Monetary Information Shocks in a Currency Union

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This paper proposes to identify monetary policy dimensions of a central bank in a currency union. For this purpose, I use the new high frequency dataset EA-MPD to estimate monetary policy surprise factors from the European Central Bank, as perceived by intraday asset price changes. I find that, when considering government bond yield changes in the factor estimation, a significant new factor is unveiled, which captures the fact that the central bank releases country-specific heterogeneous information. To demonstrate the relevance of this finding, I make use of variance and historical decompositions to show the importance of the new factor in explaining monetary policy transmission not only to yield spreads, but also to labor market dispersion and stock market volatility.

With the generalized decline of interest rates after the Great Recession, and more recently with the need for exceptional accommodative monetary policy to face the pandemic's economic consequences, the global economy is currently facing a scenario where most nominal interest rates are zero or close to zero. As of April 2021, the Federal Reserve is setting a target Federal Funds Rate between 0% and 0.25% and the European Central Bank (ECB) has defined its three key policy interest rates between -0.5% and 0.25%, placing both central banks at their Effective Lower Bound (ELB)[1]. When binding, the ELB constraint makes it unsustainable for monetary authorities to lower their policy rates in order to

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[1] In this paper I refer to this phenomenon as ELB, and not Zero Lower Bound (ZLB), given that nominal policy rates can achieve negative values.

face any given adverse shock in the economy. Consequently, when faced with such constraint, central banks may provide accommodative policy by looking into other types of conventional and unconventional policies. To understand the magnitude to which the ELB constrains the economy, it then becomes necessary to assess how alternative types of monetary policy behave in terms of effectiveness on the real economy.

In this paper, I make progress in the assessment of policy effectiveness for the case of a central bank in a currency union, by characterizing the multidimensionality of monetary policy from the ECB. More specifically, I address the question if country-specific developments should be considered in the measurement of ECB monetary policy dimensions, and then estimate the relevance of such inclusion for ECB monetary policy transmission to dynamics in sovereign yield spreads, labor market dispersion and stock market volatility in the currency union.

Addressing such issues, however, requires a clear identification of monetary shocks. Given the fact that central banks try to endogenize their policies as much as they possibly can, this is no easy task. Most monetary shocks stemming from central bank announcements arrive at times when the economy is contemporaneously facing other shocks, making it difficult to distinguish what is caused by the action of the central bank.

A good method to overcome this issue in the identification of monetary shocks is what is known in the literature as the High Frequency Identification approach, which consists in estimating monetary shocks based on asset price changes in narrow windows around central bank announcements. The main assumption behind this method is that the asset price changes around each event are caused entirely by the announcement. This approach has been used in the literature for an extensive set of applications, from studying the control that the Federal Reserve has on interest rates in Cook and Hahn (1989) and in Kuttner (2001), to the estimation of monetary policy multidimensional factors from the Fed through factor rotation methods in Gürkaynak, Sack and Swanson (2005) and Swanson (2021), and more recently the application of a similar methodology for the European case in Altavilla et al. (2019).

To estimate monetary policy factors for the Euro area, in this work I adopt a factor rotation methodology, making use of the recently released high frequency dataset Euro Area Monetary Policy Event-Study Database (EA-MPD), developed by Altavilla et al. (2019), which includes intraday asset price changes around each ECB announcement, from January 1999 to January 2020. In contrast to the above mentioned work, and motivated by empirical evidence that shows how different countries in the currency union react heterogeneously to its central bank announcements[2], in this paper I consider the addition of national government bond yields from Germany, France, Italy and Spain in the set of high frequency data used to estimate the factors, which results in the relevant finding of an additional significant monetary policy factor. This result, along with further factor analysis based on high frequency regressions, implies that monetary policy in a currency union is best characterized as four dimensional, as opposed to the usual three dimensional characterization considered in previous literature.

Given both the methodology chosen and the identification assumptions taken in the construction of the new factor, it comes as a natural interpretation that the factor reflects country-specific heterogeneous information shocks from ECB policies. This paper addresses this interpretation in detail through a narrative account lens and an analysis of how the factor loads on different assets, and additionally considers alternative interpretations, making use of high frequency regressions and ECB Taylor rule estimations augmented with country-specific information to find that the new factor indeed measures the ECB policy decisions that release national-level information of currency union members, ultimately reflecting a fundamental difference between the Federal Reserve and the ECB.

Taking into account the addition of the new factor, I then propose to demonstrate the relevance of this finding by estimating the shares of variance explained

[2]This evidence is described in detail in Section II.A.

by each factor in variables such as government bond yield spreads, labor market dispersion and stock market volatility. This is done firstly for high frequency asset price changes around ECB announcements, and posteriorly for monthly series, by estimating a local projection using each factor as an exogenous shock one at a time, and then computing forecast error variance decompositions (FEVDs) and historical decompositions (HDs), to measure both the overall variance shares explained by each factor and the impact of the factor over time. The respective results show the importance of the new factor in explaining how central bank communication contributes to divergences within the currency union, especially since crucially different conclusions are taken when following previous literature, which does not consider national bond yields in the factor estimation, and consequently does not take into account the new factor.

This paper is organized as follows. Section I summarizes the related literature and highlights the contribution of this work. Section II describes in detail both the data used and the methodology followed to estimate the unique set of significant structural factors, and analyzes the estimated factors. In Section III, I define the local projection specification considered and analyze the respective results, including a discussion of several robustness checks from variations to my proposed methodology. Finally, Section IV concludes with recommendations for future research.

I. Literature Review

This work relates to five main branches in the literature. Firstly, and more generally, it is based in an event study approach that aims to empirically assess the effectiveness of different forms of monetary policy on the real economy in the Euro area. Other event study based works asking related questions include Andersson and Hofmann (2009), who found that the ECB policy effects on German bond yields are not as significant as the effects of Federal Reserve announcements on US bond yields, Eser and Schwabb (2016), who studied the impact of asset purchases inserted in the Securities Markets Programme of the ECB, and the comprehensive analysis of 20 years of ECB monetary policy in Hartmann and Smets (2018).

In relation to the adopted methodology, this paper can be associated to literature that makes use of High Frequency Identification (HFI) methods to quantify the effects of monetary policy shocks. Relevant works in this category include Kuttner (2001) and more recently Nakamura and Steinsson (2018), both considering US data, but also Brand et al. (2010) and Andrade and Ferroni (2018), who analyzed high frequency intraday data around ECB announcements. More specifically, this work is included in a sub-branch of the HFI literature that estimates monetary policy surprise factors from asset price changes around central bank announcements. This methodology was pioneered by Gürkaynak, Sack and Swanson (2005) and developed by Swanson (2021), both using US data around FOMC announcements. More recently, Altavilla et al. (2019) used this methodology for their EA-MPD dataset.

Furthermore, I use the estimated factors in a local projection framework to measure the shares of variance accounted by each of the factors in dynamics of yield spreads, a measure of aggregate unemployment rate dispersion in the currency union and stock market volatility. For this reason, this paper builds on previous literature that estimates forecast error variance decompositions and historical decompositions. Of course, this includes seminal works such as Jorda (2005) and Stock and Watson (2007), but also more recent papers that provide econometric robustness to estimating FEVDs in a local projection framework, as Plagborg-Møller and Wolf (2017) and Gorodnichenko and Lee (2019).

As I propose to measure the relevance of government bond yield spreads in monetary policy transmission with the estimation of the new factor, this work relates to literature that has shown the importance of spreads or national asymmetries for a central bank in a currency union. On the theoretical side, this includes Benigno (2009) and Bhattarai, Lee and Park (2015), whereas empirical works on this topic include Bouvet and King (2013) and Theobald and Tober (2019).

Lastly, a good theoretical foundation for the issues discussed in this paper is found in the Optimum Currency Area (OCA) literature, as pioneered by Mundell (1961), which defines a set of optimality conditions for a currency union, among which high symmetry in economic shocks. Later in the OCA literature, Bayoumi and Eichengreen (1992) consider the loss of national-level monetary policy as a significant cost for a currency union as the Euro area, given the inherent asymmetry in shocks. A good illustration of this asymmetry is the European debt crisis period, which made it clear that the periphery countries with persistently increasing borrowing costs demanded specific action by the ECB.

The contribution of this work to the existing literature lies in two main aspects. Firstly, I identify a new monetary policy factor from the ECB by including government bond yield changes in the high frequency data used for the factor estimation. This new factor reflects the ECB-specific communication that signals different information related to distinct member states in the Euro area, empirically measuring the cost highlighted by the OCA literature, and it is particularly significant during the European debt crisis. Secondly, I use these estimated factors as exogenous shocks in a local projection setting, which allows me to determine the dynamic effects of different types of ECB communication, or monetary policy dimensions, on the real economy and specifically on yield spreads, labor market dispersion and stock market volatility.

II. ECB Information Shocks

In order to achieve the objectives of this paper, I propose a methodology divided in two main parts.

In the first part, described in this section, I estimate monetary policy factors, which represent different policy dimensions of the ECB, by considering asset price changes around ECB Governing Council announcements, reflecting both the term structure of risk-free interest rates and the cross-country structure of government bond yields. The hypothesis behind this methodology is that including government bond yields data in the estimation will unveil a new factor that measures the release of currency union-specific central bank heterogeneous information regarding its member states.

As for the second part, which is described in detail in Section III, I quantify the explanatory power of each of these identified factors on the real economy, specifically on stock market volatility and a measure of aggregate unemployment spread in the Euro area, by developing a local projection framework that enables me to analyze the relevance of each estimated factor for dynamics in such variables.

A. Factor Estimation

To construct measures of monetary information shocks from the ECB, I make use of the recently made available EA-MPD dataset, which includes intraday asset price changes for both Press Release and Press Conference windows[3] for the whole history of ECB Governing Council announcements. The assets covered in the dataset are Overnight Index Swap (OIS) rates with 1, 3 and 6 month, 1 to 10, 15 and 20 year maturities, German bond yields with 3 and 6 month, 1 to 10, 15, 20 and 30 year maturities, French, Italian, and Spanish bond yields with 2, 5 and 10 year maturities, as well as stock price indices and exchange rates.

I consider data spanning 269 announcements from the ECB Governing Council, from January 1999 to January 2020. Due to significant noise in the data unrelated to monetary shocks, I remove all observations before 2002 and the two first observations after the Great Recession in 2008. I use this dataset to estimate the latent monetary policy surprise factors considering two different variants.

The first variant follows Altavilla et al. (2019) and considers asset price changes for OIS of 1, 3 and 6 month, 1, 2, 5 and 10 year maturities. This set of assets is chosen to represent the homogeneous monetary policy surprise effects on the term structure of risk-free interest rates, as shown in Lloyd (2017), since the price

[3] In the Press Release, the ECB announces the policy decision, and the Press Conference follows with an explanation for the decision, along with further considerations about the future outlook of the economy.

of an OIS of maturity h at time t is given by $p_t^h = \mathbb{E}_t\left(i_{t+h}\right) + \zeta_t^h$, where $\mathbb{E}_t\left(i_{t+h}\right)$ is the expected Euro area short-term interest rate at time $t+h$ and ζ_t^h is the respective risk premium. Consequently, the price change in such an OIS contract, after a window of length Δ around a central bank announcement, reflects the expectation revision from the markets in relation to the interest rate at $t+h$:

$$p_t^h - p_{t-\Delta}^h = \Big[\mathbb{E}_t\left(i_{t+h}\right) - \mathbb{E}_{t-\Delta}\left(i_{t+h}\right)\Big] + \Big[\zeta_t^h - \zeta_{t-\Delta}^h\Big] \approx \mathbb{E}_t\left(i_{t+h}\right) - \mathbb{E}_{t-\Delta}\left(i_{t+h}\right)$$

assuming that the risk premium is unaffected by the announcement, or $\zeta_t^h \approx \zeta_{t-\Delta}^h$.

For the second variant, I use an alternative set of data which considers both the selection of asset prices included in the first variant and 10 year government bond yields for Germany, France, Italy and Spain. This set of assets represents both homogeneous and heterogeneous surprises from central bank announcements, since the yield of a national government bond of maturity h at time t for country c, $i_t^{c,h}$, depends on the market expectations of the future path of the country's short-term interest rates:

$$i_t^{c,h} = \mathbb{E}_t\left[\frac{1}{h}\sum_{j=1}^{h} i_{t+j}^c\right] + \phi_t^{c,h}$$

where $\phi_t^{c,h}$ reflects the respective term premium for country c.

Following the same reasoning as for the OIS price changes, and assuming the term premium does not change with the announcement, the government bond yield changes will measure market expectation revisions relative to country c up to time $t+h$:

$$i_t^{c,h} - i_{t-\Delta}^{c,h} \approx \frac{1}{h}\sum_{j=1}^{h}\Big[\mathbb{E}_t(i_{t+j}^c) - \mathbb{E}_{t-\Delta}(i_{t+j}^c)\Big]$$

This alternative procedure is motivated by the observable fact that in many ECB announcements, especially around the time of the European debt crisis, national bond yields moved abruptly in opposite directions. When considering every ECB announcement in the sample, the correlation of Italian and German yield changes is around 41%, and when considering the debt crisis subsample, from January 2011 to December 2012, the same correlation has the negative value of -35%. At the same time, the changes in OIS rates do not change significantly for this subsample when compared to the rest of the sample. This can be observed in Figure 1, which plots the difference of changes around ECB events in the 10 year government bond yields for Italy, France and Spain, when compared to the changes in the equivalent German yield. We can observe that up until the Great Recession there was comovement in the national yields reaction, whereas from then on, and especially around the debt crisis, there was a significant disparity in how each country's yield reacted to ECB announcements.

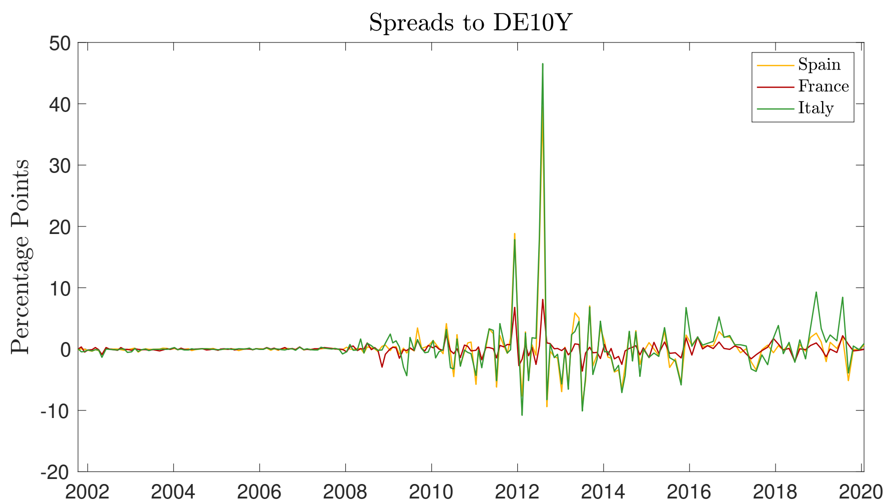

Figure 1. Asset price variations around ECB Press Conference windows

Note: This plot presents the difference in asset price changes of Spanish, French and Italian 10 year government bond yields around ECB Press Conference Windows, from October 2001 to January 2020, to the respective changes in German 10 year government bond yields.

