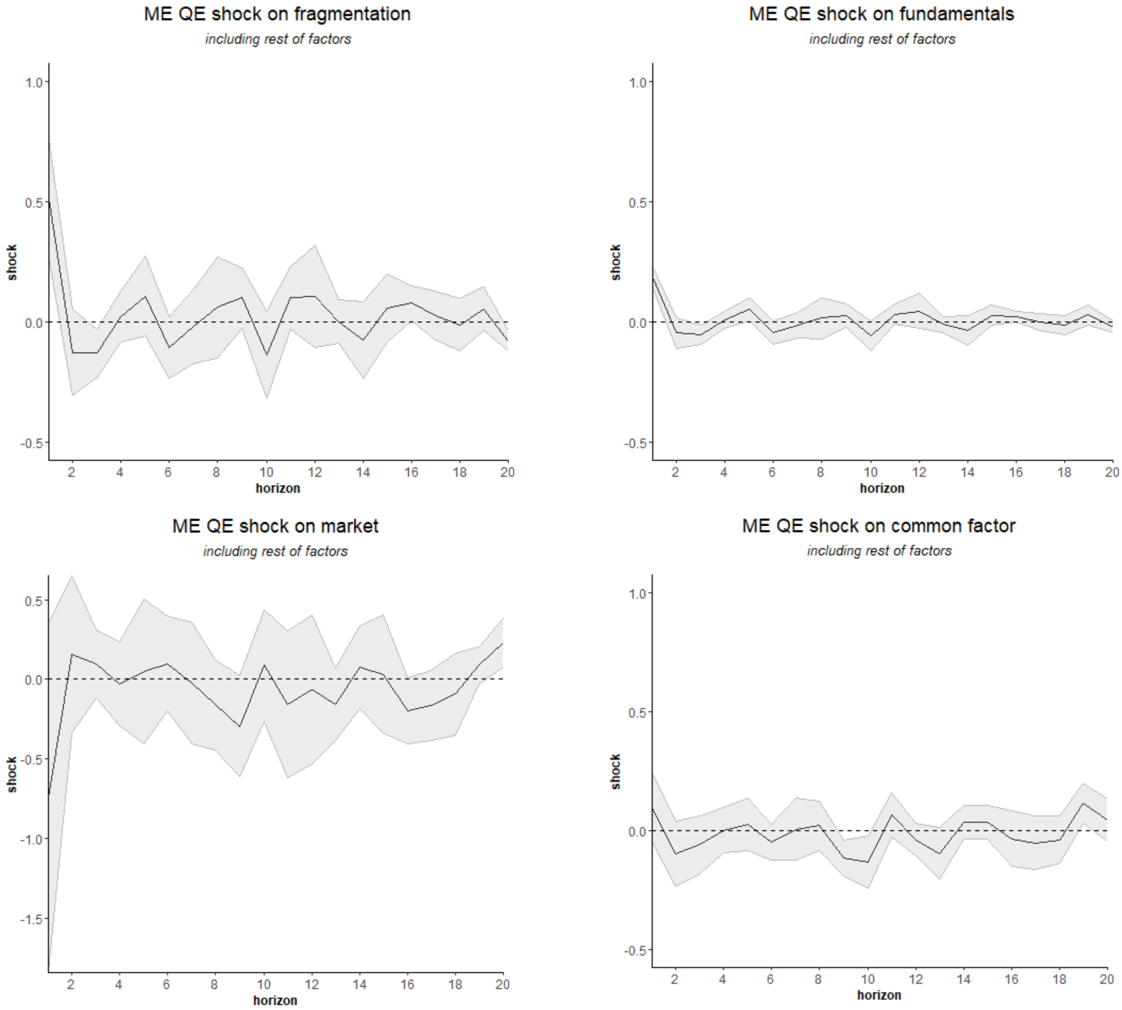
b) fundamentals loadings



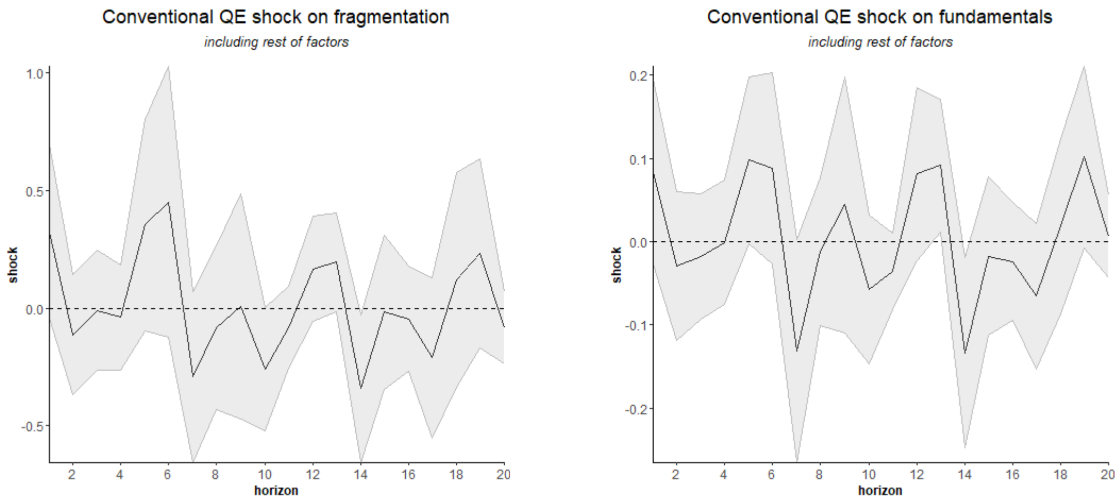
Source: author's computations. Estimated rotated loadings as specified in section 3.4.

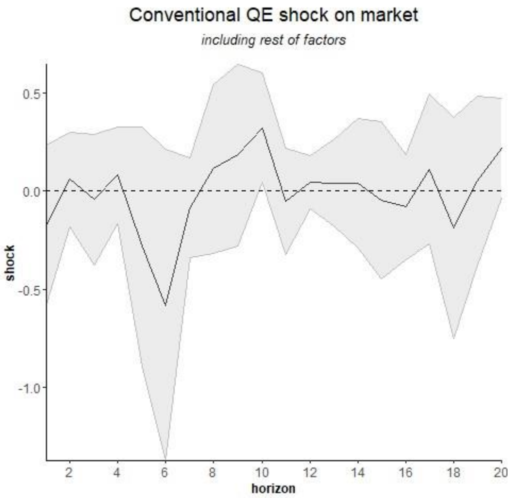
Figure A4: Impulse responses to a one standard deviation MPS using local projections, controlling for other factors

a) Responses to a Market Stabilization shock



a) Responses to a Conventional QE shock




Conventional QE shock on market
including rest of factors
shock
horizon
0.5
0.0
-0.5
-1.0
2
4
6
8
10
12
14
16
18
20

