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Euro Area Government Bond Yield and Liquidity Dependence during different Monetary Policy Accommodation Phases

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ABSTRACT

In this paper, we analyze the relationship between various risk factors and euro area government bond yield spreads, focusing particularly on the monetary policy stance. Our results show that credit and common risk factors are consistently priced in government bond yield spreads, while liquidity differentials are relevant especially during periods of stressed market conditions. We demonstrate that the liquidity component has been more prominent during periods of declining interest rates and increasing reserves, while it has diminished on announcement days of monetary policy decisions related to PSPP. Overall, the liquidity component has been statistically insignificant since the announcement of accommodative non-standard monetary policy measures.

Keywords: monetary policy, liquidity, government bonds, yield spreads, panel analysis.

JEL codes: C23, E62, H50.

1. INTRODUCTION

Financial markets play a critical role in the process of both formulating and implementing monetary policy. As discussed by Reinhart and Sack (2002), the relevant influence of monetary policy on the real economy and inflation is largely transmitted through asset prices. The developments of long-term rates affect firm investments and home purchases, thus driving changes in the real economy. Central banks also rely on financial markets to inform their policy decisions, with market interest rates encapsulating vast amounts of information regarding the expected course of monetary policy and the economy. The issue, however, is that market rates can be influenced by many factors that are not necessarily related to monetary policy. Thus, in order to correctly interpret the signals from financial markets, monetary policymakers must have a firm understanding of the factors underlying market rate movements. The importance of such factors may have shifted in recent years due to new non-standard monetary policy measures and financial-economic developments.

The pricing of bonds is frequently analyzed in terms of bonds' liquidity risk (Alquist, 2010; Afonso et al., 2015). When the liquidity of a particular bond diminishes, investors require an additional premium, known as the "liquidity premium", which reflects the increased risk of selling or buying a security in an illiquid market at a lower price. Understanding the relationship between bond returns and market liquidity is especially important during times of financial turbulence, when market liquidity may swiftly evaporate. During such circumstances, market participants tend to value liquidity and shift into more liquid government bonds under the so-called "flight-to-liquidity", suggesting hence that the price of more liquid bonds will be less sensitive to abrupt changes in market liquidity (Favero et al., 2010). Liquidity is thus valuable for market participants, rendering the variation in liquidity a key explanation for divergence in yields on comparable government bonds.

Nevertheless, the importance of government bond market liquidity from a monetary policy perspective remains an open question. Prior to the 2008-2009 financial crisis, liquidity was not regarded as relevant to the monetary policy decision-making process because government bond markets were seen as considerably liquid (Bernoth and Burco, 2004; Jankovich et al., 2006). Liquidity is a difficult concept to measure empirically, especially in the case of government bond markets for which different maturity bonds are issued periodically (Favero et al., 2010). Its importance has increased since the onset of the 2008-2009 crisis, when the deprived liquidity conditions highly amplified the jump in government bond yields (Ejsing and Sihvonen, 2009). While a high degree of liquidity can foster the link between the central bank's monetary policy decisions and the yield curve, thus stimulating the financial flow in the economy, the opposite situation – with liquidity conditions being deprived – poses risks for achieving monetary policy goals. The availability of liquid government bonds could also limit the size of potential asset purchases that central banks would otherwise want to acquire for reasons of monetary policy. A large liquidity premium may also indicate incomplete bond market integration across euro area countries and point to the necessity of further harmonization in bond market regulations (Alexopoulou et al., 2009). As a result, monitoring liquidity conditions became a routine task for monetary policymakers across most central banks.

This paper aims to identify the risk factors that are related to euro area government bond yield spreads. Diverging from previous studies, we focus specifically on the liquidity component as well as on the monetary policy perspective. Although euro area government bond markets have converged significantly since the establishment of the Economic and Monetary Union, these bond markets still exhibit heterogenous yield levels and dynamics. It is possible that these persistent disparities can be accounted for by the differences that exist between risk components embedded in government bond yields, including liquidity risk.

Our contribution to the existing literature on this topic is several-fold. First, to the best of our knowledge, this is the first paper to analyze liquidity–yield dependence in light of asset purchases by a major central bank. Our dataset covers the periods before and after the euro area sovereign debt crisis and the introduction of non-standard monetary policy measures, thus allowing us to assess whether the determinants of yields and liquidity component changed during different monetary policy accommodation phases. Second, while the bulk of previous research has centered only on benchmark 10-year maturity government bonds or on bonds with different maturities from the same jurisdiction, we analyze both cross-country and cross-maturity dimensions. By covering around 500 different government bonds, we are able to capture important liquidity–yield spread linkages on the full spectrum of government bonds and evaluate these effects on different bond clusters. Third, we seek to shed light on the underlying factors that drive the liquidity component embedded in government bond yield spreads over time.

By employing panel regression models with around 500 different euro area government bonds, we find that yield spreads have been linked to various risk factors. Credit risk and common market risk factors are positively and consistently related to government bond yield spreads. Meanwhile, liquidity risk becomes a statistically insignificant factor after the introduction of non-standard monetary policy measures. These findings should be of particular importance to government bond market participants and policymakers.

The remainder of the paper is organized as follows. The next section reviews the related literature. The third section presents the data set and methodology. The fourth section examines the determinants of yield spreads, and focuses on the liquidity component and the driving factors of the liquidity component. The final section concludes.

2. LITERATURE REVIEW

Numerous studies have linked the return of securities with their liquidity conditions. Nonetheless, the interaction of government bond market liquidity and returns has been analyzed most extensively for the US case. Compared to other economies, US Treasury bonds are issued in larger lots, have fewer maturities and usually do not add exotic features to their debt. Reinhart and Sack (2002) explored movements in 10-year Treasury and other markets and found that yield spreads have been increasingly influenced by a higher variety of risk factors, making them harder to interpret. Goyenko et al. (2011) investigated the liquidity of US Treasury bonds over an extensive time period (1967–2005) and reported that liquidity conditions in the bond market are significantly affected by the economic environment. They also found that off-the-run illiquidity rather than that of on-the-run issues was the source of the liquidity premium in the US Treasuries. Similar results have been documented by Ejsing and Sihvonen (2009). Related work was also carried out by Longstaff (2004), Fontaine and Garcia (2009) and Albagli et al. (2018).

The euro-denominated government bond market is considered more fragmented than the US one and the available time-series data is much shorter; consequently, the euro area case has received less scholarly attention. Unlike the US Treasury market, the order flow is dispersed over a large number of heterogeneous European markets and bonds; such market fragmentation impedes the informational efficiency and liquidity of euro area government bonds (Ejsing and Sihonen, 2009). This implies poorer liquidity conditions and pricing mechanism, meaning that the yield and liquidity interrelations are also different in the case of the euro area. Hence, studies have tended to analyze the yield and liquidity of different euro area government bond markets from a cross-country perspective. Beber et al. (2009) reported that government bond yield spread in ten euro area markets relate to differences in the credit quality and liquidity of these markets. Favero et al. (2010) found a common cross-market trend in yield differentials that is correlated with a measure of aggregate euro area risk. Meanwhile, Dunne et al. (2006) determined that execution quality is closely related in most euro area bond markets to the size of the issuer, the issuance techniques and the obligations imposed on primary dealers.

