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Market-stabilization QE

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Abstract

We identify a novel dimension of monetary policy from high-frequency changes in asset prices around ECB policy events, orthogonal to surprises extracted from risk-free interest rates. We find that it is present in policy events that were interpreted by real-time market commentaries as containing information about asset purchase programmes aimed to stabilise financial markets and safeguard the monetary policy transmission by implementing asset purchases in a flexible manner across asset classes and euro area countries. We label this dimension of policy "market-stabilization QE" to contrast it with conventional QE programmes such as the APP launched by the ECB in 2015 aimed to extract duration risk. When including our market-stabilization QE, the R^2 for the regression of sovereign yields during the sovereign debt crisis increases by about 50 percentage points and the one of the stock market by 35 percentage points; during the COVID-19 pandemic by 25 and 15 percentage points, respectively. Although it moves euro area stressed-country sovereign yields down and German sovereign yields up as a result of the reversal of flight-to-safety dynamics, it generates strong expansionary macroeconomic effects in all euro area countries including Germany.

JEL Classification: E43; E44; E52; E58; E65; G01; G14.

Keywords: Central Bank Communication; Monetary Policy Shocks; European Debt Crisis; COVID-19 Pandemic; Unconventional Monetary Policies;

Non-Technical Summary

Over time the ECB has announced several asset purchase programmes, and depending on their objectives and modalities they can be classified in two categories. The first category includes purchase programmes aimed to deliver the monetary accommodation required to ensure medium-term price stability by compressing the term or duration risk premium. This is the case of the APP adopted in 2015. We refer to this type of asset purchase programmes as "conventional QE". The second category includes asset purchase programmes announced by the ECB with the aim to stabilize markets, address market segmentation and illiquidity, safeguard the monetary policy transmission and reverse flight-to-safety dynamics. It includes the SMP and OMT, announced during the sovereign-debt crisis, and (one dimension of) the PEPP announced during the COVID-19 pandemic.

How to tell apart the impact of asset purchase programmes from standard monetary policy and forward guidance, and more specifically how to identify the impact of conventional QE vs. market-stabilization QE? The literature analysing the high-frequency reaction of financial markets to the central bank's monetary policy announcements has shown that surprises extracted from risk-free interest rates can be mapped, through suitable identification, into economically-interpretable surprises corresponding to standard monetary policy, forward guidance and QE programmes such as LSAP in the US and the APP in the euro area. However, this leaves out purchase programmes such as the SMP, OMT and (one dimension of) PEPP.

Extensive research has been carried out on the impact of conventional QE, while the studies that have analyzed asset purchase programmes such as the SMP, OMT and PEPP are fewer and have typically investigated the reaction of euro area financial markets around selected policy announcements using an event-study methodology at daily frequency. However, the announcements of these purchase programmes often contained information also about other types of policy measures. Therefore, changes in asset prices surrounding central bank announcements of a purchase programme may be the result of the simultaneous announcement of other policy measures and updates of their likelihood, or the result of concomitant non-policy news.

Using intra-daily data we propose an identification approach to isolate a new dimension of high-frequency monetary policy news, which we label "market-stabilization QE". It goes above and beyond what can be extracted from risk-free interest rates. We find that our market-stabilization QE captures news about purchase programmes such as the SMP, OMT and PEPP. We are one of the first papers to study the ECB policy measures taken during the pandemic.

Our approach allows to identify monetary policy news that may be perceived by financial markets as simultaneously revealing information about different policy measures. Indeed, we find that policy announcements of such programmes were often interpreted by markets as containing also information about other policy measures.

Our market-stabilization QE provides a significant contribution to explaining the high-frequency change in asset prices around policy events. Its contribution to euro area periphery-country sovereign yields is very large, with an increase in the adjusted R^2 in the debt-crisis sample by 50-60 percentage points depending on the maturity. In the sample including the COVID-19 pandemic the increase is 15-25 percentage points. Market-stabilization QE rises the adjusted R^2 of the regression of the high-frequency change in the stock market index by 35 percentage points in the sample including the debt-crisis and 15 percentage points in the one including the pandemic.

We study the channels through which market-stabilization QE affects sovereign yields across euro area countries and the persistence of the effects. We find that the credit-risk channel is important and that the cross-asset impact points to the relevance of general equilibrium effects that can generate a virtuous feedback loop.