I then hypothesize that my variant methodology for estimating the factors will unveil a new factor that can account for these heterogeneous effects, and represents the currency union-specific policy communicated by the ECB that releases diversified information relative to each of the countries in the currency union, as perceived by financial market participants. By doing so, I will be able to account for both homogeneous and heterogeneous components of ECB communication in the monetary policy factors.

The factor estimation methodology broadly follows Swanson (2021) and it relies on a factor rotation procedure. The idea behind this method is to identify the monetary policy shocks separately, according to the policy type, by taking a T x n matrix X, composed by the high frequency asset price changes around ECB announcements, that reflects short, medium and long-term Euro area risk free interest rates, as well as country-level risk free interest rates for my variant methodology. For this purpose, matrix X is described in terms of a factor model:

$$X = F\Lambda + \varepsilon$$

where F is a T x k matrix containing significant monetary policy factors, Λ is a k x n loadings matrix quantifying the effects of the factors on each of the asset price changes, and ε is a T x n matrix of residuals.

I start by inferring the rank of the unobservable matrix F by conducting the Cragg-Donald (1997) test on matrix of price changes X. This rank gives us an accurate estimate of the number of dimensions that adequately account for the reaction of asset prices to the monetary events. The test was done for both variants considered, and for Press Conference data only, since the type of communication that this work aims to explain takes place during the central bank's press conference window. For each null hypothesis of rank k_0 versus rank $k > k_0$, the test considers all possible factor models with k_0 factors that explain matrix X and chooses the one that minimizes the distance between the residuals ε and a white noise process, with the distance being measured by a Wald statistic. The test results for both variants, which I refer to as X_1 and X_2, are presented in Table 1.

As expected, by considering the same X matrix as in Altavilla et al. (2019), X_1 - only with the addition of new observations from 2019 and 2020 -, I obtain

Table 1—Rank test - with and without government bond yields

	$\mathbf{H_0 : k_0 = 0}$	$\mathbf{H_0 : k_0 = 1}$	$\mathbf{H_0 : k_0 = 2}$	$\mathbf{H_0 : k_0 = 3}$	$\mathbf{H_0 : k_0 = 4}$
$\mathbf{X_1}$	115.33	40.37	18.12	3.57	
	(0.000)	(0.000)	(0.020)	(0.312)	
$\mathbf{X_2}$	177.48	85.16	62.01	43.01	21.04
	(0.000)	(0.000)	(0.002)	(0.014)	(0.224)

Note: The table reports the Wald statistics and associated p-values in parenthesis for the Cragg-Donald (1997) test. The X_1 row refers to using the OIS data as used in Altavilla et al. (2019), while the X_2 row refers to the same set of data with the addition of changes in 10 year government bond yields of Germany, France, Italy and Spain.

very similar results here. Moreover, these results allow us to conclude that by adding the national bond yield data in matrix X_2, a new explanative factor is identified, as hypothesized initially. I interpret these findings as monetary policy being three dimensional when simply considering the changes in OIS rates, and four dimensional when adding the changes in national bond yields.

It should be noted, however, that we cannot infer anything about the factors yet. For this purpose, I estimate the factors for both variants of matrix X. I start by normalizing each column of X to have zero mean and unit variance. Then the set of k factors F are estimated by extracting the k principal components of X, where k is the rank inferred in the Cragg-Donald test above. The k principal components are the first k columns of a matrix of singular vectors U, which is obtained from a singular value decomposition of X:

$$X = U * S * V'$$

The corresponding matrix of loadings Λ is then obtained by multiplying the first k rows of S by V'. Having estimated the set of latent factors, no interpretation of these can yet be given, as they simply result from a statistical procedure. For this reason, I rotate the factors to make them economically interpretable. I consider a unique k x k rotating matrix Z such that structural factors are given by $F^* = FZ$ and structural loadings are given by $\Lambda^* = Z'\Lambda$.

This unique matrix Z is identified by imposing a set of economic conditions which guarantee that the structural factors F^* are orthogonal measures of surprises that represent separate dimensions of monetary policy:

1) Columns of Z have unit length: $Z'_{\cdot i}Z_{\cdot i} = 1 \; \forall i \in \{1, ..., k\}$

2) Columns of Z are orthogonal: $Z'_{\cdot i}Z_{\cdot j} = 0 \; \forall i \neq j \in \{1, ..., k\}$

3) Non-target factors do not load on the 1-month OIS: $Z'_{\cdot i}\Lambda_{\cdot 1} = 0$ for i non-target factors

4) The new factor does not load on any of the OIS assets: $Z'_{\cdot 4}\Lambda_{\cdot m} = 0$ for $m \in \{1, ..., 7\}$

This set of restrictions still does not fully identify the rotation matrix Z. The final restrictions come from a minimization problem. In the case of X_1, where we have $k = 3$ factors, I minimize the variance of the third rotated factor, known in the literature as the QE factor, in the pre-QE period[4], subject to conditions 1) to 3) above. When considering X_2 and its latent $k = 4$ factors, the final identification restrictions come from minimizing the variance of the new unveiled rotated factor in the pre-crisis period, subject to conditions 1) to 4). The fourth condition is unknown to previous literature, and it serves the purpose of isolating the interpretation of the new factor to the effects on the government bond yield changes, in order to identify a “pure” spread shock.[5] The QE period for the Euro area is defined as the sample starting in January 2015. This problem is fully defined in the Mathematical Appendix. The resulting structural factors for both scenarios X_1 and X_2 are plotted in Figure 2, whereas the corresponding structural loadings are presented in Table 2 and Table 3, for X_1 and X_2 respectively.

By observing the structural loadings of each factor, we can see that we have a *target factor* - which loads more significantly on short term assets and reflects information about the current target rate -, a *path factor* - which has loadings

[4]The QE period for the Euro area is defined as the sample starting in January 2015.
[5]Baumeister and Benati (2013) impose similar restrictions on their yield curve “pure” spread shock in a VAR framework.

Table 2—Factor Loadings - without government bond yields

	OIS1M	**OIS3M**	**OIS6M**	**OIS1Y**	**OIS2Y**	**OIS5Y**	**OIS10Y**
Target	1.00	0.68	0.59	0.49	0.41	0.31	0.21
Path	0.00	−0.26	−0.13	0.03	0.28	0.68	1.00
Curvature	0.00	0.75	0.91	0.99	1.00	0.91	0.72

Note: Matrix of structural loadings Λ^* obtained from the factor estimation using matrix X_1. Following Altavilla et al. (2019), the Target factor is normalized to have unit effect on the 1-month OIS; the Path factor is normalized to have unit effect on the 10-year OIS; the Curvature factor is normalized to have unit effect on the 2-year OIS.

Table 3—Factor Loadings - with government bond yields

	OIS1M	**OIS3M**	**OIS6M**	**OIS1Y**	**OIS2Y**	**OIS5Y**	**OIS10Y**	**DE10Y**	**ES10Y**	**FR10Y**	**IT10Y**
Target	1.00	0.70	0.60	0.50	0.40	0.30	0.21	0.18	0.11	0.17	0.12
Path	0.00	0.22	0.35	0.47	0.61	0.81	1.00	1.01	0.48	0.98	0.44
Curvature	0.00	0.89	1.04	1.08	1.00	0.71	0.25	0.17	0.19	0.14	0.14
Spread	0.00	−0.01	0.00	0.00	0.00	0.00	0.00	−0.03	1.00	0.28	1.03

Note: Matrix of structural loadings Λ^* obtained from the factor estimation using matrix X_2. The new Spread factor is normalized to have unit effect on the 10-year Spanish bond yield. The remaining factors follow the initial normalization.

increasing in maturity and mostly reflects information on long term rates - and a *curvature factor* - which has loadings that increase in maturity only up until 2 years and then decrease, and therefore measures mostly medium term expectations. This nomenclature follows related works that unveiled similar monetary policy factors, such as Inoue and Rossi (2018) or Andrade and Ferroni (2018). A natural interpretation of these factors is that they represent different dimensions of monetary policy, and in some works the target factor is naturally associated with interest rate changes, the path factor with Forward Guidance announcements, and the curvature factor with Quantitative Easing announcements.

When considering my variant X_2, we have a new factor, which I have named *spread factor*, given that it only loads significantly in national bond yields, and very differently for each country, as expected. It should be noted that the initial three factors obtained when considering X_1 remain generally unchanged in my variant estimation, both from observing its time series plots and its structural

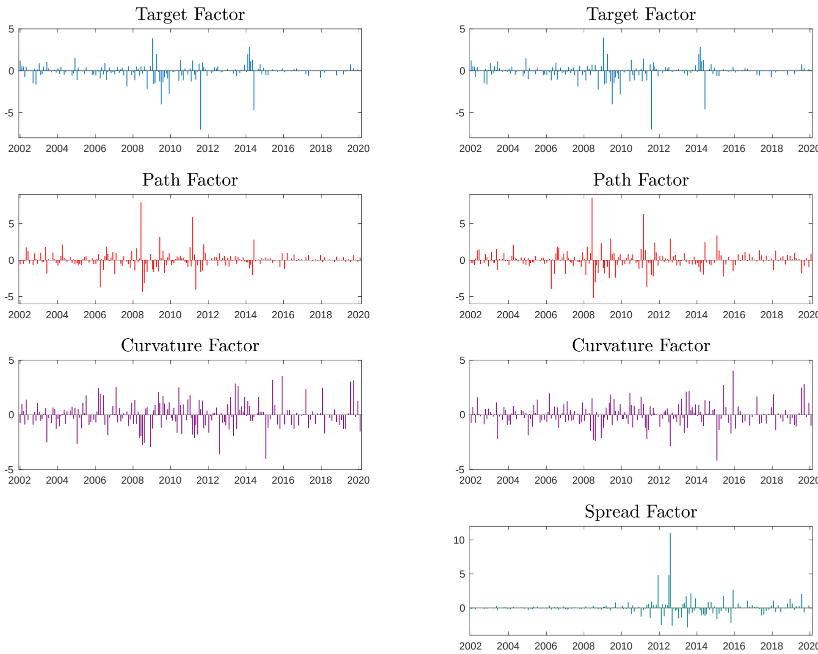

FIGURE 2. FACTORS - WITH AND WITHOUT GOVERNMENT BOND YIELDS

Note: These structural factors F^* are estimated from following the factor rotation methodology described in Section II.A. For the case without national government bond yields, presented in the left panel, I consider matrix X_1 of changes in OIS rates of 1, 3 and 6 month, 1, 2, 5 and 10 year maturities for all ECB announcements from January 2002 to January 2020, with the exception of two events around the Great Recession in 2008. For the case with national government bond yields, presented in the right panel, I use X_2, which considers the addition of changes in 10 year government bond yields of Germany, France, Spain and Italy to the data in X_1. The sample of events remains unchanged.

loadings. This means that my variant estimation is able to identify a new factor, which reflects heterogeneous changes in expectations in the Euro area stemming from ECB announcements, while maintaining the same interpretation for the remaining three factors.

B. Factor Analysis

From a preliminary analysis of the estimated factors and loadings, we can see that the addition of government bond yields to the data in X_1 does not change significantly the initially estimated factors, while revealing a new factor, which is defined by having minimal variance in the pre-debt crisis period. Moreover, besides this new factor, the remaining factors obtained using X_2 have similar loadings to previously reported in related literature, and they correlate very high with the three factors initially obtained in Altavilla et al. (2019)[6]. These facts constitute initial supporting evidence to the hypothesis that monetary policy from the ECB has an additional dimension that reflects central bank actions that lead to cross-country divergences.

In order to investigate the extent to which the new factor is relevant, I measured the relative contribution of each identified factor in explaining the volatility of asset price changes for assets relevant for monetary policy transmission, including OIS futures of different maturities; 2 year, 5 year and 10 year government bond yields and the respective spreads in relation to the german government bond yields of the corresponding maturity; and finally stock market indexes. This was done by measuring the R^2 of regressing the high frequency changes of these asset price changes on each factor, one at a time. The results are presented in Table 4.

When looking at Table 4, we can start by comparing how the common factors target, path and curvature differ in terms of how much of the asset price volatilities is explained by each factor. This is done by comparing the first 3 columns of R^2 values in the table to the first 3 columns of the section section, where $k = 4$. Immediately we see that the numbers do not differ significantly for all the assets considered, again providing evidence that these factors remain relatively unchanged. On top of that, many assets, namely government bond yield spreads and stock market indexes, cannot be explained by any of these three factors in any of the scenarios - $k = 3$ and $k = 4$. In relation to the last column of R^2 values, which measures the volatility of asset price changes that can be explained by the spread factor, we see that this factor does not have any explanative power

[6]The correlation between both Target factors is 99.8%; the correlation between both Path factors is 96.8% and the correlation between both Curvature factors is 91.9%.