Although scholars have offered a variety of explanations for euro area bond yield changes, the determinants usually fall into four groups: credit risk, liquidity, general risk aversion (market risk) and other (e.g. control) variables. Starting with the credit risk component, Manganelli and Wolswijk (2009) argue that this factor constitutes the key to government yield spreads as it reflects the financial compensation that investors require to cover government default risk, and is typically approximated by using daily/weekly credit default swaps or monthly/quarterly fiscal performance indicators. Afonso et al. (2015), for their part, look at monthly fiscal variables such as government budget balance, debt, industrial production and credit rating. The authors contend that the increase in country-specific credit risk indicators leads to higher yield spreads over the risk-free rate, while the general risk aversion (international / common market risk factor) reflects the level and price of perceived financial risk affecting the yields of all the euro area markets. The international risk factor is proxied by subtracting the US corporate bond yield or the fixed interest rate swap from US treasury bills (Bernoth and Erdogan, 2010; Favero et al., 2010) and / or US stock market volatility (Beber et al., 2009; Afonso et al., 2015), while the common market risk factor is proxied by approximating the cross-country risk, e.g. a combination of euro area financial stress indicators (Alessandrini et al., 2012). This variable is highly linked to the “flight-to-safety” phenomenon since, during stressed market conditions, funds usually flow to the most secure (risk-free) securities (Zeman, 2014). Borgy et al. (2011) found that the time-varying risk aversion of international investors accounts for over 80% of the total spreads variation; similar findings were reported by Favero et al. (2010). Various researchers also use a wide range of other variables. For instance, Alonso and Blanco (2002) add lags of yield spreads and the dummy variable showing the bonds benchmark status, while Afonso et al. (2015) additionally add the euro effective exchange rate and the variable that accounts for heterogeneity between periphery and core countries.

In this paper, we concentrate on the liquidity component embedded in euro area government bond yields. Favero et al. (2010) state that there are two, not mutually exclusive, views on why liquidity should affect yield differentials: illiquidity creates trading costs as well as additional risks. According to Manganelli and Wolswijk (2009), the liquidity premium shows the extra interest rate that investors require for bearing the risk of having to liquidate security at a lower price with respect to a benchmark. Alexopoulou et al. (2009) mention that liquidity risk mirrors investors’ risk preferences, thus implying that risk-adjusted yields should be higher for less liquid bonds. Kempf and Homburg (2000) propose that bond liquidity should be used as an additional pricing factor even for German government bonds, as liquidity risk usually increase for all bonds during heightened market stress. Somewhat contrarily, Barrios et al. (2009) found that liquidity changes explain the evolution of yields only in vulnerable countries.

Scholars obtain different results regarding the relative importance of the liquidity component embedded in yields. Ejsing and Sihvonen (2009) note that the liquidity component was not statistically significant during tranquil times, but the situation has changed since the 2008-2009 financial crisis. Afonso et al. (2015) also find that liquidity effects are stronger during phases of tighter financial conditions and higher interest rates, while the effect of liquidity risk is rather limited during 'normal' times. Meanwhile, Bernoth and Erdogan (2010) report that the liquidity premium never plays a significant role for a given country after its entrance to the European Monetary Union.

The direct concern of government bond market liquidity from the monetary policy implementation perspective arose due to the introduction of Quantitative Easing Programmes in advanced economies. After reaching the zero lower bound in the aftermath of the global financial crisis, the focus shifted towards a bigger influence on long-term yields. In January 2015, the President of the European Central Bank (ECB), Mario Draghi, announced the Eurosystem's version of Quantitative Easing, namely, the Public Sector Purchase Programme (PSPP). The Eurosystem, so it seemed, was poised to become a dominant investor in the European government bond market, a move that would naturally affect the liquidity conditions in the secondary government bond market.

The effects of recent non-standard monetary policy measures introduced on euro area market liquidity are highly contested. It has long been argued that monetary policy may affect the liquidity component of government bond yields (Fleming and Remolona 1999). According to the IMF (2015), the main channels through which monetary policy impacts liquidity are bank funding, market functioning and risk appetite. Overall, monetary policy expansions have had a positive impact on euro area market liquidity in recent years due to the reduction of market making and trading costs. Christensen and Gillan (2017) argue that asset purchases can reduce search-and-bargaining frictions and, subsequently, increase liquidity premium embedded in yields of bonds that are most actively purchased by a central bank. By employing different liquidity indicators, Jurkšas et al. (2018) argue that government bond market liquidity has diminished only around political and economic events, but not after important PSPP announcements such as the introduction of the PSPP and its following modifications and extensions. However, Boermans and Keshkov (2018) assert that the PSPP had market distortionary effects due to asymmetric portfolio rebalancing and increased ownership concentration. These effects have altered the concerns for bond scarcity and market liquidity dry-ups that have led to increased financial fragility and thus diminished the effectiveness of government bond pricing. Schlepper et al. (2017) show that the PSPP effect on bond prices varies with market conditions, being larger during periods of low liquidity and higher yields.

The topic of how liquidity enters euro area bond pricing in relation to monetary policy actions has not been broadly addressed. Most of the related research on the post-crisis period has studied US corporate and government bond markets, thus leaving aside the euro area markets. Even fewer studies have adopted monetary policy perspective. To the best of our knowledge, no other study has examined how the Eurosystem's non-standard monetary policy measures have affected the relationship between euro area government bond yields and liquidity, as well as what drives the liquidity component during various market regimes.

3. DATA AND METHODOLOGY

The data employed in this study is mainly sourced from Thomson Reuters as well as EuroMTS Ltd (hereafter – MTS), the biggest inter-dealer platform for European government bonds. This trading platform is operated as a central limit order-book where executable prices are offered in advance of any request to trade (MTS, 2017). The most extensively used MTS dataset in this study is the order-book data that covers information about high-frequency limit-orders and their subsequent revisions (including the prices and quantities on both ask and bid side of the market) on a microsecond time stamp. In order to use this dataset in econometrical models, the order-book data was sampled to discrete daily intervals. Most other studies use much longer intervals due to the limitation of high-frequency data.

We used order book data from June 2011 until March 2018. This period encompasses the euro area sovereign debt crisis in 2011-2012, various financial turbulences (e.g. 'Taper Tantrum' in 2013, 'Bund Tantrum' in 2015), political events (Brexit vote in June 2016, US presidential election in November 2016) and the introduction of important monetary policy measures: the announcement of Outright Monetary Transactions (OMT) in August 2012, the negative Deposit Facility Rate (DFR) in June 2014, the PSPP in January 2015, and so on. Although several authors use a very long time series (e.g. Alquist (2008) – from 1871 until 1907; Afonso (2015) – from 1999 until 2010), the majority of scholars employ much shorter time spans without different business cycle phases (e.g. Favero et al. (2010) – for the period 2002-2003). To the best of our knowledge, no other similar studies have scrutinized the effects of non-standard monetary policy measures on the government bond yield–liquidity function on different market regimes.