We find that market-stabilization QE lowers periphery-country sovereign yields and, while it rises core-country sovereign yields, all market segments (e.g. stock market and corporate bonds) improve both in core and periphery countries, and irrespective of whether an asset class is targeted by the purchase programme.

We find that market-stabilization QE strengthens macroeconomic conditions both in periphery and core countries, with unemployment declining and inflation increasing, and it lowers global risk.

1 Introduction

The literature analysing the high-frequency reaction of financial markets to the central bank's monetary policy announcements has shown that surprises extracted from risk-free interest rates can be mapped, through suitable identification, into economically-interpretable surprises corresponding to standard monetary policy (or 'target'), forward guidance and QE programmes such as LSAP in the US and the APP in the euro area (e.g., Gürkaynak et al. (2005) and Swanson (2021) for the US, and Altavilla et al. (2019) for the euro area).

However, factors extracted from risk-free rates account only for a small portion of the high-frequency changes in euro area sovereign yields and stock market index especially in some subsamples. For instance, Altavilla et al. (2019) show that the contribution (as measured by the R^2) of risk-free rate surprises in explaining the high-frequency response of Italian and Spanish sovereign yields drops significantly during the period 2008-2014. And the contribution in explaining the high-frequency response of the euro area stock market index is 30 percentage points lower in the pre, compared to the post, 2014 sample. Similarly, Wright (2019) emphasizes that factors heavily loading on risk-free interest rates are not able to explain a large fraction of the variance of sovereign yields during the sovereign-debt crisis.

The focus of this paper is on a dimension of the ECB monetary policy that goes above and beyond what captured by risk-free interest rates. We show that it is associated to ECB's purchase programmes such as the Securities Markets Programme (SMP) and the Outright Monetary Transactions (OMT), both announced during the sovereign debt crisis, as well as the Pandemic Emergency Purchase Programme (PEPP), announced during the COVID-19 pandemic. We label this additional dimension of monetary policy as "market-stabilization QE".

But what does it set apart purchase programmes such as the SMP, OMT and PEPP from more traditional QE programmes? Over time the ECB has announced several purchase programmes, and depending on their objectives and modalities they can be classified in two categories. The first category includes traditional purchase programmes aimed to compress the term or duration risk premium (see, among others, Altavilla et al. (2021), and Rostagno et al. (2021b)). This is the case of the APP, launched in 2015 and aimed to deliver the monetary accommodation required to ensure medium-term price stability. As regards its modalities, the allocation of purchases of public sector securities across euro area countries is guided by the ECB's capital key, which is based on euro area countries' relative GDP and population. We refer to this type of asset purchase programmes as “conventional QE”. The second category of asset purchase programmes includes the SMP, OMT and, as explained below, one dimension of the PEPP announced during the COVID-19 pandemic. Although each of these programmes displays some specificities, they have similar aims: stabilizing markets, addressing market segmentation and illiquidity, safeguarding the monetary policy transmission, addressing self-fulfilling debt crises and reversing flight-to-safety dynamics. As regards their modalities, they flexibly target market segments and euro area countries depending on their level of stress — i.e. with no constraint coming from the ECB’s capital key in the allocation of public sector purchases across euro area countries — and there are no stated purchase limits.

For instance, the ECB’s Chief Economist Philip Lane explained the market-stabilization dimension of PEPP as follows: “In the absence of active *market stabilisation* by the central bank, the intrinsic self-validating nature of flight-to-safety dynamics creates the risk of asset price movements and cross-border financial flows that, in terms of their magnitude, are unwarranted by fundamentals, but that also reflect a switch across multiple self-fulfilling beliefs-driven equilibria” (Lane (2020), emphasis added). We refer to this type of purchase programmes as market-stabilization QE, and to achieve identification we exploit their aim of reversing flight-to-safety dynamics.[1]

The paper belongs to the recent literature showing that surprises extracted from risk-free interest rates may not contain sufficient information for characterising all dimensions of monetary policy. For instance, Campbell et al. (2012), Nakamura and Steinsson (2018), Jarociński and Karadi (2020), and Andrade and Ferroni (2021), among others, emphasise the need of additional information for distinguishing monetary policy shocks from information or Delphic shocks, while Cieslak and Schrimpf (2019), Wright (2019), Leombroni et al. (2021) and Kroencke et al. (2021) focus on the additional informational requirements for distinguishing monetary policy shocks from risk shocks.