Table 4—Variance Decompositions of Asset Price Changes

Assets	**k = 3**			**k = 4**			
	Target	**Curv**	**Path**	**Target**	**Curv**	**Path**	**Spread**
OIS1M	0.99	0.00	0.00	0.98	0.00	0.00	0.00
OIS3M	0.46	0.45	0.01	0.49	0.37	0.04	0.00
OIS6M	0.35	0.63	0.00	0.36	0.50	0.11	0.00
OIS1Y	0.25	0.72	0.02	0.25	0.54	0.19	0.00
OIS2Y	0.16	0.69	0.10	0.16	0.47	0.33	0.00
OIS5Y	0.23	0.15	0.55	0.23	0.04	0.62	0.00
OIS10Y	0.07	0.03	0.90	0.07	0.28	0.93	0.00
OIS15Y	0.02	0.01	0.90	0.02	0.46	0.93	0.29
OIS20Y	0.02	0.01	0.85	0.02	0.47	0.89	0.29
DE2Y	0.12	0.67	0.14	0.11	0.79	0.02	0.00
FR2Y	0.13	0.67	0.12	0.13	0.78	0.01	0.00
ES2Y	0.08	0.38	0.07	0.07	0.48	0.01	0.18
IT2Y	0.06	0.33	0.06	0.06	0.42	0.01	0.28
DE5Y	0.08	0.50	0.36	0.07	0.69	0.14	0.01
FR5Y	0.09	0.46	0.36	0.08	0.65	0.17	0.00
ES5Y	0.04	0.26	0.11	0.04	0.37	0.05	0.39
IT5Y	0.03	0.17	0.09	0.03	0.27	0.06	0.53
DE10Y	0.03	0.24	0.62	0.03	0.42	0.50	0.02
FR10Y	0.03	0.21	0.59	0.03	0.39	0.53	0.02
ES10Y	0.01	0.09	0.14	0.01	0.17	0.15	0.65
IT10Y	0.02	0.06	0.12	0.02	0.13	0.15	0.69
SpIT2Y	0.00	0.02	0.01	0.00	0.01	0.03	0.61
SpES2Y	0.01	0.08	0.03	0.01	0.03	0.08	0.44
SpFR2Y	0.00	0.04	0.05	0.00	0.02	0.06	0.01
SpIT5Y	0.00	0.01	0.03	0.00	0.00	0.04	0.81
SpES5Y	0.01	0.02	0.06	0.00	0.00	0.08	0.69
SpFR5Y	0.00	0.03	0.01	0.00	0.03	0.01	0.14
SpIT10Y	0.00	0.00	0.02	0.00	0.00	0.03	0.94
SpES10Y	0.00	0.00	0.04	0.00	0.00	0.05	0.91
SpFR10Y	0.00	0.00	0.00	0.00	0.00	0.00	0.57
STOXX50	0.00	0.01	0.00	0.00	0.00	0.01	0.32
SX7E	0.00	0.01	0.01	0.00	0.02	0.00	0.44

Note: The table reports R^2 values from regressing $\Delta \mathrm{y_t} = \alpha + \beta \mathrm{F_t^j} + \varepsilon_\mathrm{t}$ for $\mathrm{j} \in \{1, \ldots, \mathrm{k}\}$ using OLS estimation. Each row reflects different assets considered as y_t for the high frequency price changes Δy_t. The first three columns represent the $k = 3$ factors from the estimation considering matrix X_1, whereas the last four columns represent the $k = 4$ factors from my estimation proposed in section II.A.

for OIS futures and german and french government bond yields. However, when looking at assets such as spanish and italian government bond yields, or yield spreads for any of the countries considered, or even - more surprisingly[7] - stock market indexes, we see that this factor is significantly relevant in explaining the corresponding volatilities.

C. A Closer Look at the Spread Factor

My estimation of four factors is successful in distinguishing the dimensions without any overlap, since the new spread factor is independent of all other factors, by construction. For this reason, we can say that the spread factor represents a dimension of policy not entirely reflected by the initial factors, which reflects central bank actions that affect sovereign yields differently and do not have any effect on OIS rates. Taking this into account, a natural interpretation of the factor is that it measures the surprises from ECB policies that include heterogeneous information about the Euro area member states.

Nonetheless, to take a closer look at this factor and hypothesize about possible interpretations, I carry out a narrative event analysis for the spread factor to study specific ECB announcement dates for which this new factor has the highest values. Therefore, I observe the 5 largest values of the factor[8] and corresponding dates, following similar narrative approaches in related literature[9], to relate them to heterogeneous surprises from the respective announcements:

Aug 2, 2012: On this date, the spread factor had a positive value of 12.21. This announcement came a week after the remarkable speech by then ECB president Mario Draghi, when he declared that "the ECB will do whatever it takes to preserve the euro". At the time, countries with increasing borrowing costs such as Italy and Spain were expecting the ECB to provide specific accom-

[7] This finding may be explained by the sensitivity of financial markets to policies reflected by the spread factor, or possibilities that affected government bond yield spreads, since most of these are related to changes in the risk perception of a hypothetical collusion of the currency union.

[8] In Table B5 from Appendix B, the 20 largest observations of the spread factor are discussed in detail.

[9] See Andrade and Ferroni (2018) or Gürkaynak, Sack and Swanson (2005).

modative policy directed at them. Given the speech a week before, the market expectations that the ECB would engage in such a policy on this date were high; however, the ECB did not take any additional measures, instead recommending countries to "push ahead with fiscal consolidation and structural reform"[10]. This resulted in a further significant increase in Spanish and Italian yields, while the German and French yields dropped.

Jul 5, 2012: This announcement preceded the above mentioned speech, and the spread factor had a positive value of 5.19. This is again well explained by inaction from the ECB, since market expectations that the ECB would engage in policy directed at the above mentioned countries were high, and despite a rate cut on this date, no direction was taken to introduce nonstandard moves directed at such countries, such as additional government bond purchases.

Dec 8, 2011: The factor had a value of 5.13 on this date. This coincided with the announcement that the ECB was limiting bond buying, by capping its weekly bond purchases at 20 billion €. This left the periphery countries with high yields significantly dependent on banks to buy their bonds.

Jul 4, 2013: On this date, the value of the spread factor was -2.86. The ECB announced its first Forward Guidance unconventional move on this day, by promising rates to stay low for "an extended period of time". This was interpreted by the markets as a signal that the central bank was finally ready to engage in nonstandard policy aimed at closing the yield spreads between countries.

Sep 6, 2012: The spread factor registered -2.62 on this event. According to a New York Times article following this announcement, on this date "the ECB took its most ambitious step yet toward easing the Euro crisis, throwing its unlimited financial clout behind an effort to protect Spain and Italy from financial collapse". More specifically, on this day the central bank gained support

[10]Citation taken from the introductory statement to the ECB Press Conference in August 2, 2012.

from its Governing Council to buy bonds from sovereign states, which immediately decreased Spanish and Italian bonds considerably.

Given the nature of the positive and negative values from the dates above, and also taking into account the values of the spread factor loadings, positive values of the spread factor may be interpreted as actions that increase spreads in the Euro area, or create divergence, and negative values as actions that close the spreads, or create convergence. Moreover, we can take from the dates of the top values that the factor is more significant around the debt crisis period, when many central bank actions moved government bond yields heterogeneously, as shown initially in Figure 1.

This narrative analysis is not sufficient, however, to pin down one exact interpretation of this new factor. For this reason, I will address two specific possible interpretations. It could be the case, for instance, that the spread factor simply represents the heterogeneous reactions of national yields to homogeneous policy from the ECB, not necessarily motivated by national developments, and as represented by the initial Target, Path and Curvature factors. On the other hand, a second possible interpretation is that the factor might also be representing monetary policy actions motivated by currency union heterogeneities in the Euro Area, which were obvious especially around the debt crisis period.

To investigate the first possible interpretation, I studied how national-level government bond yields reacted to different monetary policy dimensions, by regressing high frequency yield changes for all Euro Area countries[11] on the three initial Target, Path and Curvature factors. To make sure that my estimates capture the effects of both observed and unobserved information released during the announcement window, I estimate these regressions following Rigobon and Sack (2006), and consequently employ a heteroskedasticity-based identification strategy which makes use of the difference in volatility during event windows and

[11] The EA-MPD does not provide data for many of these countries. Therefore I constructed the price changes series by making use of high frequency data from Refinitiv and calculating the respective changes around the ECB Press Conference windows.

non-event windows[12] to estimate the regression coefficients. This results in highly significant coefficients and very high R^2 values. We should take in mind, however, that the interpretation to be taken out of these coefficients should reflect both the effects of the observed information, explicitly released during the ECB press conferences, and the effects of unobserved information during the announcement window.

The results of these national-level regressions are presented in Tables B1 and B2 of the Tables Appendix, respectively for the three initial factors obtained using matrix X_1, and for the four factors obtained using X_2. The estimates suggest that none of the homogeneous policies from the ECB - reflected by the initial target, path and curvature factors - can explain changes in national-level yields, whereas the spread factor accounts significantly for these changes, and very differently for periphery countries such as Italy and Spain, in comparison to core countries such as Germany and France. For this reason, spread-type policies indeed seem to be the only central bank actions affecting market perceptions of national-level default risk. This means that national default risk indicators do not respond to homogeneous ECB policies, and it constitutes further evidence to consider the spread factor as a separate policy dimension.

As for the second possible interpretation, we want to test whether the spread factor may be representing central bank intentions in relation to specific countries, motivated by national-level developments, rather than only looking at aggregate developments in the currency union. To address this possibility, I assume that the ECB sets its policy rate according to a simple Taylor rule of the form:

$$i_t = \alpha + \rho i_{t-1} + \phi_\pi \pi_t^{EUR} + \phi_x x_t^{EUR} + \varepsilon_t$$

The specification above was chosen since it is commonly used in previous literature, as discussed in Sauer and Sturm (2003) and Belke and Klose (2011), but

[12] In my estimation, I considered non-event windows at the same time of the day from ECB press conference windows, but exactly one week before each announcement, when there is no central bank announcement occurring.

also since it proved to be the best among the alternatives considered in terms of fit[13], and since it avoids multicollinearity issues. I assume that the information set of aggregate developments in the currency union considered by the central bank is well encapsulated by the specification above.

The regression was estimated using quarterly data obtained from Eurostat. More specifically, HICP and GDP quarterly data was collected to compute inflation and output gap series as defined by the following transformations:

$$\pi_t = 100\left[\log\left(HICP_t\right) - \log\left(HICP_{t-4}\right)\right]$$

$$x_t = 100\left[\log\left(y_t\right) - \log\left(y_t^*\right)\right]$$

where y_t reflects nominal GDP and y_t^* reflects potential output. The latter is estimated by detrending the actual GDP series with an HP filter with smoothing parameter of 1.600.

In relation to the policy rate i_t, a quarterly series of a Euro area-level short term shadow rate was considered, as estimated in Wu and Xia (2016). This series is equal to the 3-month Euro area money market interest rate in non-ELB times, and to a counterfactual series that represents unconventional monetary policy actions during ELB times, which started in the Euro area in 2014. As for possible national considerations in the ECB asset purchase policies, the national shares adopted by the central bank are institutionally defined by a capital key rule, which depends only on national population and economic activity indicators, making it difficult to explicitly measure such changes in ECB intentions. However, it is still possible that unconventional policy decisions were also motivated by national developments, and using the shadow rate as the policy instrument i_t means that we account for both standard and non-standard monetary policy actions.

[13] Alternative specifications considered additional lags of the monetary policy instrument i_t and expectations of future inflation and output gap values, as measured by forecasts from the Survey of Professional Forecasters.

The estimation of the Taylor rule specification was done using GMM[14], considering first lags of national inflation and output gap series as instruments. To evaluate if the ECB changed its consideration about specific countries during the debt crisis, as the spread factor suggests, I augmented the initial Taylor rule with national level information in the form of interaction terms $\pi_t^i * D_t$ and $x_t^i * D_t$ to the regression specification, where D_t is a dummy variable that takes values of 1 in debt crisis observations. This was done separately for each country in the currency union, and the respective estimates are included in Table B3. These results show that generally the ECB was more reactive to output gap than inflation, and most importantly that national-level information during the debt crisis was considered in the central bank's information set, instead of considering only aggregate developments. This is especially evident in periphery countries such as Italy, Greece and Portugal, and it suggests a shift in ECB intentions relative to specific countries.

For robustness purposes, and to avoid possible multicollinearity issues, an additional method was considered, where the residuals from the initial simple form of the Taylor rule, consisting of aggregate information only, are regressed on the same country-specific information, $\pi_t^i * D_t$ and $x_t^i * D_t$. The respective estimates are presented in Table B4, and the findings are identical to the takeaways from Table B3.

According to the evidence presented above, it seems more adequate to interpret the spread factor as release of heterogeneous information by the ECB, motivated by national developments in the Euro area, rather than a reflection of different national sensitivities to common central bank policy.

[14]Carvalho et al. (2019) show that both OLS and IV estimation of Taylor rules produce estimates close to the true parameter values.

III. Dynamic Effects on the Real Economy

A. Local Projection Analysis

Now that the structural factors and respective loadings are identified, we might ask ourselves "why are these factors useful?". A good answer is that, as explained in Section II, each of the factors reflects a different type of monetary intervention, and together they account for the multidimensionality of monetary policy. For this reason, the estimated factors series can be used to quantify the relevance of these different monetary policy dimensions on the real economy. In this section, I propose to do so, with special focus on labor market divergences and stock market dynamics within the Euro area, using a local projection approach.

Some of these aspects were addressed in section II, but only by looking at the respective high frequency asset price changes around central bank announcements. In this section, however, monthly series will be considered to check for the persistence of the relevance of each shock in accounting for variations in these variables that are key to monetary policy transmission, by computing Forecast Error Variance Decompositions (FEVDs), and the respective variation of effects throughout time, by computing Historical Decompositions (HDs).

Since the factors were constructed as time series for each ECB announcement, it is necessary to first convert them to monthly frequency to use them in a monthly local projection. One way of doing so is to follow Gertler and Karadi (2015), and for each day of the month cumulate the factors of the last 31 days, and then create the monthly value as the average of the daily cumulated values of each month. However, as mentioned in Ramey (2016), the Gertler-Karadi conversion may result in serial correlation of the shocks, which is not desirable given that the shocks are supposed to capture only unanticipated changes in policy[15]. For this reason, I choose to follow the straightforward approach from Eberly, Stock

[15] As a robustness check, I tested for serial correlation in the monthly measures of the factors by using both the Gertler and Karadi (2015) and the Eberly, Stock and Wright (2019) conversion methods. The results are discussed in Section III.B.

and Wright (2019) and simply convert the factors by creating monthly measures that are equal to the factor in months with announcements, and equal to zero in months without announcements[16].

In relation to the local projection framework, I consider a setup usually encountered in related literature such as Jorda (2005) or more recently Gorodnichenko and Lee (2019). I consider y_t to be the variable of interest and z_t the exogenous shock, which will be the factor series for each of the identified monetary policy factors, i.e. $z_t \in \{F_t^{Target}, F_t^{Path}, F_t^{Curvature}, F_t^{Spread}\}$. The projection of $y_{t+h} - y_{t-1}$ on the information set $\Omega_{t-1} = \{\Delta y_{t-1}, z_{t-1}, \Delta y_{t-2}, z_{t-2}, \ldots\}$ is given by:

$$y_{t+h} - y_{t-1} = c_h + \sum_{i=1}^{L_y} \gamma_i^h \Delta y_{t-i} + \sum_{i=1}^{L_z} \beta_i^h z_{t-i} + f_{t+h|t-1}$$

The residual term is defined as the forecast error for the h-period ahead value of the endogenous variable. This forecast error can be decomposed due to innovations in the shock of interest z:

$$f_{t+h|t-1} = \psi_{z,0} z_{t+h} + \cdots + \psi_{z,h} z_t + v_{t+h|t-1}$$

where $v_{t+h|t-1}$ is the error term, reflecting innovations orthogonal to Ω_{t-1} and $\{z_t, z_{t+1}, ..., z_{t+h}\}$.