In this study, we consider the six largest euro area markets with, overall, 500 different government bonds. Previous research has studied several 10-year benchmark government bonds or different maturity bonds from the same market. As we wish to analyze the results from the perspective of different countries and maturities, we concentrate on all government bonds that were traded in MTS market from June 2011 for the six largest euro area countries, that is, Germany, France, Italy, Spain, the Netherlands and Belgium. We selected these markets on the basis of the availability of different bonds at various maturity groups. The diverse cross-sections of issuers and maturities ensure dispersion in factor sensitivities across different bonds, which facilitates conducting panel regressions with higher statistical power.

The dependent variable in our regression model is the yield spread. Although other studies use prices, yields and mostly government bond yield spreads over German maturity-matched yield, we opt for yield spreads over the overnight index swap (OIS) rate. Given that the bonds issued by AAA-rated issuers are not regarded as perfect substitutes, we include German bonds not as a control bonds but as one of the six analyzed markets. By using the yield–OIS spread, we sought to separate the "flight-to-safety" component from the yields; German government bonds are regarded as the "safe-haven" asset class whose yields often diverge from fundamental value during financial turmoil and/or when central banks employ non-standard monetary policy measures (Coeure, 2017). In this vein, the OIS rate is more strongly linked to the rate set by monetary policy decision-makers and is thus much less affected by "flight-to-safety" issues. We then construct a common market risk indicator that is used to account for the "flight-to-safety" factor. We match yields of particular government bonds with the OIS rate that has the closest maturity to this bond (0.5-, 1-, 2-, 3-, 4-, 5-, 7-, 10-, 20-, 30-years to maturity).

We regress government bond yield spreads contemporaneously over the several most commonly analyzed factors. The description of the explanatory variables used in the panel regression model as well as the mean value and expected sign of the effect of these variables on yield spreads are provided in Table 1. Starting with our main explicative variable of focus, the (il)liquidity indicator, when markets become less liquid, investors start requiring higher yields; thus, the illiquidity indicator should be positively linked to yield spreads. Liquidity risk creates trading costs, so yield spreads should react endogenously to changes of market liquidity. In most cases, credit risk is found to be positively linked with yield spreads, meaning that the deterioration of market expectations of countries fiscal stance should increase yields. The composite risk indicator should reflect changes in financial market risk and hence correspond to the “flight-to-safety” phenomenon. Bonds with higher residual maturity naturally exhibit higher yields, while the newest issuances attract more investors, increase the relative scarcity of seasoned bonds and therefore often trade with smaller yields.

Table 1. Description of the dependent and explanatory variables and average values across euro area sovereign bonds

Name	Brief Description	Source	Mean value	Min value	Max value	Standard deviation	Exp. Sign
Yield Spread	Difference between government bond yield and maturity matched overnight index swap rate	MTS, Thomson Reuters	0.00147	-0.4067	0.6585	0.0752	
Liquidity Indicator	Different types of indicator: illiquidity score (+ separately ask and bid side indicators), average bid-ask spread, quoted size	MTS	-0.0009	-2.8633	3.0443	0.1783	+
CDS	Country- and maturity-matched price of particular credit default swap	Thomson Reuters	-0.00429	-30.14	31.4671	4.6583	+
Common Market Risk	First principal component from four risk indicators: Composite Indicator of Systemic Stress (share from overall index = 0.52), VStoxx euro area volatility index (share = 0.54), MOVE bond market volatility index (share = 0.47), spread between BBB and AAA rating euro area corporate bonds (share = 0.48)	Thomson Reuters	0.00166	-0.8511	1.1561	0.2132	+
Maturity Spread	Difference in years between government bond maturity and comparable OIS maturity	MTS, Thomson Reuters	0.00302	-0.021	3.0603	0.1239	+
Dummy: On-The-Run Status	Three newest issuances from the same country and maturity bucket	MTS	0.42747	0.198	0.7485	0.2029	-

Note: Mean, min, max values and standard deviations are at first calculated from the daily changes of individual sovereign bonds for the full sample, and then averaged across all bonds. The expected sign of the effect of the explanatory variable is based on the results from other studies and market intuition.

The main focus in this study is the liquidity component of yield spreads. The most often used market liquidity indicator is the bid-ask spread (usually composed of the prices of the indicative quote) or liquidity proxies (e.g. outstanding government debt, stock volatility index). Few authors use different liquidity indicators in the same study. The main liquidity indicator used in this analysis is the order-book illiquidity-score (Jurkšas et al., 2018), calculated as a winsorized (at 10% level) value from intraday 1-minute frequency metrics according to equation 1:

$$\text{Illiquidity-Score}_{5,t} = \frac{(\sum_{j=1}^{5} P_{t,Ask(J)} - \sum_{j=1}^{5} P_{t,Bid(J)})/5}{\sum_{j=1}^{5} Q_{t,Ask(J)} + \sum_{j=1}^{5} Q_{t,Bid(J)}}, \quad (1)$$

where *t* is the time at which the limit-order book is calculated; *P* is the price in the limit-order book; *Q* is the quoted size that can be traded at a given quoted price; *Ask* and *Bid* denote the side of the limit-order book and *j* is the order of priority of the offers in the limit-order book, i.e. from first to fifth best ask/bid price and its corresponding quantity.

The order-book illiquidity-score concerns the two most important liquidity dimensions, namely, cost and depth. According to BIS (2016), market liquidity is a concept with multiple dimensions, so that an appropriate indicator should be derived as a composite measure. The order-book illiquidity score mainly indicates the average transaction costs of the five best buy and sell orders relative to their sizes, i.e. how on average the bid-ask spread would be impacted if the five best bids and five best asks were to be transacted. In general, the lower the order-book illiquidity-score and the average bid-ask spread and the higher the corresponding quoted size, the more liquid the bond market.

In this study, we also compare results across different constituents to this liquidity indicator: average bid-ask spread of five best prices, quoted size at five best prices as well as bid and ask side illiquidity scores separately[2]. It is important to note that these indicators are constructed not from indicative quotes (e.g. obtained from Bloomberg), which are much less representative and do not always reflect actual market prices, but from firm limit-orders submitted by dealers who want to execute their orders.

The divergence of cross-country average dynamics can be observed for the majority of analyzed variables (see Appendix 1). It is noticeable, for instance, that yield spreads increased substantially in 2011-2012, as did all other risk factors: credit, common market and liquidity risks. This is especially evident in the Italian and Spanish sovereign bond markets, while German bonds did not exhibit such high volatility. Meanwhile, the ask- and bid-side illiquidity-score increase was very similar to that of the composite illiquidity-score, although their construction is somewhat different. Also, it is important to notice that the dynamics of the illiquidity-score is more similar to the average bid-ask spread than to the quoted size.