We make five contributions to the literature. The first contribution is to propose an identification approach using intra-daily data to isolate a dimension of monetary policy news that goes beyond what can be extracted from risk-free interest rates. The use of intra-daily market reaction in a narrow window around monetary policy announcements was pioneered by

[1] In the analysis we carry out in this paper, we identify policy surprises using intra-daily financial markets reaction to the central bank’s communication. Therefore, we capture markets’ perception about the likely features of the programmes. This is especially relevant for this type of asset purchase programmes, as the ECB announcements about the SMP and OMT did not contain information about the likely magnitude, the allocation across countries and maturities. In the case of the PEPP, the allocation was not communicated at the time of the launch of the programme.

Kuttner (2001) and Cochrane and Piazzesi (2002). The challenge is to identify monetary policy news that may be perceived by financial markets as simultaneously revealing information about different policy measures.

We construct risk-free rate surprises, i.e. target, FG and conventional QE, following the methodology employed in Swanson (2021) and Altavilla et al. (2019), in turn building on Gürkaynak et al. (2005). They propose to extract factors from changes in risk-free interest rates and suggest a factor rotation to make them interpretable. Building on the insights of Wright (2019), we extend the cross-section of asset price changes from which we derive the factors by including also sovereign bond yields of the largest euro area countries. In our baseline specification we focus on scheduled policy meetings to ensure that the policy signal is not confounded with other concomitant news.

We allow for an additional factor compared to the literature that has focused on risk-free rate surprises; thus, we need to impose additional identifying restrictions. First, we impose that market-stabilization QE does not load on risk-free rates or does it with opposite sign compared to the loading on sovereign yields of periphery countries. The latter captures the notion of flight-to-safety dynamics within the euro area referred to in Lane's quote above. Flight-to-safety dynamics within the euro area has been documented for instance in De Santis (2012) and Monfort and Renne (2013) during the sovereign-debt crisis period, in Rogers et al. (2014), Krishnamurthy et al. (2017) and Wright (2019) in event studies around monetary policy announcements during the sovereign-debt crisis and in Corradin et al. (2021) in event studies around monetary policy announcements during the COVID-19 pandemic. Second, we assume our new factor has the smallest variance outside the sovereign-debt crisis and the COVID-19 pandemic period.

To build confidence that we have identified a new and meaningful dimension of the ECB monetary policy and it is economically different from conventional QE, we assess the largest surprises against the content of the ECB announcements and market commentaries. We find that our market-stabilization QE captures news about large-scale purchase programmes such as the SMP, OMT and PEPP. The aim of these programmes motivates the name we give to this new factor. Reassuringly, the largest "conventional QE" surprises correspond to the policy meetings of January 2015, March 2016 and December 2016, which mark the most important policy announcements of the APP programme. And we find that in these events market-stabilization QE does not play a role.

Our market-stabilization QE provides a significant contribution to explaining the high-frequency change in asset prices. Its contribution to periphery-country sovereign yields is very large, with an increase in the adjusted R^2 in the debt-crisis sample by 50-60 percentage points depending on the maturity. In the sample including the COVID-19 pandemic the increase is 15-25 percentage points. We find that market-stabilization QE leads to a level shift of the periphery-country sovereign yield curve in the segment 2 to 10 years. Market-stabilization QE rises the adjusted R^2 of the regression of the high-frequency change in the stock market index by 35 percentage points in the sample including the debt-crisis and 15 percentage points in the one including the pandemic.

Our second contribution is to examine the channels through which market-stabilization QE affects sovereign yields across euro area countries and the persistence of the effects. We decompose the spread between sovereign yields and risk-free rates by using country-specific proxies for credit default risk, redenomination risk and illiquidity. Due to the unavailability of intra-daily data for most of these proxy variables, we employ a daily financial VAR, which allows us to assess the impact and the evolution over time. Our estimation strategy relies on instrumenting the reduced-form VAR residuals with our high-frequency market-stabilization QE surprises, following the approach of Stock and Watson (2012) and Mertens and Ravn (2013) and many others.