The estimator of FEVD is given by the coefficient of determination of regressing the predicted value of the forecast error, $\hat{f}_{t+h|t-1}$, on current and future innovations in the shock of interest. This measures the share of variance that current and future innovations in the shock of interest can explain of the endogenous variable, after controlling for Ω_{t-1}. In other words, for each horizon of h periods ahead, FEVD is estimated by the R^2 of the following regression:

$$\hat{f}_{t+h|t-1} = \alpha_{z,0} z_{t+h} + \cdots + \alpha_{z,h} z_t + \tilde{v}_{t+h|t-1}$$

[16]Given that the ECB press conferences are held every six weeks, most months have non-zero values.

As for the HDs, we want to measure the share of developments in each variable that can be accounted by each of the shocks at each point in time, from 2002 to 2020. Therefore the estimates are given by:

$$\hat{HD}_t^{z_t,y_t} = \sum_{i=0}^{h} \hat{\alpha}_{z,i} z_{t-i}$$

since it can be shown that the coefficients $\{\alpha_{z,i}\}$ correspond to the impulse response coefficients $\{\psi_{z,i}\}$.

As endogenous variables of interest y_t, I started by considering monthly series of 10 year government bond yield spreads for all Euro Area countries, in relation to the 10 year German government bond yield. Notice that the impact of the spread factor on these variables cannot come by construction since the factor was extracted from high frequency changes around central bank announcements, and here we are considering monthly series, but also since many countries in these figures were not considered in the initial dataset that unveiled the spread factor. Figure 3 below presents the FEVDs of these national spreads h for each monetary policy factor and Figure 4 plots the respective HDs.

When looking at Figure 3, we see estimates of the amount of variance that each factor is able to account for in the dynamics of government bond yield spreads h periods ahead, where h ranges from 0 to 20. The main finding to report from these FEVDs is that the shares explained by the spread factor are very significant in comparison to the shares explained by the remaining factors, and on top of that these shares are greater for periphery countries such as Italy, Ireland, Spain or Portugal than for core countries such as Netherlands, Finland or Austria.

As for the historical decompositions, presented in Figure 4, the main observations are that ECB actions represented by the spread factor seemed to have greater impact around the debt crisis period, as expected, and again more so in periphery countries than in core countries. Moreover, the figures suggest that spread-type policies contributed to a general decrease in spreads around 2012 to

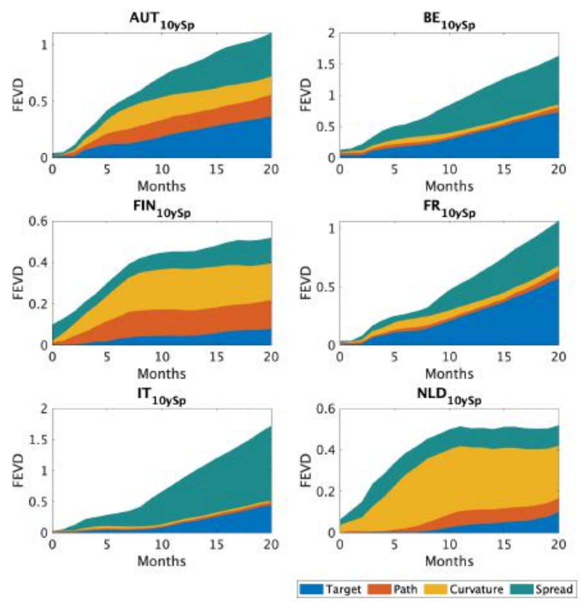

FIGURE 3. FORECAST ERROR VARIANCE DECOMPOSITIONS - YIELD SPREADS

Note: The colored areas represent the shares of variance that each shock accounts for in the h period ahead variable of interest, where $h \in \{0, 1, ..., 20\}$. In this case the variables of interest are the monthly 10 year government bond yield spreads in relation to the German bond yield, for 9 countries of the Euro area. The estimator is described in detail in section III.A.

2014, during the peak of the debt crisis period, but the contribution of such actions from 2014 to 2016 seems to be an increase in government bond yield spreads. This may be explained by the start of asset purchase programs by the ECB in 2015, which meant that the shares of asset purchases attributed to each country were formally defined, and the ECB could not target specific countries anymore in these types of policies.

Additionally, as previously mentioned I want to measure the relevance of the spread factor in the developments of labor market dispersion in the Euro area, as well as in stock market indexes and corresponding volatility, motivated by the findings in Table 4 discussed in section II. For this purpose, I started by computing a measure of Aggregate Unemployment Spread (AUS) to provide an aggregated account, for the whole Euro area, of how each monetary policy factor contributes

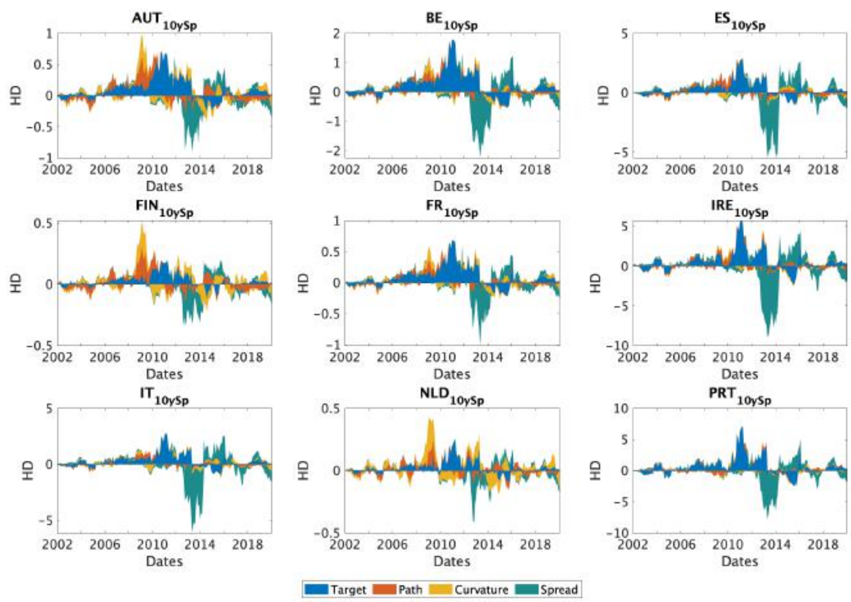

Figure 4. Historical Decompositions - Yield Spreads

Note: The colored areas represent the amounts of the variable of interest explained by each shock at each point in time, between January 2002 and January 2020. In this case the variables of interest are the monthly 10 year government bond yield spreads in relation to the German bond yield, for 9 countries of the Euro area. The estimator is described in detail in section III.A.

to divergences in labor markets. To do so, I compute a monthly series AUS_t, by summing the squared difference of each country's unemployment rate to the Euro area aggregate unemployment rate, weighted by the Labor Force level of each country:

$$AUS_t = \sum_{i \in EA} \omega_t^i \ (u_t^i - u_t^{Eur})^2$$

where $EA = \{$ AU, BE, FN, FR, DE, GR, IR, IT, NL, PT, ES $\}$ - in other words, i considers all the Euro area countries[17]. However, I also considered two alternative measures of AUS_t: one considering core countries only, where $i \in \{$ AU, BE, FN, FR, DE, NL $\}$, and another where periphery countries are considered, or $i \in \{$ GR, IR, IT, PT, ES $\}$. Moreover, ω_t^i are Labor Force national weights[18] and u_t^i

[17] More precisely, all the Eurozone members since 2001 with the exclusion of Luxembourg.

[18] Labor Force is computed for each country as the interpolated monthly series of the quarterly sum

are national unemployment rate monthly series.

The respective FEVD and HD figures for monthly series of AUS_t, and of stock market indexes STOXX[19], SX7E[20] and stock market implied volatility index VSTOXX are presented in Figures C1, C2, C3 and C4 in the Figures Appendix. Before taking conclusions from the figures presented, I should mention that my hypothesis was that the spread factor, which measures the heterogeneous dimension of monetary policy from the ECB, would represent a relevant share in the developments of labor market dispersion within the Euro area. By looking at the FEVDs and HDs, the main takeaway is that the spread factor is relevant to the measure of AUS, and especially in the groups of periphery countries and again more evidently around the debt crisis period.

As for the stock market variables figures, it seems that the spread factor is impacting mostly the volatility of the markets, and not so much the monthly series of stock market indexes, despite the effects on the high frequency index changes around ECB announcements shown in Table 4. This suggests that spread-type ECB actions affect the market perception of currency union risk, and, according to the historical decompositions, these actions seem to mitigate the risk around the debt crisis period, but seem to contribute to an increase in volatility from 2014 to 2016.

All things considered, the spread factor seems to be significantly relevant for variables of extreme importance to monetary policy transmission in the Euro area. These include government bond yield spreads, as expected, but also labor market dispersion and stock market volatility.

B. Robustness Checks

In this section, some of the results are discussed by presenting many forms of robustness checks to what was presented so far. Firstly, and most importantly, I

of Unemployment and Employment levels available from Eurostat.

[19] General EuroStoxx index of stock prices of blue-chip companies in the Euro area.

[20] Index of stock prices of the main banks in the Euro area.

provide the FEVD and HD figures for the case where the factors are obtained from the estimation procedure without government bond yields, using matrix X_1, and hence not containing any spread factor. The resulting counterfactual FEVD and HD of government bond yield spreads, labor market dispersion and stock market volatility are presented in Figures E1, E2, E3, E4, E5 and E6 in Appendix E. In the FEVD figures, it can be seen that the total amount of variance accounted by the set of factors altogether decreases significantly. As for the HD figures, we see that the main difference of not considering the spread factor is that, according to this set of monetary policy dimensions, the central bank would not have had any actions that contributed to decreasing government bond yield spreads during the debt crisis. The same takeaway applies to labor market dispersion and stock market volatility.

As mentioned in Section III.A., the monetary policy surprise factors series were converted to monthly series by considering the simple approach in Eberly, Stock and Wright (2019), given that the approach in Gertler and Karadi (2015) may result in undesirable serial correlation in the factors. Here I test for serial correlation in the factors for both conversion procedures by using the Ljung-Box (1978) test. The respective results are presented in Table 5 below, where we can see that the Gertler and Karadi (2015) measures indeed result in serial correlation in at least two of the factors, whereas in the method followed in this paper, as done in Eberly, Stock and Wright (2019), the factors are all serially uncorrelated.

Table 5—Ljung-Box test for serial correlation in factor monthly measures

	$\mathbf{F_t^{Target}}$	$\mathbf{F_t^{Path}}$	$\mathbf{F_t^{Curvature}}$	$\mathbf{F_t^{Spread}}$
GK (2015)	4.67	26.96	14.51	16.01
	(0.792)	(0.001)	(0.069)	(0.042)
ESW (2019)	6.69	12.18	11.94	7.28
	(0.571)	(0.144)	(0.154)	(0.507)

Note: The table reports the Q^* statistics and associated p-values in parenthesis for the Ljung-Box (1978) test. The GK (2015) row refers to using the monthly conversion of factors as in Gertler and Karadi (2015), while the ESW (2019) row refers to the simpler conversion method in Eberly, Stock and Wright (2019).

An additional robustness check was pursued in relation to the identification procedure to obtain the spread factor. As described in Section II.A, condition 4) of the identification problem imposes that the spread factor does not load on any of the OIS assets. As an alternative procedure, I estimated the four factors ignoring this condition, and therefore considering only conditions 1) to 3), which results in a more "natural" spread shock, as opposed to the "pure" shock estimated in the original problem. The remaining structure of the problem remains unchanged.

The results of this alternative identification procedure are presented in Appendix D. More specifically, the mathematical problem is formally defined; the loadings are presented in Table D1 and the factor time series are presented in Figure D1. Moreover, the high frequency asset price changes variance decompositions are presented in Table D2 and the monthly FEVDs and HDs are presented in Figures D2, D3, D4, D5, D6 and D7 for government bond yield spreads, as well as for measures of labor market dispersion and stock market volatility. Generally, the outcomes from following this alternative identification scheme would provide very similar takeaways as the original identification strategy. For this reason, we conclude that the addition of condition 4) in the minimization problem does not change the interpretation of any of the factors radically, while guaranteeing that the interpretation of the spread factor is orthogonal to any effects on Overnight Index Swaps.

Finally, an additional test was performed on the results of the table of high frequency variance decompositions. Firstly, the sample considered was changed to isolate the debt crisis period from the remaining dates in the original sample. Separate tables were computed for each of these subsamples, which are presented in Appendix F as Figures F1 and F2. As expected, the spread factor has greater explanative power of government bond yields during the debt crisis than in non-crisis periods. Then a similar exercise was done for ELB and non-ELB periods, and the respective results are presented in Figures F3 and F4. The results expose stark differences in the factors during the ELB period: the curvature factor explains much less variation that in non-ELB periods. This suggests that the curvature factor represents mostly conventional policies from the ECB that have effects on medium-term expectations, whereas the path factor seems to be the best factor to represent regular unconventional policies. The target and spread factors remain relatively consistent during the ELB period, despite the fact that during this period most effects on national government bond yields seem to come from actions measured by the path factor, rather than the spread factor.

As a last robustness procedure, the same tables were computed by isolating positive and negative values of the spread factor, to check for possible asymmetries in the effects of the factor. The respective results are presented in Figures F5 and F6, and we may say that despite the non-existence of a very significant difference between the numbers of positive and negative values of the factor, positive values generally have greater explanative power on most variables considered than negative values of the spread factor.

IV. Conclusion

The main results achieved in this paper are based on the identification of a new factor among a set of monetary policy factors, which reflects the surprise component of ECB actions that signal heterogeneous information about Euro area countries. This factor, which I have named spread factor, is especially evident during the Euro area debt crisis, since the increasing borrowing costs of periphery countries in the currency union resulted in significant pressure on the central bank to take actions to decrease their sovereign yields and close the spreads in relation to Germany. This paper is the first work in the literature that unveils such a monetary policy factor.

This new factor was estimated by considering a procedure of factor rotation alternative to what has previously been considered in the literature, which accounted for national government bond yields and was motivated by the fact that these national yields reacted very differently to many ECB announcements. In addition, it is shown that the factor represents a dimension of monetary policy independent of other dimensions previously known in the literature that is able to account for dynamics in economic variables such as bond yields or stock market indexes in a way that the other factors are not, and that the most adequate interpretation of the factor is the release of heterogeneous national-level information by the ECB. These findings are especially relevant since the spread factor reflects an inherent cost of a central bank conducting monetary policy for several countries with asymmetric shocks - as highlighted by OCA literature - and consequently represents a significant element of the nature of the ECB, and a fundamental difference to the Federal Reserve.