The baseline equation of the panel least squares regression model with fixed effects used in this paper is as follows:

$$\Delta Y_{i,t} = \beta_1 \times \Delta L_{i,t} + \beta_2 \times \Delta CDS_{i,t} + \beta_3 \times \Delta R_{i,t} + \beta_4 \times \Delta C_{i,t} + \beta_5 \times D_{i,t} + \alpha_i + u_{i,t}, \quad (2)$$

where *i* is a particular bond, *t* is time (particular day), *ΔY* is the daily change of yield spread, *ΔL* is the daily change of a particular liquidity indicator, *ΔCDS* is the daily change of the maturity matched CDS value, *ΔR* is the daily change of the first principal component of various financial risk factors, *C* is the control variable (e.g. residual maturity gap), *D* is a dummy showing on-the-run status, *β* is the coefficient of the explanatory variable effect, *α* is time-invariant fixed-effect (in this case – bond-specific effect), and *u* is the error term.

[2] Bid and ask side indicators are naturally calculated differently than the composite illiquidity-score. For instance, as it is not possible to calculate the average spread of the five best quotes separately on the bid side, the numerator of the bid-side indicator is the difference between the mid-point price and the fifth-best bid price, while the numerator is the sum of the five best quantities of the bid-side quotes. Thus, the magnitude of the estimates of the illiquidity-score and bid (or ask) side indicators cannot be directly compared.

We conduct a panel least squares regression in order to inspect the relation between various risk factors and yield spreads. The above-described variables are used in panel regressions with bond-specific fixed effects. Similar models were applied by Zeman (2014) and Afonso et al. (2015). The assumption of the panel model with fixed effects is that the specific effects of different bonds are highly correlated with the level of the explanatory variable[3]. A Hausmann test was carried out to corroborate our use of fixed effects. We use a contemporaneous function of yield spreads and risk factors because there is no clear reason to suspect that the daily change of a particular risk factor would affect yield spreads later than the same day. We also use first differences, as some variables were found to be non-stationary for many of the bonds in the sample[4].

Additionally, we run a panel cointegration procedure for a robustness check because this model is often used to account for possible endogeneity of dependent variables. Liquidity, credit and common market risk factors are regarded as exogenous variables in our panel regression framework as they directly affect investors' preference for particular sovereign bonds and, therefore, their pricing[5], but in some cases it could be presumed that risk factors could also be affected by yield spread dynamics. We acknowledge the relative relevance of endogeneity among the variables that we use in this study since liquidity can be considered as an equilibrium object, nevertheless this fact shall not cause serious interferences in our concluding results. Although the endogeneity issue is less clear-cut in contemporaneous setting and because dynamics of risk factors might be related to intrinsic behavior of a particular market (e.g. illiquidity score is calculated from the limit order books), we run an additional cointegration model for robustness reasons.

4. EMPIRICAL RESULTS

4.1 BASELINE MODEL

In order to check how liquidity is related to government bond yields and how this relation changes with different model specifications, we first add variables progressively one by one to the panel regression model. As can be seen in Table 2, the results of the model with only one variable – the liquidity indicator – show that changes of the illiquidity score are positively linked with the dynamics of yield spreads, implying that when liquidity diminishes (improves), the yield spreads tend to increase (decrease) on the same day. The liquidity component is a significant element in shaping yield spreads as (il)liquidity risk creates higher trading costs for traders.

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[3] We cluster standard errors because the estimate of the standard errors might be greatly understated (and the significance of the variable – overstated) in a setting with heterogeneous groups (Cameron and Miller, 2015).
[4] Augmented Dickey-Fuller and non-parametric Phillips-Perron tests revealed that around 90% of bonds exhibited unit roots for the dependent variable–yield spreads. Many other variables were also found to be non-stationary in the levels for the majority of bonds. Hence, we decided to proceed with our regressions in first differences, avoiding thus the possibility of carrying out spurious regressions in the individual OLS panel regressions.
[5] The changes of yield might have both positive and negative signals for investors. On one hand, increasing yields could indicate elevated investors' nervousness and risk-off sentiments. On the other hand, increasing yields might be related to expectations of higher economic growth and/or inflation.

Table 2. Results of the panel regressions with different risk factors and government bond yield spreads

	Dependent Variable: Δ Yield Spread			
Δ Illiquidity Score	0.01076***	0.00815***	0.00803***	0.00811***
	(4.2)	*(3.99)*	*(3.96)*	*(4.01)*
Δ CDS		0.00532***	0.00526***	0.00535***
		(39.20)	*(38.44)*	*(39.21)*
Δ Common Market Risk			0.00769***	0.00723***
			(9.1)	*(8.54)*
Δ Maturity Spread				0.06754***
				(29.46)
Dummy: On-The-Run				-0.00057**
				(-2.36)
DW statistic	*2.0236*	*2.2281*	*2.2276*	*2.236*
Adjusted R^2	*0.02*	*0.158*	*0.158*	*0.179*
Observations	450 410	450 410	450 410	450 410
Unique ISINs	501	501	501	501

Notes: The dependent variable in panel regression model is the daily change of yield spread of a particular bond from the six largest euro area markets. |The first line at each variable denotes the estimate of the effect of the explanatory variable specified on the left-hand side. Asterisks indicate statistical significance at the 10% (*), 5% (**) and 1% (***) levels. The second line (in parentheses) shows *t* statistics. ISIN-specific fixed effects are added to the model, while standard errors are clustered.

When additional variables are included in the model, the liquidity component does not change materially in size. The inclusion of country-specific CDS variable leads to a somewhat smaller estimate of the liquidity component. Overall, changes of credit risk are highly (and positively) linked to the dynamics of yield spreads. This is not surprising because, as Manganelli and Wolswijk (2009) and Beber et al. (2009) explain, this factor is usually found to be the most important in explaining government bond yield spreads since it reflects the financial compensation that investors require to cover the default risk. The addition of a common market risk factor is also statistically significantly related to yield spread dynamics, and does not change the estimates of other variables. Not surprisingly, the coefficient of this risk factor has the same sign as credit risk and illiquidity score variables – when risk-off sentiments intensify, investors start requiring higher compensation for holding securities. The addition of two control variables – maturity spread over OIS maturity and a dummy of the on-the-run status – barely changes the coefficients and significance of the other variables. The coefficients of these two variables are in line with other studies, i.e. bonds with a longer maturity usually exhibit higher yields, while newest bond issuances tend to exhibit lower yields due to their benchmark status.

Other liquidity indicators have a very similar relation with yields spreads as the illiquidity score. As can be seen in Table 3, only the indicator of quoted size has an opposite sign, which is due to the fact that this indicator and liquidity conditions are linked directly (i.e. increase of quoted size implies improved market depth and thus liquidity conditions), while all other indicators are inversely related to liquidity. Interestingly, independently from the liquidity indicator included in the model, the coefficients and statistical significance remain very similar, implying that different liquidity dimensions and sides of liquidity are linked with yield spreads rather homogenously. Therefore, our main conclusion stands: worsening (improving) liquidity conditions put an upward (downward) pressure on yield spreads.