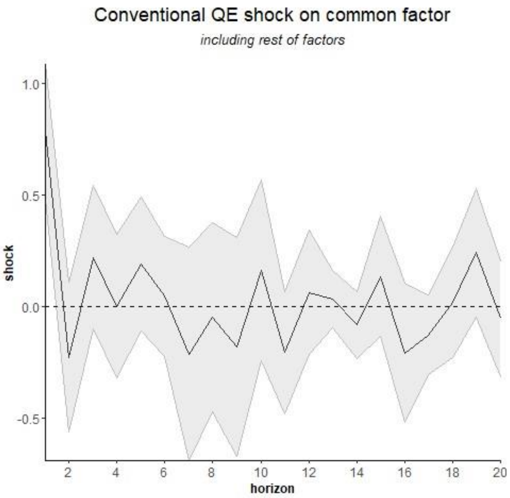
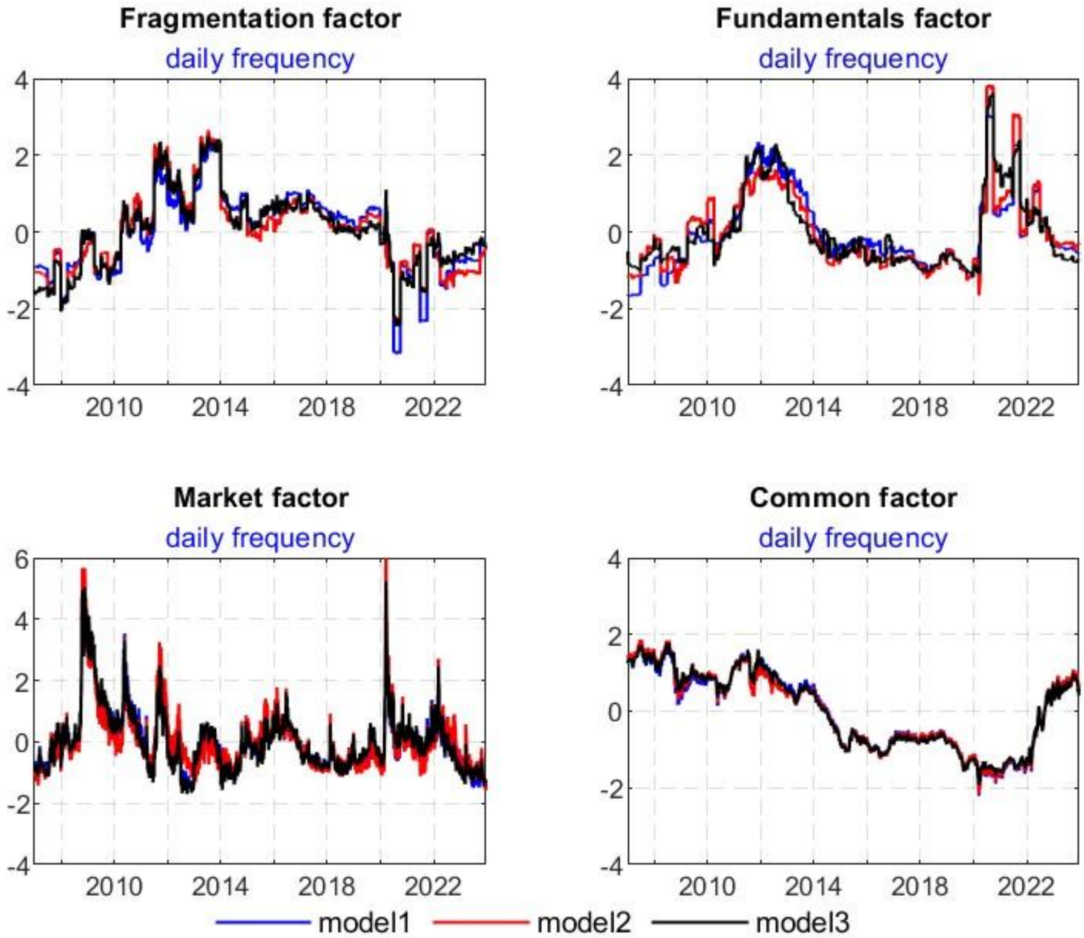
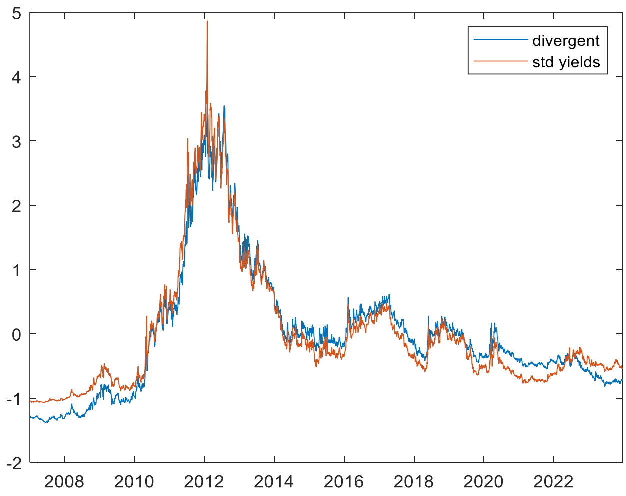