Following this initial result, I established the hypothesis that this factor would have the greatest explanatory power among the estimated monetary policy factors in accounting for effects in the monthly developments of government bond yields, but also labor market heterogeneity and stock market volatility within the currency union. To test this, I estimated FEVDs and HDs of these variables with respect to the four identified monetary policy factors, by making use of a local projection framework. These estimates show that the spread factor accounts for significant shares of variation of yield spreads for the periphery countries, labor market dispersion also mainly in the periphery countries and stock market volatility. The findings are robust to using an alternative identification method for the spread factor that does not impose zero loadings on OIS rates, and demonstrate the relevance of the new factor in explaining the relation between ECB policy and currency union divergences, given that following previous studies, which did not take into account the new factor, leads to substantially distinct takeaways.

Furthermore, there is still a good amount of work to be done on this topic, and the research findings in this paper open a wide range of possibilities to study monetary policy in the Euro area[21], by accounting for this new monetary policy

[21]It should be noted, however, that a similar methodology may be applied to the case of the United States, by appropriately measuring how the Federal Reserve releases heterogeneous information in relation to each U.S. state.

dimension measured by the spread factor. Many applications can be pursued in this area, such as IRF methods or VAR specifications where the factors may be used as external instruments, to quantify the dynamic effects of each of the monetary policy dimensions reflected by the estimated factors.

Finally, this paper may also have relevant implications to optimal monetary policy literature. Given the relevance of the heterogeneous information released by the central bank to labor market dispersion and yield spreads, as shown in this study, future research might study how policy decisions change if the central bank considers currency union heterogeneities when defining optimal policy and, if this is the case, what implications these changes have.

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A. Mathematical Appendix

Factor Rotation - Identification Problem

The minimization problem that fully identifies the unique 4 x 4 rotation matrix Z for the structural latent factors of the X_2 matrix, as described in Section II.A, is defined below:

$$Z^{*} = \arg\min_{\{z_{ij}\}} \frac{1}{T} \sum_{t=1}^{T} \left(F_{t.}^{\text{pre-crisis}} Z_{4.} \right)^{2}$$

subject to

$$Z'_{.i} Z_{.i} = 1 \ \forall i \in \{1, 2, 3, 4\}$$

$$Z'_{.i} Z_{.j} = 0 \ \forall i \neq j \in \{1, 2, 3, 4\}$$

$$Z'_{.2} \Lambda_{.1} = 0, Z'_{.3} \Lambda_{.1} = 0$$

$$Z'_{.4} \Lambda_{.m} = 0 \ \forall m \in \{1, 2, 3, 4, 5, 6, 7\}$$

This problem results in 16 first order conditions. Given that we have 12 Lagrangian multipliers to solve for, this system brings in 4 new conditions for the elements of matrix Z. Consequently, along with the initial 19 constraints, these 4 conditions fully define the 4 x 4 matrix Z.

As defined above, the variance of the fourth factor is minimized in the pre-crisis period, which is defined as the whole sample until August 8, 2008. This fourth factor is the newly unveiled spread factor, which represents policies related to currency union heterogeneity, hence being minimized before the debt crisis.

In relation to the three latent factors of the X_1 matrix, the identification problem is equivalent. However, in that case the variance of the curvature factor is minimized in the pre-QE period, which is defined as the sample until December 4, 2014. The respective minimization problem fully identifies the corresponding 3 x 3 rotation matrix Z.

B. Tables Appendix

Table B1—National Reactions to Non-Spread Policy

	at10y	**be10y**	**de10y**	**es10y**	**fi10y**	**fr10y**	**ie10y**	**it10y**	**nl10y**	**pt10y**
Target	0.63***	0.73***	0.57***	0.52***	0.98***	0.53***	0.72***	0.66***	0.54***	0.74***
	(.05)	(.09)	(.06)	(.09)	(.32)	(.05)	(.10)	(.12)	(.04)	(.12)
Path	1.47***	1.45***	1.53***	1.30***	1.18***	1.50***	1.37***	1.18***	1.48***	1.16***
	(.06)	(.07)	(.07)	(.10)	(.13)	(.07)	(.14)	(.13)	(.07)	(.21)
Curv	2.27***	2.34***	2.46***	1.73***	1.98***	2.53***	1.83***	1.72***	2.49***	2.44***
	(.09)	(.10)	(.08)	(.28)	(.12)	(.10)	(.17)	(.36)	(.09)	(.19)
R^2	0.8556	0.8485	0.8798	0.9388	0.4225	0.9028	0.3351	0.9443	0.8604	0.3387

Note: This table presents estimates of regressing $\Delta y_t = \alpha + \sum_{j=1}^{k} \beta_j F_t^j + \gamma l_t + \varepsilon_t$ for the case of $k = 3$, by following the heteroskedasticity-based estimation procedure in Gurkaynak et al. (2019). This means that $\hat{\beta}^{HET} = \frac{[\hat{\Omega}^E]_{1,1} - [\hat{\Omega}^{NE}]_{1,1}}{[\hat{\Omega}^E]_{1,2}}$, where Ω^E and Ω^{NE} are variance-covariance matrices for event days and non-event days, respectly. For this purpose, event days are days when there are ECB announcements, and non-event days correspond to the same window exactly one week before each announcement.

Table B2—National Reactions to Non-Spread and Spread Policy

	at10y	**be10y**	**de10y**	**es10y**	**fi10y**	**fr10y**	**ie10y**	**it10y**	**nl10y**	**pt10y**
Target	0.62***	0.72***	0.56***	0.49***	0.99***	0.51***	0.73***	0.65***	0.53***	0.71***
	(.04)	(.10)	(.04)	(.03)	(.32)	(.05)	(.09)	(.04)	(.03)	(.12)
Path	0.43***	0.38***	0.40***	0.57***	0.19***	0.35***	0.52***	0.43***	0.34***	0.12***
	(.04)	(.04)	(.04)	(.03)	(.10)	(.03)	(.16)	(.03)	(.04)	(.18)
Curv	2.80***	2.86***	3.01***	2.11***	2.50***	3.06***	2.36***	2.09***	3.02***	2.80***
	(.05)	(.05)	(.03)	(.04)	(.10)	(.03)	(.12)	(.04)	(.05)	(.17)
Spread	0.50***	0.80***	−0.08***	3.66***	0.00***	0.78***	0.99***	4.48***	0.11***	1.14***
	(.05)	(.08)	(.02)	(.04)	(.06)	(.06)	(.24)	(.05)	(.05)	(.24)
R^2	0.8918	0.8717	0.9617	0.9655	0.4795	0.9357	0.4514	0.9737	0.9325	0.9741

Note: This table presents estimates of regressing $\Delta y_t = \alpha + \sum_{j=1}^{k} \beta_j F_t^j + \gamma l_t + \varepsilon_t$ for the case of $k = 4$, by following the heteroskedasticity-based estimation procedure in Gurkaynak et al. (2019). This means that $\hat{\beta}^{HET} = \frac{[\hat{\Omega}^E]_{1,1} - [\hat{\Omega}^{NE}]_{1,1}}{[\hat{\Omega}^E]_{1,2}}$, where Ω^E and Ω^{NE} are variance-covariance matrices for event days and non-event days, respectly. For this purpose, event days are days when there are ECB announcements, and non-event days correspond to the same window exactly one week before each announcement.

Table B3—Taylor Rule with Country-Level Information

	eur	at	be	de	es	fi	fr	gr	ie	it	nl	pt
$\mathbf{i_{t-1}}$	0.974***	0.975***	0.973***	0.976***	0.971***	0.974***	0.974***	0.972***	0.974***	0.974***	0.973***	0.975***
	(0.0315)	(0.0325)	(0.0317)	(0.0314)	(0.0325)	(0.0322)	(0.0313)	(0.0340)	(0.0316)	(0.0327)	(0.0313)	(0.0330)
π_t^{EA}	0.401	0.354	0.412	0.378	0.468	0.386	0.399	0.469	0.431	0.391	0.433	0.414
	(0.298)	(0.312)	(0.302)	(0.289)	(0.314)	(0.308)	(0.294)	(0.352)	(0.299)	(0.316)	(0.289)	(0.321)
$\mathbf{x_t^{EA}}$	0.264**	0.348***	0.278**	0.270**	0.312**	0.324**	0.259**	0.384***	0.261**	0.344**	0.249***	0.354**
	(0.123)	(0.132)	(0.130)	(0.113)	(0.129)	(0.131)	(0.127)	(0.123)	(0.126)	(0.133)	(0.124)	(0.128)
$\pi_t^i \mathbf{D_t}$		-0.0184	-0.0956	-0.112	-0.337	-0.0878	0.0271	-0.691*	-0.253	-0.118	-0.123	-0.364
		(0.227)	(0.310)	(0.242)	(0.259)	(0.219)	(0.364)	(0.362)	(0.450)	(0.228)	(0.241)	(0.265)
$\mathbf{x_t^i D_t}$		-0.392**	-0.0814	-1.018**	-0.208	-0.254	0.0778	-0.345***	-0.154	-0.272***	0.0671	-0.536***
		(0.199)	(0.185)	(0.393)	(0.198)	(0.204)	(0.368)	(0.0650)	(0.295)	(0.140)	(0.238)	(0.172)
α	-0.403	-0.367	-0.400	-0.377	-0.418	-0.378	-0.404	-0.479	-0.405	-0.381	-0.408	-0.382
	(0.244)	(0.262)	(0.250)	(0.243)	(0.256)	(0.259)	(0.244)	(0.292)	(0.245)	(0.259)	(0.242)	(0.260)
N	71	71	71	71	71	71	71	71	71	71	71	71
R^2	0.972	0.973	0.971	0.976	0.972	0.972	0.972	0.974	0.972	0.973	0.972	0.974

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Note: This table presents quarterly GMM estimates of regressing $i_t = \alpha + \rho i_{t-1} + \phi_\pi \pi_t^{EUR} + \phi_x x_t^{EUR} + \varepsilon_t$ and $i_t = \alpha + \rho i_{t-1} + \phi_\pi \pi_t^{EUR} + \phi_x x_t^{EUR} + \phi_{\pi,i} \pi_t^i D_t + \phi_{x,i} x_t^i D_t + \varepsilon_t$, where i correspond to the countries in each column of the table. The set of instruments includes first lags of euro area inflation and output gap series.

Table B4—Residuals from Taylor Rule

	at	be	de	es	fi	fr	gr	ie	it	nl	pt
$\pi_t^i \mathbf{D_t}$	-0.0153	-0.0935	-0.114	-0.318	-0.0862	0.0270	-0.670**	-0.241	-0.118	-0.118	-0.354
	(0.192)	(0.247)	(0.240)	(0.215)	(0.178)	(0.294)	(0.285)	(0.322)	(0.191)	(0.183)	(0.231)
$\mathbf{x_t^i D_t}$	-0.331**	-0.0741	-1.010***	-0.180	-0.213	0.0733	-0.310***	-0.153	-0.233**	0.0561	-0.479***
	(0.148)	(0.133)	(0.311)	(0.149)	(0.148)	(0.271)	(0.0909)	(0.237)	(0.105)	(0.196)	(0.165)
μ	0.00145	0.00903	0.00963	0.0261	0.0130	-0.00242	-0.0336	0.0167	0.0124	0.0158	0.0248
	(0.0717)	(0.0723)	(0.0685)	(0.0691)	(0.0726)	(0.0729)	(0.0634)	(0.0709)	(0.0692)	(0.0723)	(0.0661)
N	71	71	71	71	71	71	71	71	71	71	71
R^2	0.069	0.006	0.135	0.046	0.032	0.001	0.172	0.015	0.068	0.007	0.125

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Note: This table presents quarterly OLS estimates of regressing $\hat{\varepsilon}_t = \alpha + \gamma_\pi \pi_t^i D_t + \gamma_x x_t^i D_t + v_t$, where i correspond to the countries in each column of the table. $\hat{\varepsilon}_t$ is the residual obtained from the GMM estimation of $i_t = \alpha + \rho i_{t-1} + \phi_\pi \pi_t^{EUR} + \phi_x x_t^{EUR} + \varepsilon_t$.

Table B5—Narrative Analysis of Top 20 Observations from the Spread Factor

Dates	Value	Description	Reference
August 2, 2012	12.21	Aftermath of "whatever it takes speech": ECB inaction	Press
July 5, 2012	5.19	Despite rate cut, no unconventional moves	Press
December 8, 2011	5.13	Cap weekly bond purchases	Press
July 4, 2013	-2.86	First unconventional move: Forward Guidance	Press
September 6, 2012	-2.82	Support from the Board to buy government bonds	Press
February 9, 2012	-2.66	ECB opens door to indirect Greek aid	Press
December 3, 2015	2.27	Markets were expecting aggressiveness, despite two MP measures	Press
September 5, 2013	2.22	Draghi "very, very cautious about the recovery"	Press
October 22, 2015	-2.08	Anticipation that the QE package might be adjusted	Press
January 10, 2013	-1.79	Communication focused on stabilization indicators	Press
July 25, 2019	1.77	Spreads narrowed significantly before the announcement	Press
July 7, 2011	-1.73	Change in eligibility of debt instruments for its credit operations	Press
March 7, 2013	-1.72	Draghi downplayed concerts about the political deadlock in Italy	Press
January 13, 2011	-1.56	German bond yields rise after Trichet says inflation might rise	Press
December 13, 2018	1.55	ECB announces the end of crisis-era stimulus	Press
June 6, 2013	1.52	Draghi ruled out negative interest rates in the near future	Press
June 3, 2015	1.43	ECB not bothered about volatility from negative rates	Press
December 5, 2013	1.36	Money markets gave up expectations of further monetary easing	Press
April 4, 2012	-1.34	"The central bank will not exit crisis mode yet"	Press
June 5, 2014	-1.27	Unprecedented step of imposing a negative interest rate	Press

Note: The observations from dates July 4, 2013; December 3, 2015 and October 22, 2015 are also discussed in Andrade and Ferroni (2020).

C. Figures Appendix

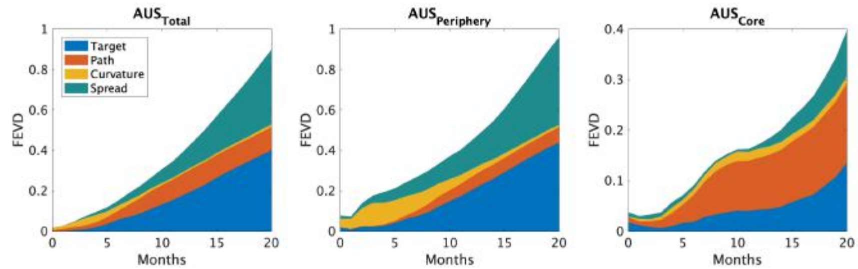

Figure C1. Forecast Error Variance Decompositions - Aggregate Unemployment Spread

Note: The colored areas represent the shares of variance that each shock accounts for in the h period ahead variable of interest, where $h \in \{0, 1, ..., 20\}$. In this case the variables of interest are the monthly Aggregate Unemployment Spread for all the countries in the Euro area, the periphery countries only and the core countries only. The construction of the labor market dispersion index AUS_t and the FEVD estimator are described in detail in section III.A.