Table 3. Results of the panel regressions with different liquidity indicators

	Dependent Variable: Δ Yield Spread				
Liquidity indicator:	**Illiquidity Score**	**Bid-Ask Spreads**	**Quoted Size**	**Bid-Side Indicator**	**Ask-Side Indicator**
Δ Liquidity indicator	0.00812***	0.01041***	-0.00009***	0.00158***	0.00156***
	(4.03)	*(3.98)*	*(-7.46)*	*(2.65)*	*(2.61)*
Δ CDS	0.00545***	0.00534***	0.00546***	0.00536***	0.00536***
	(40.33)	*(39.17)*	*(39.33)*	*(39.26)*	*(39.26)*
Δ Common Market Risk	0.00747***	0.00747***	0.00764***	0.00779***	0.00779***
	(8.84)	*(8.89)*	*(8.79)*	*(9.01)*	*(9.04)*
Δ Maturity Spread	0.06764***	0.06754***	0.06742***	0.06749***	0.06759***
	(29.41)	*(29.45)*	*(29.46)*	*(29.47)*	*(29.47)*
Dummy: On-The-Run	-0.00053**	-0.00054**	-0.00053**	-0.00053**	-0.00053**
	(-2.03)	*(-2.19)*	*(-2.18)*	*(-2.18)*	*(-2.16)*
DW statistic	*2.236*	*2.2359*	*2.2375*	*2.237*	*2.237*
Adjusted R^2	*0.179*	*0.180*	*0.179*	*0.178*	*0.178*
Observations	450 410	450 410	450 410	450 410	450 410
Unique ISINs	501	501	501	501	501

Notes: The dependent variable in the panel regression model is the daily change of the yield spread of a particular bond from the six largest euro area markets. The first line at each variable denotes the estimate of the effect of the explanatory variable specified on the left-hand side. Asterisks indicate statistical significance at the 10% (*), 5% (**) and 1% (***) levels. The second line (in parentheses) shows *t* statistics. ISIN-specific fixed effects are added to the model, while standard errors are clustered.

The links between various determining factors and yield spreads are, however, not static; they change during different monetary policy accommodation phases. To investigate this, we divide the sample period into four parts: 1) from 1 June 2011 until 1 August 2012, when no exclusive non-standard measures were announced and market stressfulness was still very high; 2) from 2 August 2012, i.e. the announcement date of the OMT[6], until 4 June 2014; 3) from 5 June 2014, i.e. the announcement of the introduction of negative DFR, until 21 January 2015; 4) from 22 January 2015, i.e. the announcement of the Public Sector Purchase Programme (PSPP), until March 2018. As can be seen in Table 4, the importance of the liquidity component in determining yield spreads seems to have decreased when the market stress abated, partly due to important monetary policy announcements. The liquidity component even became statistically insignificant from June 2014 when the introduction of negative DFR and other measures were announced, and later on when the PSPP was implemented. Monetary policy actions through confidence channels influence financial assets, especially by tackling uncertainty (Falagiarda et al., 2015), which is also highly linked to the liquidity component embedded in government bond yield spreads. This implies that liquidity risk may have become less of a concern for

[6] On 2 August 2012, the Governing Council of the ECB announced that it would undertake outright transactions in government bond markets to safeguard "an appropriate monetary policy transmission and the singleness of the monetary policy". The OMT was only available for use when a particular euro zone government requested financial assistance. Although the OMT was never used in practice, the announcement of this instrument was regarded to have delivered a positive impact for reinforcing the monetary transaction mechanism.

government bond investors, thus the liquidity premium demanded by investors decreased more than yield spreads.

Table 4. Results of the panel regressions of yield spreads on different periods

	Dependent Variable: Δ Yield Spread			
Period:	**Until Aug 2012**	**Aug 2012 - Jun 2014**	**Jun 2014 - Jan 2015**	**After Jan 2015**
Δ Illiquidity Score	0.02975***	0.00703**	0.00395	0.0015
	(7.41)	*(2.01)*	*(1.54)*	*(0.92)*
Δ CDS	0.00544***	0.0053***	0.00441***	0.00412***
	(32.9)	*(30.3)*	*(16.79)*	*(18.16)*
Δ Common Market Factor	0.00673**	0.00218**	0.01447***	0.00913***
	(2.86)	*(2.00)*	*(10.48)*	*(12.01)*
Δ Maturity Spread	0.06332***	0.07959***	0.06416***	0.06132***
	(9.91)	*(15.1)*	*(7.49)*	*(22.12)*
Dummy: On-The-Run	-0.00082	-0.00277***	-0.00095	-0.00017
	(-0.55)	*(-4.21)*	*(-1.64)*	*(-0.55)*
DW statistic	*2.2722*	*2.174*	*2.2285*	*2.1945*
Adjusted R^2	*0.227*	*0.195*	*0.116*	*0.069*
Observations	70 923	115 845	42 052	221 590
Unique ISINs	278	320	286	389

Notes: The dependent variable in panel regression model is the daily change of yield spread of a particular bond from the six largest euro area markets. The first line at each variable denotes the estimate of the effect of the explanatory variable specified on the left-hand side. Asterisks indicate statistical significance at the 10% (*), 5% (**) and 1% (***) levels. The second line (in parentheses) shows *t* statistics. ISIN-specific fixed effects are added to the model, while standard errors are clustered.

The importance of the credit risk component remained almost the same throughout all the periods, meaning that this type of risk is always priced by bond investors. Beber et al. (2009) similarly show that, in times of market stress, investors chase liquidity more than credit quality, while in tranquil times both factors are important. The relation of the common market risk component with yield spreads remained positive throughout all the periods, but the estimate was lowest from the OMT announcement on, i.e. the period that is characterized by the largest yield spread compressions and increasing risk-on sentiments. Only during this period, the on-the-run status was also statistically significant, meaning that benchmark bonds experienced the largest yield compressions. It is also important to notice that the estimates of different variables on average decreased over time, implying that it is harder to associate the analyzed factors with yield spreads as these spreads were affected by other factors such as monetary policy actions or political events.