We find that the response of periphery-country sovereign yields to a surprise in market-stabilization QE is persistent. The credit default risk is the main channel for Italy while the liquidity channel is relevant on impact but fades away over time. The liquidity channel is dominant in Spain, especially on impact. The redenomination risk channel is relatively less important.

Turning to German sovereign yields, on impact they move in opposite direction of periphery sovereign yields. We find they have moderate persistence. The main channel is the reversal of flight-to-safety and liquidity flows into Bunds.

Our third contribution is to analyse the transmission of market-stabilization QE throughout financial markets. We document via regression analysis the high-frequency response of the stock market and the exchange rate, for which intra-daily data are available. We then build on our daily VAR described above and extend it to assess the effect of market-stabilization QE on the most important asset classes and the persistence of the effects. We find that all market segments improve both in periphery countries as well as in Germany, and irrespective of whether an asset class is targeted by the purchase programme. This holds true both for the impact effect and its response over time. We find that in each of the main euro area countries the impact decline in high-yield (HY) financial and non-financial corporate bond spreads is larger than the one in investment-grade bonds even though HY corporate bonds are not targeted assets by the purchase programmes. This result is consistent with our finding described above that the credit-risk channel is dominant for periphery countries. HY bonds have higher probability of default and thus are more sensitive to a decline in the premium per unit of default risk.

Turning to other asset classes, we find that an expansionary surprise in market-stabilization QE, which leads to a decrease in periphery-country sovereign yields, triggers an increase in the stock market index both in periphery and core countries, and the effect is persistent. The euro appreciates against the dollar in a persistent manner. Rogers et al. (2014) were the first to show that during the sovereign debt crisis monetary policy can lead to a decline in periphery sovereign spreads and trigger an appreciation of the euro (see also Wright (2019)), and they call it save-the-euro effect.

The strong response of all risk assets, including non-targeted assets, suggests that market-stabilization QE has a systemic dimension. To provide further insights we compute the response of three proxies of global and systemic risk to a market-stabilization QE surprise that lowers periphery yields. We find that the Swiss franc, which typically behaves as safe-haven currency, depreciates against the euro. The VIX, which is often used as a proxy for global investors' risk aversion, and the CISS (a measure of euro area systemic stress, see Holló et al. (2012)) decline significantly and persistently. These results stand in contrast to the evidence on the impact of conventional QE shocks in the euro area. Specifically, Wieladek and Garcia Pascual (2016) show that the VIX slightly increases following an accommodative conventional QE shock, and Lewis and Roth (2019) report a similar pattern for the CISS.

Our fourth contribution is to quantify the macroeconomic effects of market-stabilization QE. We build a monthly VAR with financial and macroeconomic variables and employ our market-stabilization QE as external instrument, as in Gertker and Karadi (2015), Jarociński and Karadi (2020), Rogers et al. (2018), Miranda-Agrppino and Ricco (2021), Andrade and Ferroni (2021), Kim et al. (2020) and many others, in turn based on Stock and Watson (2012) and Mertens and Ravn (2013). In light of the divergent response of sovereign yields across euro area countries that we have documented, we model the euro area as a two-country block system, with core and periphery countries respectively. This allows for country heterogeneity and cross-country spillovers while keeping the model parsimonious. We find that market-stabilization QE triggers expansionary effects both in periphery and core countries, with unemployment declining and inflation increasing. The peak effect is stronger in periphery countries. The expansionary effect in Germany is remarkable given that it is the main target of flight-to-safety flows during times of financial tensions and hence benefits from the associated downward pressure on its sovereign yields. This notwithstanding, macroeconomic conditions in Germany improve when the ECB announced policy measures that had the effect of reversing such flows and increasing German sovereign yields.