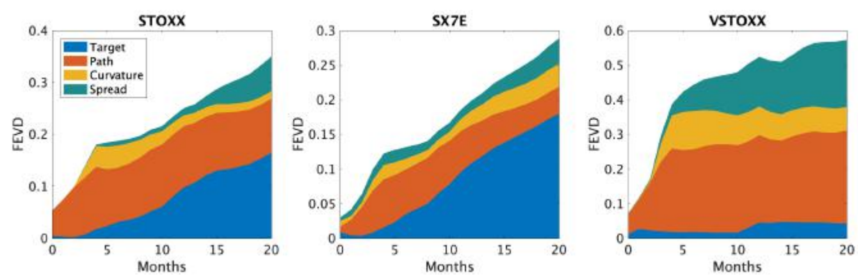

Figure C2. Forecast Error Variance Decompositions - Stock Market Indexes

Note: The colored areas represent the shares of variance that each shock accounts for in the h period ahead variable of interest, where $h \in \{0, 1, ..., 20\}$. In this case the variables of interest are the monthly Euro area stock market indexes EuroStoxx and SX7E, and the stock market volatility index VStoxx. The FEVD estimator is described in detail in section III.A.

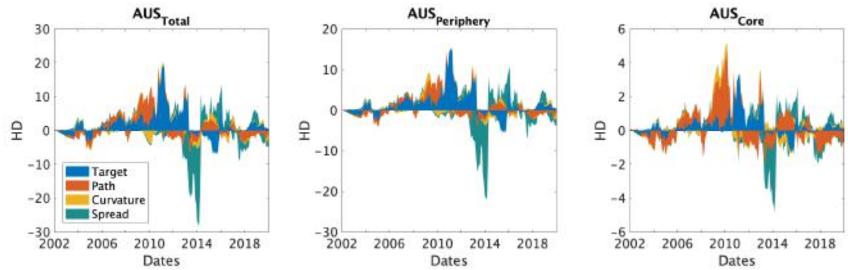

Figure C3. Historical Decompositions - Aggregate Unemployment Spreads

Note: The colored areas represent the amounts of the variable of interest explained by each shock at each point in time, between January 2002 and January 2020. In this case the variables of interest are the monthly Aggregate Unemployment Spread for all the countries in the Euro area, the periphery countries only and the core countries only. The construction of the labor market dispersion index AUS_t and the HD estimator are described in detail in section III.A.

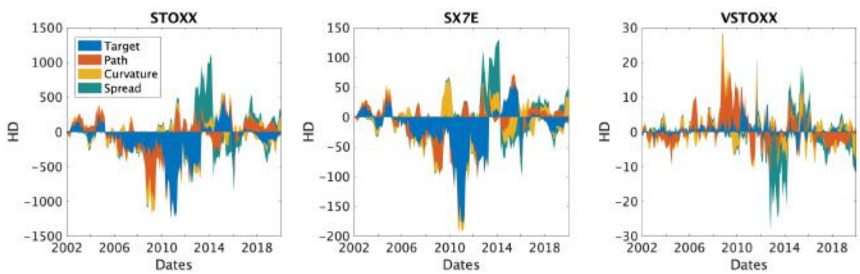

Figure C4. Historical Decompositions - Stock Market Indexes

Note: The colored areas represent the amounts of the variable of interest explained by each shock at each point in time, between January 2002 and January 2020. In this case the variables of interest are the monthly Euro area stock market indexes EuroStoxx and SX7E, and the stock market volatility index VStoxx. The HD estimator is described in detail in section III.A.

D. Alternative Identification Appendix

Factor Rotation - Identification Problem

The minimization problem that fully identifies the unique 4 x 4 rotation matrix Z for the structural latent factors of the X_2 matrix, for the alternative identification procedure described in Section III.B, is defined below:

$$Z^* = \arg\min_{\{z_{ij}\}} \frac{1}{T} \sum_{t=1}^{T} \left(F_{t.}^{\text{pre-crisis}} Z_{4.} \right)^2$$

subject to

$$Z'_{.i} Z_{.i} = 1 \; \forall i \in \{1,2,3,4\}$$

$$Z'_{.i} Z_{.j} = 0 \; \forall i \neq j \in \{1,2,3,4\}$$

$$Z'_{.2} \Lambda_{.1} = 0, Z'_{.3} \Lambda_{.1} = 0$$

This problem results in 16 first order conditions. Given that we have 12 Lagrangian multipliers to solve for, this system brings in 4 new conditions for the elements of matrix Z. Consequently, along with the initial 12 constraints, these 4 conditions fully define the 4 x 4 matrix Z.

As defined above, the variance of the fourth factor - the spread factor - is minimized in the pre-crisis period, which is defined as the whole sample until August 8, 2008.

Table D1—Factor Loadings - with government bond yields

	OIS1M	OIS3M	OIS6M	OIS1Y	OIS2Y	OIS5Y	OIS10Y	DE10Y	ES10Y	FR10Y	IT10Y
Target	1.00	0.70	0.60	0.50	0.40	0.30	0.20	0.18	0.12	0.17	0.13
Path	0.00	−0.28	−0.21	−0.09	0.12	0.51	1.00	1.06	0.59	1.08	0.57
Curvature	0.00	0.69	0.86	0.96	1.00	0.95	0.78	0.73	0.46	0.71	0.40
Spread	−0.01	−0.03	−0.03	−0.04	−0.06	−0.10	−0.13	−0.17	1.00	0.16	1.04

Note: Structural loadings obtained from the alternative identification method presented in Appendix D.

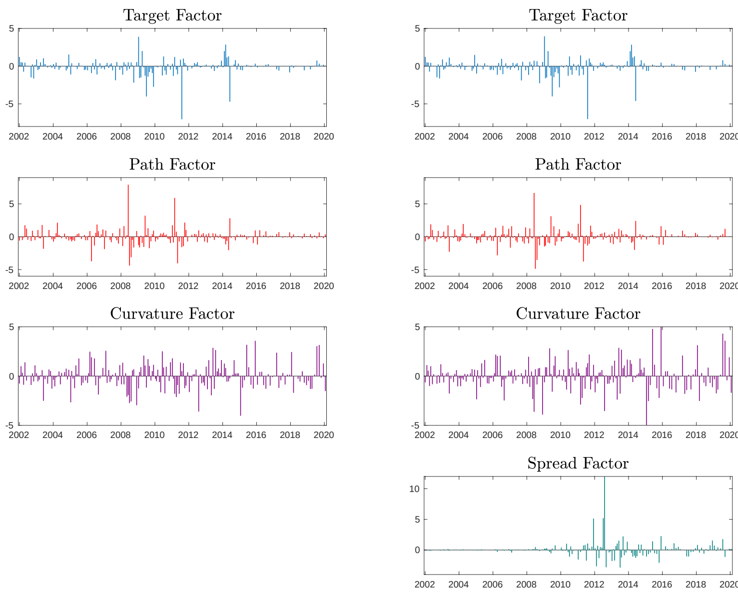

Figure D1. Factors - with and without government bond yields

Note: The figure presents the time series for the initial three factors obtained by considering matrix X_1 in the left panel, and in the right panel the four factors obtained from the alternative identification method presented in Appendix D.

Table D2—Variance Decompositions

Assets	k = 3			k = 4			
	Target	**Curv**	**Path**	**Target**	**Curv**	**Path**	**Spread**
OIS1M	0.99	0.00	0.00	0.98	0.00	0.00	0.00
OIS3M	0.46	0.45	0.01	0.49	0.38	0.03	0.00
OIS6M	0.35	0.63	0.00	0.36	0.59	0.02	0.00
OIS1Y	0.25	0.72	0.02	0.25	0.73	0.00	0.00
OIS2Y	0.16	0.69	0.10	0.16	0.79	0.01	0.00
OIS5Y	0.23	0.15	0.55	0.23	0.45	0.45	0.00
OIS10Y	0.07	0.03	0.90	0.07	0.29	0.83	0.01
OIS15Y	0.02	0.01	0.90	0.03	0.26	0.91	0.14
OIS20Y	0.02	0.01	0.85	0.02	0.22	0.88	0.14
DE2Y	0.12	0.67	0.14	0.11	0.79	0.02	0.00
DE5Y	0.08	0.50	0.36	0.07	0.69	0.14	0.01
DE10Y	0.03	0.24	0.62	0.03	0.42	0.50	0.02
SpIT2Y	0.00	0.02	0.01	0.00	0.01	0.00	0.62
SpES2Y	0.01	0.08	0.03	0.01	0.08	0.00	0.47
SpFR2Y	0.00	0.04	0.05	0.00	0.06	0.02	0.01
SpIT5Y	0.00	0.01	0.03	0.00	0.01	0.00	0.85
SpES5Y	0.01	0.02	0.06	0.00	0.03	0.01	0.73
SpFR5Y	0.00	0.03	0.01	0.00	0.03	0.01	0.14
SpIT10Y	0.00	0.00	0.02	0.00	0.00	0.00	0.97
SpES10Y	0.00	0.00	0.04	0.00	0.00	0.01	0.95
SpFR10Y	0.00	0.00	0.00	0.00	0.00	0.01	0.56
STOXX50	0.00	0.01	0.00	0.00	0.02	0.02	0.30
SX7E	0.00	0.01	0.01	0.00	0.01	0.00	0.45

Note: The table reports R^2 values from regressing $\Delta y_t = \alpha + \beta F_t^j + \varepsilon_t$ for $j \in \{1, \ldots, k\}$ using OLS estimation. Each row reflects different assets considered as y_t for the high frequency price changes Δy_t. The first three columns represent the $k = 3$ factors from the estimation considering matrix X_1, whereas the last four columns represent the $k = 4$ factors obtained in the identification method presented in Appendix D.

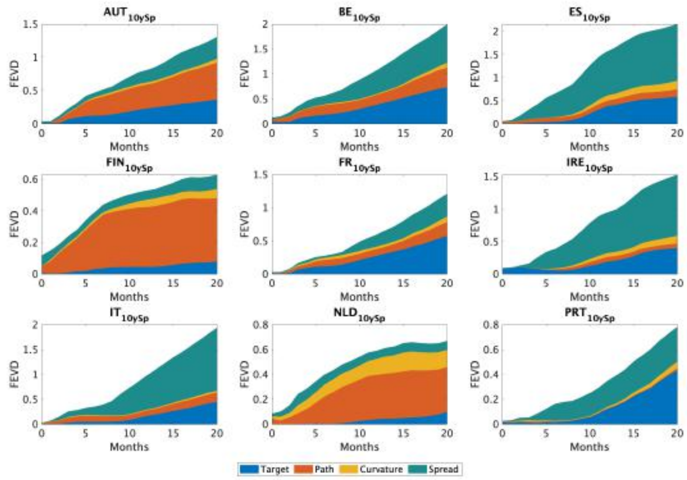

FIGURE D2. FORECAST ERROR VARIANCE DECOMPOSITIONS - YIELD SPREADS

Note: This figure is equivalent to Figure 3, but instead of considering the four factors from the identification procedure described in Appendix A, it considers the four factors from the alternative identification procedure described in the beginning of Appendix D.

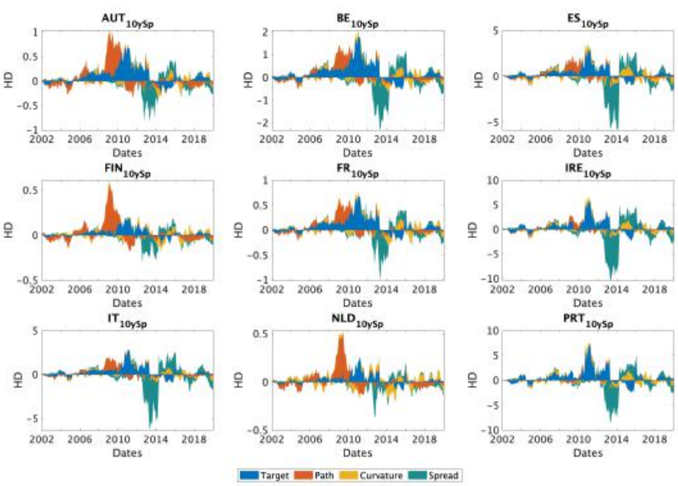

FIGURE D3. HISTORICAL DECOMPOSITIONS - YIELD SPREADS

Note: This figure is equivalent to Figure 4, but instead of considering the four factors from the identification procedure described in Appendix A, it considers the four factors from the alternative identification procedure described in the beginning of Appendix D.

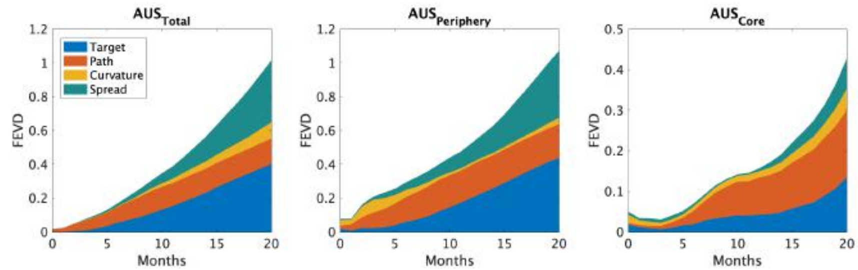

Figure D4. Forecast Error Variance Decompositions - Aggregate Unemployment Spreads

Note: This figure is equivalent to Figure C1, but instead of considering the four factors from the identification procedure described in Appendix A, it considers the four factors from the alternative identification procedure described in the beginning of Appendix D.

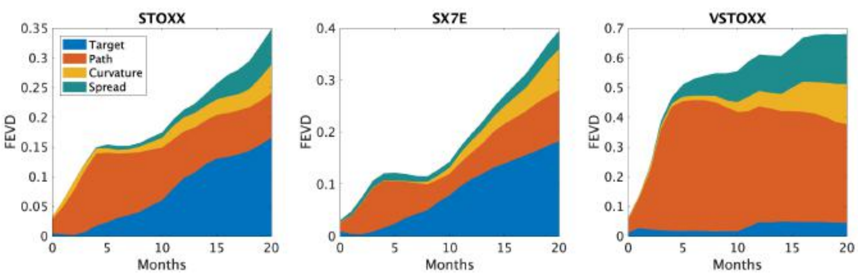

Figure D5. Forecast Error Variance Decompositions - Stock Market Indexes

Note: This figure is equivalent to Figure C2, but instead of considering the four factors from the identification procedure described in Appendix A, it considers the four factors from the alternative identification procedure described in the beginning of Appendix D.