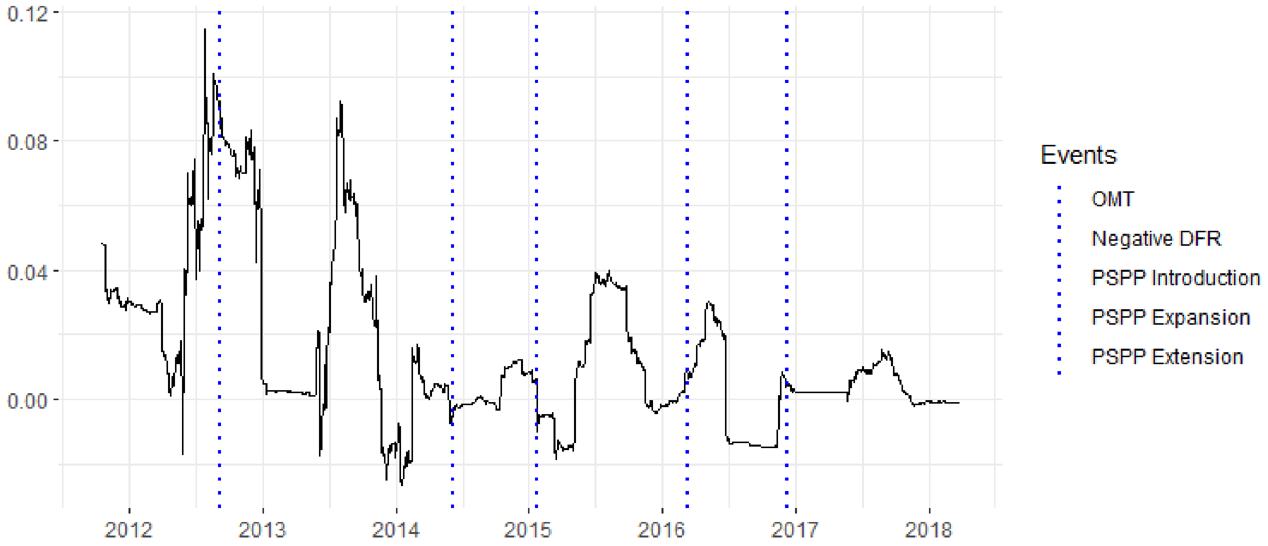
We have additionally used the panel cointegration method for robustness checks. Correcting for cross-sectional dependence and using variables in levels, we could not reject the null of unit root for the panel (in favor of the hypothesis that there are members of the panel for which the series are stationary). The variables were found to be cointegrated via the Pedroni test and consequent results with the Fully Modified OLS procedure were very like those from the baseline model.[7]

4.2 MODEL WITH ROLLING WINDOWS

The panel least squares regression with the same variables as in the baseline model was performed on a 100 trading-day rolling window set-up. This application enables us to determine how liquidity and other components affect euro area government bond yield spreads over time, and identify structural break-points. Christensen and Gillan (2018) argue that the effects tied to the liquidity channel should have a different dynamic profile than the effects from other transmission channels, such that the liquidity risk component should dissipate towards the end of the asset purchases.

As can be seen in Figure 1, the estimate of the liquidity component fluctuates highly over time. Interestingly, the liquidity component is not always positive, possibly indicating that during tranquil periods with ample liquidity, bond yields can even become smaller than other factors would imply. It is also important to note that announcements of monetary policy decisions related to non-standard measures had notable effects on the size of the liquidity component embedded in yield spreads. For instance, following Draghi's famous remark "to do whatever it takes"[8], and after the announcement of the possibility of using OMT, the importance of the liquidity component started to shrink. It also decreased on the day of the negative DFR announcement. An even stronger slump of liquidity component can be observed on the announcement day of the PSPP. Meanwhile, the later announcements of PSPP modalities only had marginal effects.

Figure 1. Estimates of **illiquidity component** from the rolling panel regression on yield spread changes



Notes: The value at a particular point in time is the estimate of liquidity component from the 100 trading-day rolling regressions. The event lines correspond to these monetary policy announcements: 1) Possibility to use OMT of a size adequate to reach its objective (2012-08-02); 2) Policy rates lowered (DFR to minus 0.1%) and launch of targeted longer-term refinancing operations (2014-06-05); 3) Launch of PSPP (2015-01-22); 4) Expansion of monthly EAPP (including PSPP) to €80 billion (2016-03-10); 5) EAPP (including PSPP) extended until December 2017 (2016-12-08).

[7] The detailed results can be obtained upon request to the authors.
[8] Full quote from the speech in London on July 26, 2012: "Within our mandate, the ECB is ready to do whatever it takes to preserve the euro. And believe me, it will be enough." See full text: https://www.ecb.europa.eu/press/key/date/2012/html/sp120726.en.html.

The liquidity component seems to be largest under stressed market conditions. It was very high during the euro area sovereign debt crisis (2011 – mid-2012) and also when worries about China's economic slowdown intensified (Q1 2016). It became more important in explaining yield spreads during the time of the 'Taper Tantrum' (starting in May 2013) and the 'Bund Tantrum' (starting in April 2015). Political events, such as the US presidential elections (8 November 2016), also had a material and positive impact on the importance of liquidity. This implies that investors' concern about liquidity risk rose during perturbations in government debt markets.

The other two risk factors – credit and common market risk – display somewhat different dynamics. The size of the credit risk component is always positive and fluctuates in a narrower range than the liquidity component. This means that credit risk is usually priced by bond traders, although the estimate value seems to be trending downwards during the sample period (see Appendix 2). Meanwhile, the estimate of common market risk component fluctuates around zero but was highest during the sovereign debt crisis and under turbulent market conditions (see Appendix 3).

4.3 DETERMINANTS OF LIQUIDITY COMPONENT DYNAMICS

Next, we turn to the analysis on how the size of the liquidity component of the yield spread differs due to monetary policy actions. First, we run 100 trading-day rolling window OLS regressions separately for all the bonds according to equation 1 but without the cross-country unit, that is, the only difference being that we now run OLS (and not panel) regressions separately for each bond. By doing this, we are able to estimate the liquidity constituent on yield spread dynamics for all the bonds separately. Ferdinandusse et al. (2017) shows that asset purchases may increase market liquidity in the very short term but may erode it in the longer term due to crowding out of other buyers and the increasing scarcity of sovereign bonds available for purchases. Then, we run a panel least squares model where the dependent variable is the liquidity estimate of each bond and the explanatory variables are related to monetary policy (other explanatory variables remain the same as in formula 2):

1) Eonia rate – 1-day interbank interest rate for the euro area. This is directly connected to the key interest rate set by the Governing Council of ECB. The Eonia rate declined by 1.21 percentage points during the sample period: from 0.849% (1 June 2016) to -0.365% (27 March 2018). During this period, the Eonia rate followed the DFR path: although the key monetary policy rate was increased by the start of the sample period by 25 bps, it was followed by seven DFR cuts by overall 1.15 percentage points from 0.75% to -0.4%. There were three main waves of interest rate cuts, i.e. at end-2011 – mid-2012, mid-2014 – end-2014 and end-2015 – start-2016.

2) Bank reserves – the sum of funds accumulated due to ECB reserve requirements, excess liquidity in current and deposit accounts. This indicator is directly related to PSPP implementation as well as to other monetary policy operations that increase bank reserves. It increased more than nine times during the sample period: from 212 bn. EUR to 1923 bn. EUR. The log of variable is used in the model.

3) ECB monetary policy announcements – dummy variable equaling 1 when an announcement was made regarding a particular monetary policy decision, i.e. lowering of key rates (see Appendix 4) or PSPP monthly volume modalities and/or extensions of the implementation phase (see Appen-

dix 5). Monetary policy meetings are held every six weeks since 2015 onwards and every month before 2015.