Conventional QE shock on common factor
including rest of factors
shock
horizon
1.0
0.5
0.0
-0.5
2
4
6
8
10
12
14
16
18
20

Figure A5: Comparison of factors using different models



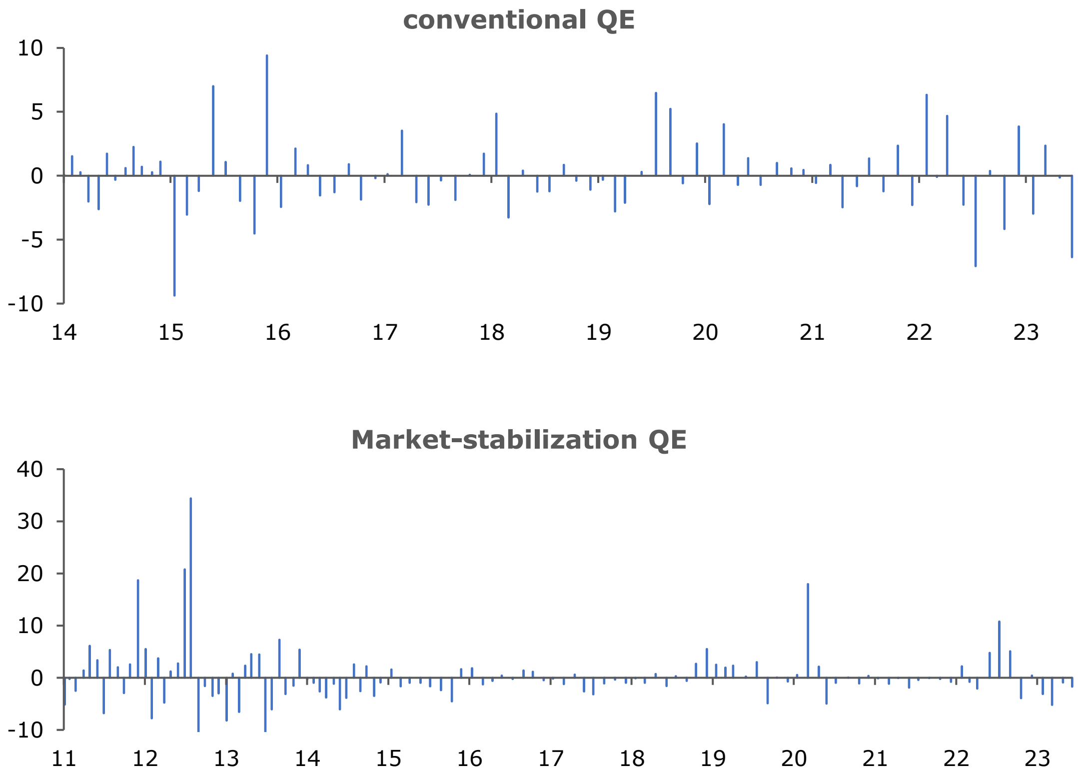
Source: own computations.
Model 1: only observed fundamentals with rating; Model 2: observed fundamentals without rating; Model 3: observed and forecast fundamentals with rating (final model).

Figure A6: Comparison of yields divergence measures



Source: author's computations. The orange line (std yields) shows cross country standard deviation of yields and the blue line (divergent) illustrates the second principal component of a PCA with 2 factors, being the first one showing the common factor and the second one, the divergences across countries.

Figure A7: Estimated conventional QE and market-stabilization QE factors



Source: own computations based on Motto and Ozen (2021). Estimated factors in basis points. The factors are identified up to scale. Conventional QE and market-stabilization QE are scaled to have unit effect on the 10-year OIS and 5-year Italian sovereign, respectively. Negative values show monetary policy easing while positive values point to policy tightening. Last data: July 2023.