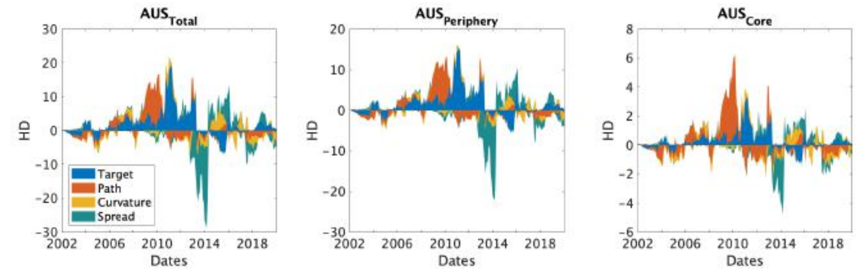

FIGURE D6. HISTORICAL DECOMPOSITIONS - AGGREGATE UNEMPLOYMENT SPREADS

Note: This figure is equivalent to Figure C3, but instead of considering the four factors from the identification procedure described in Appendix A, it considers the four factors from the alternative identification procedure described in the beginning of Appendix D.

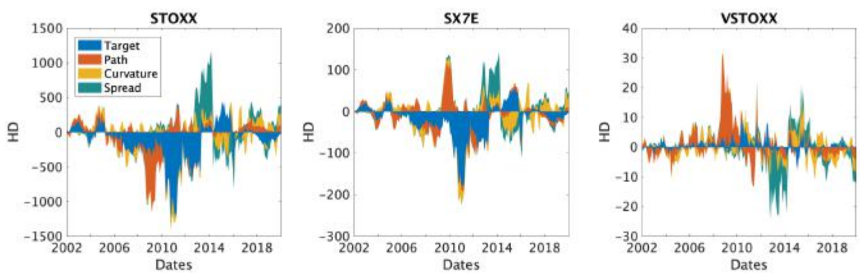

FIGURE D7. HISTORICAL DECOMPOSITIONS - STOCK MARKET INDEXES

Note: This figure is equivalent to Figure C4, but instead of considering the four factors from the identification procedure described in Appendix A, it considers the four factors from the alternative identification procedure described in the beginning of Appendix D.

Table D3—National Reactions to Non-Spread and Spread Policy

	at10y	**be10y**	**de10y**	**es10y**	**fi10y**	**fr10y**	**ie10y**	**it10y**	**nl10y**	**pt10y**
Target	0.63***	0.72***	0.56***	0.53***	0.99***	0.52***	0.74***	0.70***	0.53***	0.72***
	(.04)	(.10)	(.04)	(.03)	(.32)	(.05)	(.09)	(.04)	(.03)	(.12)
Path	1.96***	1.97***	2.04***	1.83***	1.58***	2.06***	1.81***	1.73***	2.00***	1.73***
	(.03)	(.05)	(.04)	(.03)	(.12)	(.03)	(.13)	(.03)	(.04)	(.19)
Curv	2.09***	2.20***	2.22***	1.81***	1.93***	2.38***	1.74***	1.96***	2.28***	2.34***
	(.05)	(.04)	(.04)	(.04)	(.08)	(.03)	(.14)	(.05)	(.06)	(.17)
Spread	0.18***	0.46***	−0.43***	3.40***	−0.30***	0.42***	0.71***	4.21***	−0.24***	0.80***
	(.05)	(.08)	(.02)	(.04)	(.06)	(.06)	(.24)	(.05)	(.05)	(.23)
R^2	0.8918	0.8717	0.9617	0.9655	0.4795	0.9357	0.4514	0.9737	0.9325	0.9741

Note: This table is equivalent to Table B2, but instead of considering the four factors from the identification procedure described in Appendix A, it considers the four factors from the alternative identification procedure described in the beginning of Appendix D.

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E. FEVD and HD Figures with 3 Factors

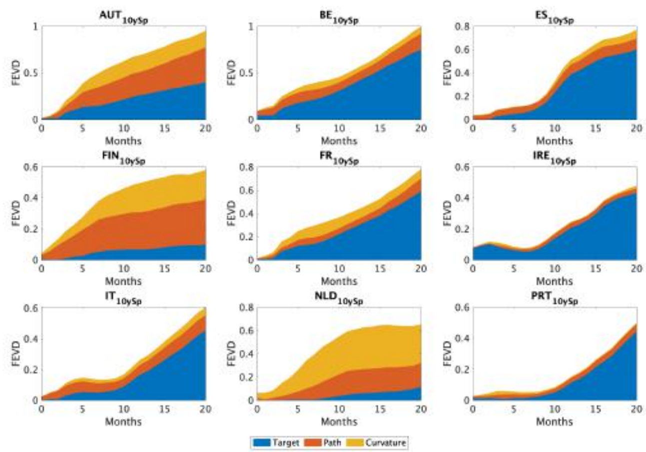

Figure E1. Forecast Error Variance Decompositions - Yield Spreads

Note: This figure is equivalent to Figure 3, but instead of considering the four factors from the identification procedure described in Appendix A, it considers the three factors from considering matrix X_1 in the factor estimation.

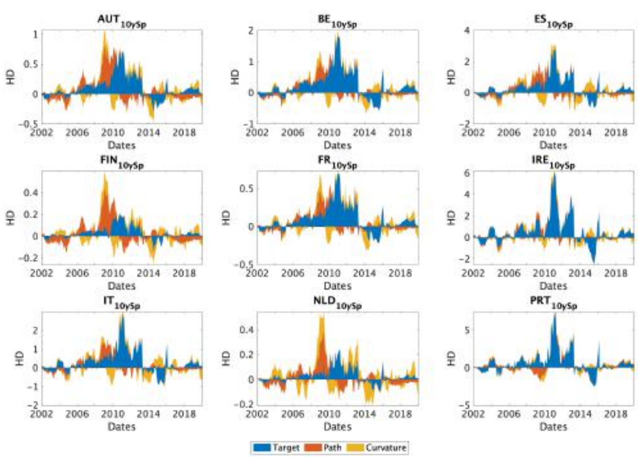

Figure E2. Historical Decompositions - Yield Spreads

Note: This figure is equivalent to Figure 4, but instead of considering the four factors from the identification procedure described in Appendix A, it considers the three factors from considering matrix X_1 in the factor estimation.

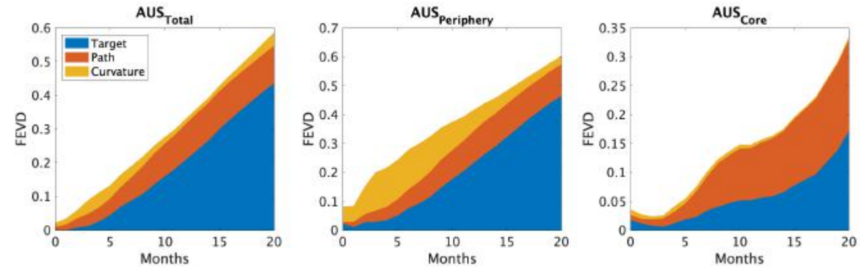

FIGURE E3. FORECAST ERROR VARIANCE DECOMPOSITIONS - AGGREGATE UNEMPLOYMENT SPREAD

Note: This figure is equivalent to Figure C1, but instead of considering the four factors from the identification procedure described in Appendix A, it considers the three factors from considering matrix X_1 in the factor estimation.

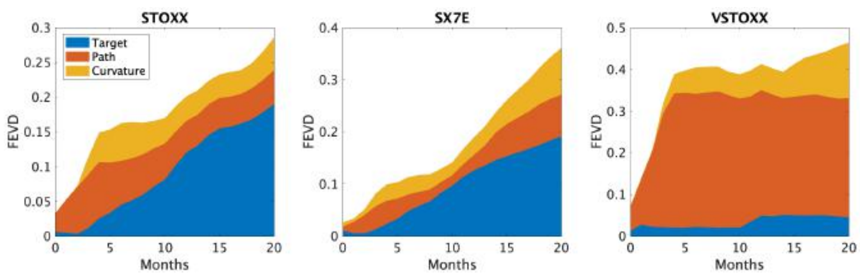

FIGURE E4. FORECAST ERROR VARIANCE DECOMPOSITIONS - STOCK MARKET INDEXES

Note: This figure is equivalent to Figure C2, but instead of considering the four factors from the identification procedure described in Appendix A, it considers the three factors from considering matrix X_1 in the factor estimation.

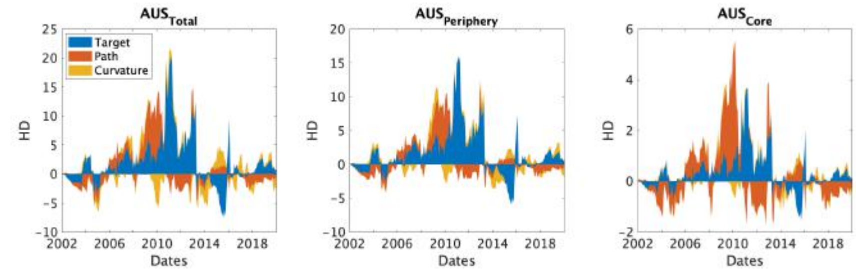

Figure E5. Historical Decompositions - Aggregate Unemployment Spread

Note: This figure is equivalent to Figure C3, but instead of considering the four factors from the identification procedure described in Appendix A, it considers the three factors from considering matrix X_1 in the factor estimation.

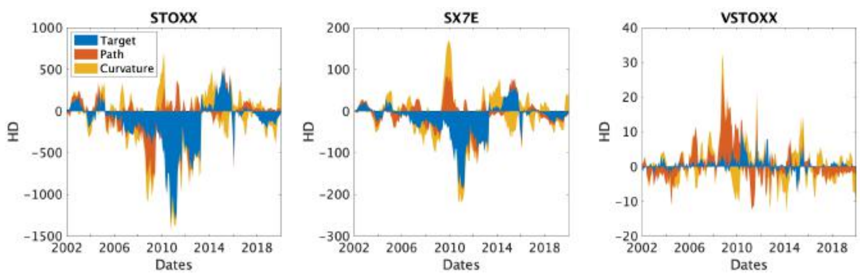

Figure E6. Historical Decompositions - Stock Market Indexes

Note: This figure is equivalent to Figure C4, but instead of considering the four factors from the identification procedure described in Appendix A, it considers the three factors from considering matrix X_1 in the factor estimation.

F. Variance Decompositions for Subsets of Data

Assets	k=3 Target	k=3 Curv	k=3 Path		k=4 Target	k=4 Curv	k=4 Path	k=4 Spread
OIS_1M	1.00	0.12	0.00		0.99	0.12	0.01	0.00
OIS_3M	0.62	0.69	0.02		0.65	0.63	0.09	0.01
OIS_6M	0.61	0.75	0.00		0.63	0.71	0.06	0.00
OIS_1Y	0.57	0.76	0.00		0.59	0.77	0.03	0.01
OIS_2Y	0.51	0.71	0.04		0.51	0.79	0.00	0.01
OIS_5Y	0.46	0.35	0.32		0.44	0.63	0.20	0.03
OIS_10Y	0.14	0.04	0.81		0.13	0.26	0.67	0.16
OIS_15Y	0.94	0.63	0.95		0.96	0.11	0.63	0.00
OIS_20Y	0.80	0.85	0.95		0.84	0.17	0.98	0.53
DE2Y	0.39	0.71	0.08		0.39	0.83	0.01	0.02
IT2Y	0.06	0.09	0.00		0.06	0.14	0.00	0.52
FR2Y	0.44	0.71	0.04		0.45	0.79	0.00	0.03
ES2Y	0.10	0.15	0.00		0.11	0.22	0.00	0.38
DE5Y	0.30	0.51	0.29		0.29	0.70	0.12	0.08
IT5Y	0.03	0.03	0.00		0.03	0.07	0.00	0.73
ES5Y	0.04	0.07	0.00		0.04	0.11	0.00	0.66
FR5Y	0.29	0.35	0.29		0.27	0.54	0.16	0.01
DE10Y	0.14	0.28	0.53		0.13	0.46	0.34	0.22
ES10Y	0.01	0.03	0.01		0.02	0.06	0.00	0.85
FR10Y	0.13	0.30	0.39		0.12	0.51	0.29	0.00
IT10Y	0.01	0.02	0.01		0.01	0.05	0.00	0.87
Spread_IT2Y	0.03	0.06	0.03		0.02	0.05	0.00	0.71
Spread_ES2Y	0.05	0.12	0.03		0.05	0.10	0.00	0.59
Spread_FR2Y	0.00	0.02	0.13		0.00	0.07	0.09	0.01
Spread_IT5Y	0.02	0.04	0.06		0.01	0.03	0.02	0.91
Spread_ES5Y	0.03	0.05	0.14		0.02	0.05	0.06	0.84
Spread_FR5Y	0.01	0.14	0.00		0.01	0.12	0.01	0.25
Spread_IT10Y	0.00	0.00	0.13		0.00	0.00	0.07	0.99
Spread_ES10Y	0.00	0.00	0.14		0.00	0.01	0.08	0.99
Spread_FR10Y	0.01	0.01	0.08		0.01	0.01	0.03	0.60
STOXX50	0.00	0.01	0.07		0.00	0.01	0.06	0.62
SX7E	0.00	0.01	0.08		0.00	0.01	0.07	0.69

Figure F1. Debt Crisis Period

Note: This table is equivalent to Table 2. However, instead of considering the full sample of data between 2002 and 2020, it considers only the observations of ECB announcements from 2010 to 2014.