The size of the liquidity component is highly related with monetary policy variables during the full sample period (see Table 5). Starting with interest rates, the change of the liquidity component is negatively linked to the Eonia rate, meaning that rate decreases enhanced the importance of the liquidity component embedded in government bond yield spreads. The liquidity component also became more important at the announcement dates of rate changes. This finding can be explained by the fact that yields decreased faster than liquidity improved after the decreases of interest rate; thus, the liquidity component began having stronger effect. A similar conclusion can be made regarding bank reserves: when reserves increased, the yields decreased and therefore more inertial liquidity component began having stronger effects on yield spreads. This could possibly be attributed to the fact that ECB decisions led to lower yield spreads, while the effect of monetary policy actions on liquidity, as mentioned in the literature review, is disputable. Interestingly, the effect was negative on the announcement days concerning PSPP, meaning that the initial market reaction was reversed afterwards, i.e. during the implementation phase. This finding that of Christensen and Gillan (2018), who argue that specific monetary policy announcements are usually not material in size for liquidity. However, as mentioned in the previous section, the overall size of the liquidity component embedded in yield spreads was smaller from the announcement date of PSPP, meaning that without monetary policy measures, the liquidity component could have been even smaller. Other monetary policy announcements also enhanced the link between liquidity and yield spreads. Indicators not directly related to monetary policy have significant links with the strength of the liquidity component. For instance, the increase of credit risk and common risk factors are positively linked to the liquidity component, possibly because all three indicators are related to the general risk sentiments.

Table 5. Results of the panel regressions of liquidity component on different periods

	Dependent Variable: Δ Liquidity Estimate				
Period:	**Full Sample**	**Until July 2012**	**July 2012 - July 2014**	**July 2014 - Jan 2015**	**After Jan 2015**
Δ Eonia	-0.01418*** *(-4.28)*	-0.0391*** *(-5.77)*	-0.0231*** *(-5.3)*	-0.01846** *(-2.11)*	0.02812* *(1.77)*
Δ Bank Reserves	0.00763*** *(3.42)*	-0.00523* *(-1.88)*	0.00587 *(0.89)*	-0.00143 *(-0.15)*	0.05358*** *(4.14)*
Dummy: MP PSPP ann.	-0.03486*** *(-4.95)*				
Dummy: MP rate ann.	0.01171*** *(5.79)*				
Dummy: MP other ann.	0.00496*** *(5.06)*				
Dummy: MP all ann.		0.01208*** *(7.08)*	0.0049*** *(4.79)*	0.00386** *(2.03)*	-0.00257 *(-1.36)*
Δ CDS	0.00007** *(2.69)*	0.00014*** *(5.66)*	-0.0003*** *(-4.65)*	0.00122*** *(4.76)*	-0.00008 *(-0.66)*

Δ Common Risk Factor	0.00304***	-0.00172**	0.01531***	-0.00381	0.00149
	(3.71)	*(-2.52)*	*(8.82)*	*(-1.24)*	*(1.33)*
Δ Maturity Spread	0.00232**	-0.00119*	0.00207	0.00205	0.0029***
	(2.58)	*(-1.81)*	*(0.95)*	*(0.66)*	*(2.89)*
Dummy: On-The-Run	-0.00038	-0.00037	-0.00067	-0.00101	-0.00047
	(-0.75)	*(-0.38)*	*(-0.49)*	*(-0.44)*	*(-0.62)*
DW statistic	*2.0008*	*1.998*	*1.9991*	*2.0035*	*2.0046*
Observations	400 820	44 214	108 225	39 720	208 661
Unique ISINs	471	249	297	272	374

Notes: The dependent variable in panel regression model is the daily change of liquidity component estimate of a particular bond from the 100 trading-day rolling window OLS regressions. The first line at each variable denotes the estimate of the effect of the explanatory variable specified on the left-hand side. Asterisks indicate statistical significance at the 10% (*), 5% (**) and 1% (***) levels. The second line (in parentheses) shows *t* statistics. ISIN-specific fixed effects are added to the model, while standard errors are clustered.

The relationship between monetary policy variables and the liquidity component became stronger during periods when the particular monetary policy measures were most actively used. To start with, changes in the Eonia rate had the most enhanced effect when interest rates were lowered, i.e. until July 2014 and, to a smaller extent, until the announcement date of the PSPP. This effect reversed after the PSPP announcement, when Eonia rates changes began having a marginal effect. Similarly, the effect of bank reserves was strongest during the period after the PSPP announcement, when reserves were steadily increasing, while the effect was marginal beforehand. The strength of all monetary policy announcements was strongest during the first half of the sample period, possibly because the liquidity component had become more inertial after the PSPP announcement.

5. CONCLUSIONS

We find that yield spreads are linked to various risk factors, and that some of the links have changed over time. Credit risk and common risk factors are positively and consistently related to government bond yield spreads. Although all constructed liquidity indicators are significantly linked to yield spreads, the liquidity component is mainly reinforced during times of market distress such as the euro area sovereign debt crisis, the 'Taper Tantrum' and the 'Bund Tantrum'. Therefore, (il)liquidity risk usually creates additional trading costs when turbulence in government debt markets increases and investors begin to demand higher liquidity premiums.

The dynamics of the liquidity component of yield spreads is also related to the monetary policy stance. The liquidity component diminished on announcement days of monetary policy decisions related to the PSPP, but this effect was reversed during periods of declining interest rates and increasing reserves. Overall, the liquidity component has been statistically insignificant since the introduction of non-standard monetary policy measures. This finding could be explained by diminishing general risk sentiments and, possibly, the shift of investors' focus to other factors such as political risk and market microstructure.

The implications of these findings should be of interest to government bond market participants and policymakers. For instance, portfolio managers who invest in government bond markets should be familiar with the risks driving bond prices and know which of these they would like to accept, i.e. credit, common market and/or liquidity risk. If, for a particular purpose, policymakers seek lower or higher yields in the government bond market, they should also have a clear understanding of the factors that affect market rates. Although the importance of individual factors shifts over time, the common market and, especially, credit risk becomes more prominent among all the factors, while the importance of liquidity risk diminishes. However, the function of risk factors and yields is not static and might abruptly change, especially under a risk-off regime, when liquidity risks become more prominent.

A promising future line of inquiry would inquire into how other policies (e.g. fiscal, macro- and micro-prudential) affect the risk factor-yields dependence. It would also be useful to inspect the economic size of the estimated effects, something that was not possible to do with the derived illiquidity score. Panel regressions could be run not on separate monetary policy accommodation periods, but in one regression with period-specific dummy variables. Additionally, alternative measures of the difference between the bond price or a possible bond price index could also be employed as dependent variable.