Assets	k=3 Target	k=3 Curv	k=3 Path		k=4 Target	k=4 Curv	k=4 Path	k=4 Spread
OIS_1M	0.99	0.02	0.00		0.98	0.02	0.00	0.00
OIS_3M	0.39	0.36	0.01		0.41	0.29	0.02	0.01
OIS_6M	0.24	0.60	0.00		0.25	0.56	0.01	0.01
OIS_1Y	0.13	0.71	0.04		0.13	0.73	0.00	0.00
OIS_2Y	0.06	0.69	0.14		0.06	0.80	0.01	0.00
OIS_5Y	0.06	0.04	0.82		0.07	0.35	0.74	0.20
OIS_10Y	0.03	0.02	0.95		0.04	0.31	0.92	0.17
OIS_15Y	0.02	0.01	0.90		0.02	0.26	0.91	0.16
OIS_20Y	0.02	0.01	0.86		0.02	0.22	0.88	0.14
DE2Y	0.05	0.66	0.18		0.04	0.78	0.03	0.01
IT2Y	0.07	0.58	0.17		0.06	0.69	0.04	0.05
FR2Y	0.05	0.65	0.17		0.04	0.78	0.03	0.01
ES2Y	0.06	0.56	0.15		0.06	0.67	0.02	0.04
DE5Y	0.03	0.49	0.39		0.02	0.69	0.14	0.02
IT5Y	0.04	0.40	0.33		0.03	0.56	0.16	0.24
ES5Y	0.04	0.47	0.34		0.04	0.64	0.14	0.12
FR5Y	0.03	0.51	0.40		0.03	0.70	0.18	0.05
DE10Y	0.01	0.23	0.66		0.01	0.41	0.56	0.09
ES10Y	0.02	0.17	0.57		0.02	0.33	0.52	0.39
FR10Y	0.01	0.19	0.67		0.01	0.36	0.61	0.17
IT10Y	0.03	0.11	0.49		0.03	0.23	0.49	0.54
Spread_IT2Y	0.02	0.01	0.00		0.02	0.00	0.01	0.18
Spread_ES2Y	0.00	0.11	0.04		0.00	0.13	0.01	0.09
Spread_FR2Y	0.00	0.07	0.02		0.00	0.08	0.00	0.00
Spread_IT5Y	0.00	0.01	0.01		0.01	0.01	0.00	0.51
Spread_ES5Y	0.00	0.02	0.04		0.01	0.03	0.00	0.22
Spread_FR5Y	0.00	0.00	0.01		0.00	0.01	0.01	0.07
Spread_IT10Y	0.02	0.01	0.01		0.02	0.00	0.04	0.85
Spread_ES10Y	0.00	0.01	0.00		0.00	0.00	0.00	0.69
Spread_FR10Y	0.00	0.00	0.10		0.00	0.00	0.18	0.49
STOXX50	0.00	0.01	0.04		0.00	0.02	0.06	0.25
SX7E	0.00	0.01	0.00		0.00	0.01	0.00	0.21

Figure F2. Full Sample Excluding the Debt Crisis Period

Note: This table is equivalent to Table 2. However, instead of considering the full sample of data between 2002 and 2020, it excludes the observations of ECB announcements from 2010 to 2014.

Assets	k=3			k=4			
	Target	Curv	Path	Target	Curv	Path	Spread
OIS_1M	0.99	0.54	0.03	0.98	0.29	0.03	0.10
OIS_3M	0.40	0.01	0.02	0.43	0.00	0.03	0.12
OIS_6M	0.23	0.04	0.25	0.25	0.19	0.25	0.23
OIS_1Y	0.07	0.13	0.44	0.08	0.43	0.41	0.15
OIS_2Y	0.02	0.18	0.56	0.02	0.57	0.52	0.14
OIS_5Y	0.07	0.03	0.85	0.08	0.39	0.79	0.20
OIS_10Y	0.03	0.02	0.95	0.04	0.37	0.94	0.17
OIS_15Y	0.02	0.01	0.90	0.03	0.31	0.92	0.16
OIS_20Y	0.02	0.01	0.86	0.02	0.28	0.89	0.15
DE2Y	0.04	0.09	0.57	0.05	0.42	0.56	0.16
IT2Y	0.15	0.00	0.46	0.16	0.15	0.46	0.34
FR2Y	0.07	0.06	0.62	0.08	0.38	0.61	0.18
ES2Y	0.20	0.00	0.41	0.22	0.10	0.48	0.62
DE5Y	0.02	0.07	0.71	0.02	0.44	0.68	0.17
IT5Y	0.15	0.00	0.43	0.17	0.11	0.48	0.77
ES5Y	0.17	0.00	0.52	0.20	0.18	0.56	0.56
FR5Y	0.05	0.03	0.80	0.07	0.37	0.80	0.25
DE10Y	0.00	0.04	0.89	0.01	0.42	0.95	0.19
ES10Y	0.08	0.00	0.70	0.10	0.23	0.80	0.63
FR10Y	0.02	0.03	0.89	0.04	0.38	0.95	0.29
IT10Y	0.08	0.00	0.62	0.10	0.21	0.72	0.73
Spread_IT2Y	0.14	0.06	0.06	0.15	0.01	0.07	0.22
Spread_ES2Y	0.09	0.16	0.03	0.09	0.18	0.01	0.19
Spread_FR2Y	0.07	0.09	0.00	0.07	0.09	0.00	0.00
Spread_IT5Y	0.16	0.09	0.00	0.18	0.05	0.01	0.62
Spread_ES5Y	0.19	0.09	0.01	0.20	0.09	0.00	0.28
Spread_FR5Y	0.19	0.07	0.18	0.22	0.00	0.26	0.21
Spread_IT10Y	0.16	0.02	0.05	0.19	0.00	0.09	0.89
Spread_ES10Y	0.21	0.06	0.00	0.22	0.03	0.01	0.70
Spread_FR10Y	0.19	0.01	0.24	0.21	0.04	0.28	0.51
STOXX50	0.08	0.00	0.16	0.10	0.08	0.21	0.46
SX7E	0.03	0.00	0.00	0.04	0.00	0.01	0.28

Figure F3. ELB Period

Note: This table is equivalent to Table 2. However, instead of considering the full sample of data between 2002 and 2020, it considers only the observations of ECB announcements from June 2014 to 2020.

Assets	k=3			k=4			
	Target	Curv	Path	Target	Curv	Path	Spread
OIS_1M	0.99	0.00	0.00	0.99	0.00	0.00	0.00
OIS_3M	0.48	0.46	0.02	0.50	0.38	0.10	0.00
OIS_6M	0.36	0.64	0.00	0.37	0.58	0.08	0.00
OIS_1Y	0.25	0.73	0.01	0.25	0.73	0.04	0.00
OIS_2Y	0.16	0.71	0.08	0.15	0.79	0.00	0.01
OIS_5Y	0.31	0.18	0.35	0.31	0.36	0.23	0.02
OIS_10Y	0.09	0.04	0.81	0.08	0.20	0.66	0.14
OIS_15Y	0.02	0.24	0.70	0.02	0.38	0.52	0.07
OIS_20Y	0.03	0.24	0.63	0.03	0.37	0.55	0.15
DE2Y	0.12	0.71	0.11	0.11	0.80	0.00	0.01
IT2Y	0.06	0.35	0.03	0.06	0.42	0.00	0.28
FR2Y	0.13	0.71	0.09	0.12	0.79	0.00	0.01
ES2Y	0.08	0.40	0.05	0.07	0.48	0.00	0.16
DE5Y	0.08	0.56	0.30	0.07	0.72	0.05	0.03
IT5Y	0.02	0.20	0.05	0.02	0.27	0.01	0.50
ES5Y	0.03	0.28	0.06	0.03	0.37	0.00	0.37
FR5Y	0.08	0.54	0.27	0.07	0.70	0.05	0.00
DE10Y	0.03	0.38	0.49	0.03	0.54	0.24	0.10
ES10Y	0.01	0.11	0.04	0.01	0.16	0.02	0.68
FR10Y	0.03	0.38	0.44	0.02	0.55	0.24	0.00
IT10Y	0.01	0.08	0.02	0.01	0.12	0.01	0.74
Spread_IT2Y	0.00	0.02	0.03	0.00	0.02	0.01	0.69
Spread_ES2Y	0.01	0.09	0.03	0.01	0.08	0.00	0.52
Spread_FR2Y	0.00	0.04	0.07	0.00	0.07	0.04	0.01
Spread_IT5Y	0.00	0.02	0.05	0.00	0.01	0.01	0.88
Spread_ES5Y	0.01	0.02	0.08	0.00	0.03	0.03	0.80
Spread_FR5Y	0.00	0.03	0.03	0.00	0.04	0.00	0.14
Spread_IT10Y	0.00	0.01	0.06	0.00	0.01	0.04	0.98
Spread_ES10Y	0.00	0.00	0.05	0.00	0.00	0.03	0.98
Spread_FR10Y	0.00	0.01	0.03	0.00	0.01	0.00	0.58
STOXX50	0.00	0.01	0.01	0.00	0.01	0.02	0.31
SX7E	0.00	0.01	0.02	0.00	0.01	0.02	0.54

Figure F4. Non-ELB Period

Note: This table is equivalent to Table 2. However, instead of considering the full sample of data between 2002 and 2020, it excludes the observations of ECB announcements from June 2014 to 2020.

Assets	k=3				k=4			
	Target	Curv	Path		Target	Curv	Path	Spread
OIS_1M	0.99	0.03	0.00		0.98	0.02	0.00	0.00
OIS_3M	0.53	0.51	0.01		0.55	0.44	0.05	0.00
OIS_6M	0.43	0.69	0.00		0.44	0.65	0.03	0.00
OIS_1Y	0.32	0.77	0.01		0.32	0.78	0.02	0.00
OIS_2Y	0.24	0.74	0.07		0.23	0.82	0.00	0.00
OIS_5Y	0.43	0.24	0.41		0.42	0.59	0.35	0.01
OIS_10Y	0.11	0.02	0.85		0.11	0.28	0.80	0.03
OIS_15Y	0.19	0.00	0.87		0.24	0.35	0.90	0.43
OIS_20Y	0.19	0.00	0.82		0.24	0.29	0.86	0.51
DE2Y	0.17	0.75	0.11		0.16	0.86	0.00	0.00
IT2Y	0.10	0.40	0.04		0.10	0.50	0.00	0.28
FR2Y	0.17	0.75	0.11		0.16	0.85	0.00	0.00
ES2Y	0.12	0.43	0.07		0.11	0.54	0.00	0.15
DE5Y	0.14	0.57	0.31		0.13	0.75	0.10	0.01
IT5Y	0.05	0.20	0.08		0.04	0.29	0.03	0.53
ES5Y	0.07	0.31	0.08		0.06	0.42	0.01	0.38
FR5Y	0.14	0.57	0.28		0.13	0.75	0.09	0.00
DE10Y	0.07	0.24	0.62		0.07	0.41	0.44	0.04
ES10Y	0.03	0.08	0.11		0.03	0.15	0.09	0.70
FR10Y	0.06	0.23	0.56		0.06	0.40	0.45	0.01
IT10Y	0.03	0.06	0.10		0.03	0.12	0.09	0.73
Spread_IT2Y	0.00	0.04	0.02		0.00	0.03	0.00	0.64
Spread_ES2Y	0.01	0.16	0.02		0.02	0.15	0.00	0.40
Spread_FR2Y	0.01	0.05	0.03		0.01	0.08	0.01	0.06
Spread_IT5Y	0.00	0.01	0.02		0.00	0.01	0.00	0.85
Spread_ES5Y	0.01	0.02	0.07		0.01	0.02	0.04	0.74
Spread_FR5Y	0.00	0.00	0.01		0.00	0.00	0.00	0.27
Spread_IT10Y	0.00	0.00	0.02		0.00	0.00	0.00	0.98
Spread_ES10Y	0.00	0.00	0.03		0.00	0.00	0.02	0.96
Spread_FR10Y	0.00	0.00	0.00		0.00	0.00	0.00	0.60
STOXX50	0.00	0.03	0.02		0.00	0.05	0.02	0.33
SX7E	0.00	0.01	0.00		0.00	0.02	0.00	0.49

Figure F5. Positive Values of the Spread Factor

Note: This table is equivalent to Table 2. However, instead of considering the full sample of data between 2002 and 2020, it considers only the 93 observations when the spread factor takes positive values.

Assets	k=3				k=4			
	Target	Curv	Path		Target	Curv	Path	Spread
OIS_1M	0.99	0.04	0.00		0.98	0.04	0.00	0.00
OIS_3M	0.38	0.36	0.01		0.41	0.29	0.02	0.00
OIS_6M	0.26	0.54	0.00		0.28	0.50	0.01	0.01
OIS_1Y	0.16	0.64	0.04		0.16	0.66	0.00	0.01
OIS_2Y	0.07	0.63	0.16		0.07	0.75	0.05	0.02
OIS_5Y	0.05	0.07	0.81		0.05	0.34	0.65	0.03
OIS_10Y	0.02	0.05	0.96		0.03	0.31	0.90	0.00
OIS_15Y	0.01	0.02	0.93		0.01	0.21	0.93	0.04
OIS_20Y	0.00	0.01	0.88		0.01	0.18	0.92	0.03
DE2Y	0.06	0.57	0.21		0.06	0.71	0.08	0.02
IT2Y	0.04	0.25	0.13		0.04	0.35	0.06	0.17
FR2Y	0.08	0.56	0.17		0.08	0.68	0.06	0.01
ES2Y	0.04	0.32	0.10		0.04	0.41	0.04	0.18
DE5Y	0.03	0.41	0.43		0.02	0.62	0.21	0.02
IT5Y	0.03	0.17	0.22		0.02	0.29	0.13	0.33
ES5Y	0.02	0.22	0.26		0.02	0.36	0.17	0.26
FR5Y	0.03	0.30	0.53		0.03	0.52	0.36	0.00
DE10Y	0.01	0.24	0.64		0.01	0.45	0.58	0.01
ES10Y	0.01	0.13	0.37		0.01	0.26	0.36	0.34
FR10Y	0.01	0.19	0.67		0.01	0.38	0.64	0.00
IT10Y	0.02	0.08	0.37		0.02	0.20	0.38	0.36
Spread_IT2Y	0.00	0.01	0.00		0.00	0.01	0.00	0.52
Spread_ES2Y	0.00	0.04	0.03		0.00	0.05	0.01	0.57
Spread_FR2Y	0.04	0.03	0.08		0.05	0.05	0.04	0.01
Spread_IT5Y	0.00	0.06	0.04		0.00	0.07	0.01	0.73
Spread_ES5Y	0.00	0.06	0.05		0.00	0.07	0.01	0.63
Spread_FR5Y	0.00	0.12	0.00		0.00	0.12	0.03	0.05
Spread_IT10Y	0.01	0.05	0.03		0.01	0.05	0.01	0.88
Spread_ES10Y	0.00	0.02	0.04		0.00	0.03	0.03	0.87
Spread_FR10Y	0.00	0.04	0.02		0.00	0.02	0.05	0.26
STOXX50	0.01	0.00	0.00		0.01	0.00	0.01	0.15
SX7E	0.00	0.00	0.01		0.00	0.00	0.00	0.20

Figure F6. Negative Values of the Spread Factor

Note: This table is equivalent to Table 2. However, instead of considering the full sample of data between 2002 and 2020, it considers only the 98 observations when the spread factor takes negative values.