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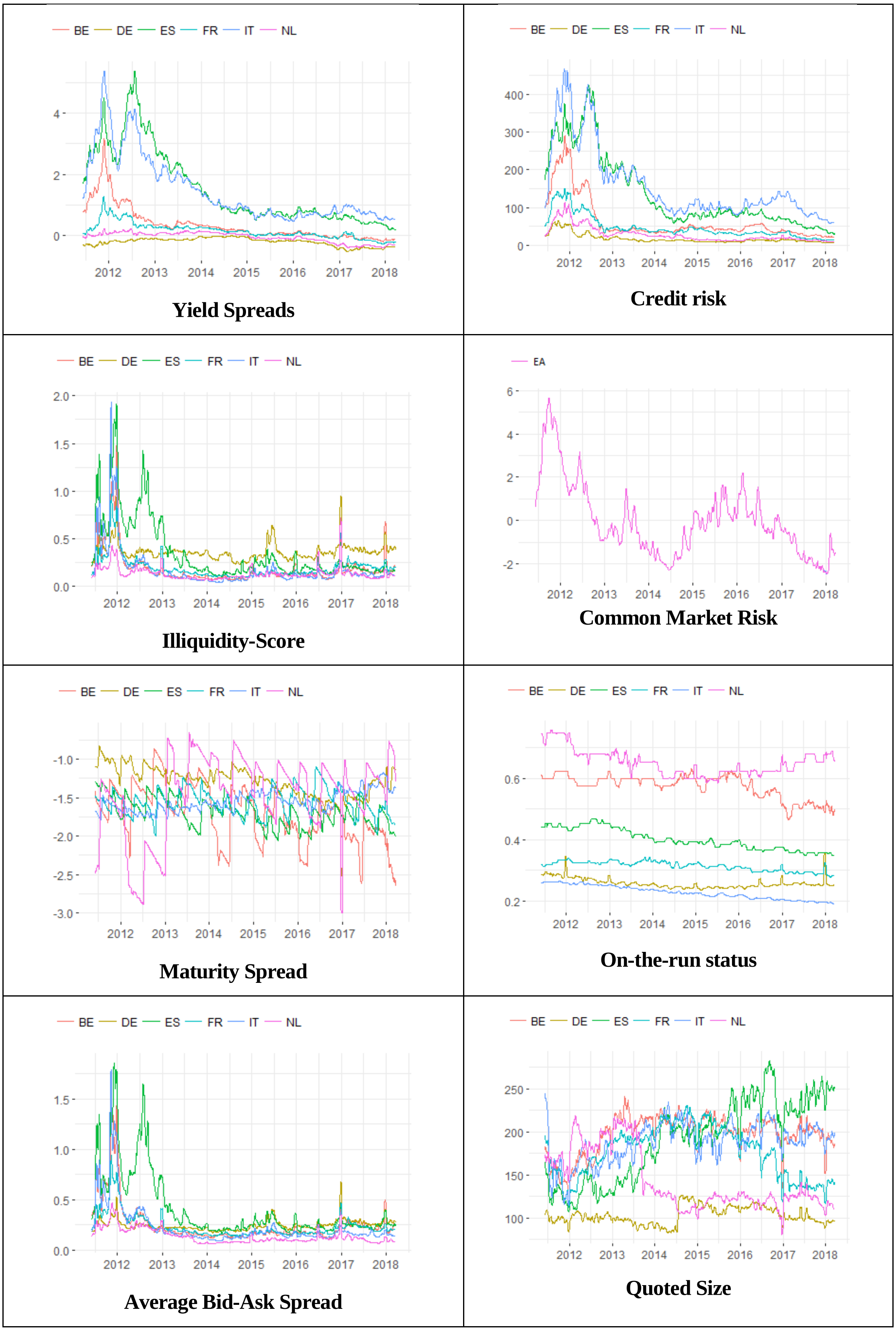
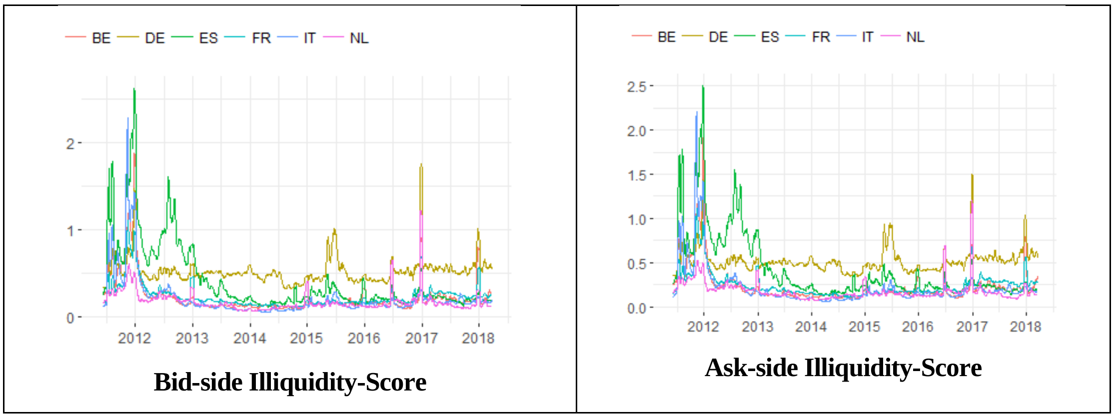
Appendix 1. Average dynamics of variables for each country from the analysis on yield spread determinants





Note: 10% of highest and lowest values are at first winsorized and then averaged to get a daily value for each country. 10-day rolling windows of country-averages.

Appendix 2. Estimates of **credit risk component** from the rolling panel regression on yield spread changes

Source: authors' calculations.
Notes: The value at particular point in time is found by running 100 trading-day rolling regressions. The event lines correspond to these monetary policy announcements: 1) Possibility to use OMT of a size adequate to reach its objective (2012-08-02); 2) Policy rates lowered (DFR to minus 0.1%) and launch of targeted longer-term refinancing operations (2014-06-05); 3) Launch of PSPP (2015-01-22); 4) Expansion of monthly EAPP (including PSPP) to €80 billion (2016-03-10); 5) EAPP (including PSPP) extended until December 2017 (2016-12-08).

Appendix 3. Estimates of **common risk component** from the rolling panel regression on yield spread changes

Source: authors' calculations.
Notes: The value at particular point in time is found by running 100 trading-day rolling regressions. The event lines correspond to these monetary policy announcements: 1) Possibility to use OMT of a size adequate to reach its objective (2012-08-02); 2) Policy rates lowered (DFR to minus 0.1%) and launch of targeted longer-term refinancing operations (2014-06-05); 3) Launch of PSPP (2015-01-22); 4) Expansion of monthly EAPP (including PSPP) to €80 billion (2016-03-10); 5) EAPP (including PSPP) extended until December 2017 (2016-12-08).

Appendix 4. Governing Council decisions related to policy rate cuts

Date	**Description**
2011-11-03	Policy rates decreased by 25 bps
2011-12-08	Policy rates decreased by 25 bps
2012-07-05	Policy rates decreased by 25 bps
2014-06-05	Policy rates decreased: MRO rate and DFR by 10 bps, MLF rate by 35 bps
2014-09-04	Policy rates decreased by 10 bps
2015-12-03	DFR decreased by 10 bps
2016-03-10	Policy rates decreased: DFR by 10 bps, MRO and MLF rates by 5 bps

Appendix 5. Governing Council decisions related to the size and/or length of PSPP

Date	Description
2015-01-22	Launch of EAPP of monthly €60 billion until September 2016
2015-12-03	Extension of EAPP until the end of March 2017; reinvestment of EAPP principal payments; inclusion of regional and local government bonds
2016-03-10	Expansion of monthly EAPP to €80 billion until the March 2017; launch of corporate sector purchase programme and 4 series 4 TLTRO II
2016-12-08	Extension of EAPP until December 2017; maturity range and yield composition broadened
2017-10-26	EAPP extended on a reduced monthly pace of €30 billion until September 2018