Our final contribution is to study the evolution of financial market perceptions of PEPP during the COVID-19 pandemic. Differently from asset purchase programmes previously announced by the ECB, the stated objective and operational modalities of PEPP encompass elements of both market-stabilization QE and conventional QE. Specifically, according to ECB communication, PEPP has two dimensions whose relative contribution may change over time: (i) market stabilization, which is implemented via purchasing in a flexible manner across euro area countries, asset classes and time, and (ii) monetary accommodation to ensure medium-term price stability similarly to the APP via duration extraction (see, ECB (2020)). To underpin the credibility of the flexible approach, the ECB stated that it does not tolerate any risks to the smooth transmission of its monetary policy in all jurisdictions of the euro area and would consider revising purchase limits that might hamper its action.[2]

Due to the shortness of the pandemic sample, we have only a few surprises occurring in the scheduled meetings after the announcement of PEPP. To overcome this, we use the approach of Altavilla et al. (2019) to decompose other policy announcements (such as unscheduled policy meetings, the publication of the PEPP legal framework and communication by Governing Council members) into our factors that we have estimated over scheduled meetings. This analysis provides also an out-of-sample assessment of our methodology to identify market-stabilization QE.

We find that the launch of PEPP on 18 March 2020, which was announced following an unscheduled monetary policy meeting, is entirely explained by our market stabilization QE. In subsequent scheduled meetings (e.g. the PEPP recalibration of 4 June 2020) and the unscheduled policy events we examine, we find the joint presence of market-stabilization QE and conventional QE. This shows that there has been an evolution in the way PEPP has been perceived by markets, with conventional QE becoming more important over time while the

[2]See, press release announcing the PEPP available at https://www.ecb.europa.eu/press/pr/date/2020/html/ecb.pr200318_1~3949d6f266.en.html. Following the publication of the legal framework governing the PEPP, the Financial Times wrote: "Almost all constraints that applied to the ECB's previous asset-purchase programmes have been removed or significantly loosened", see article entitled "ECB shakes off limits on new €750bn bond buying plan", by Martin Arnold and Tommy Stubbington, 26 March 2020.

market-stabilization role of PEPP being predominant in the early phase of the crisis. Indeed, deviations from the ECB capital key have been larger in the initial phase.[3] This cautions against analyses that treat ECB communication about PEPP as being one-dimensional.

The paper is organised as follows. Section 2 outlines how our paper relates to the literature. In Section 3 we present the methodology to identify our new factor. In Section 4 we discuss the identified surprises and factor loadings on risk-free rates and sovereign yields. Section 5 studies the channels through which market-stabilization QE affects sovereign yields. Section 6 presents evidence on the transmission to other asset classes and the persistence of the effects. In Section 7 we turn to the macroeconomic effects of market-stabilization QE. In Section 8 we study unscheduled policy events. Section 9 offers conclusions. The paper is supplemented by several Appendixes containing additional details and results as well as robustness analysis.

2 Related Literature

Extensive research has been carried out on the impact of conventional QE programmes (see, among others, for the US Gagnon et al. (2011), Hamilton and Wu (2011), Krishnamurthy and Vissing-Jorgensen (2011), Christensen and Rudebusch (2012), D'Amico and King (2013), Kim et al. (2020); for the euro area, see Andrade et al. (2016), Rostagno et al. (2021b), Altavilla et al. (2021), Eser et al. (2019), Koijen et al. (2021)). The studies that have focused on the SMP, OMT and PEPP have typically investigated the reaction of euro area financial markets around selected policy announcements using an event-study methodology.[4] Using daily data, Krishnamurthy et al. (2017) analyse the announcements of the SMP and OMT, while Altavilla et al. (2016) study the impact of OMT announcements. Szczerbowicz (2015) and Falagiarda and Reitz (2015) carry out event-based regressions of changes in asset prices around selected policy announcements using daily data. Rogers et al. (2014) employ an event-study approach across countries using intra-daily changes in asset prices around announcements of policy measures over 2007-2014 and for the euro area they measure monetary policy surprises as the change in

[3]ECB President Christine Lagarde stated: "Let me just remind you what I would call the dual key of PEPP is: on the one hand, it has a monetary policy stance about it but on the other hand – as you know because that was the one that certainly predominated in the early phase of the crisis – it is critically important because of its flexibility in order to transmit monetary policy, in order to reduce market stress in order to avoid fragmentation", see Q&A during the press conference following the policy meeting of 4 June 2020, available at `https://www.ecb.europa.eu/press/pressconf/2020/html/ecb.is200604~b479b8cfff.en.html#qa`. Schnabel (2021) discusses the time series of deviations from the ECB's capital key and the large deviations that took place in the early phase of PEPP.

[4]Eser and Schwaab (2016) and Ghysels et al. (2017) employ flow data on bond purchases under the SMP and find large changes in bond yields upon purchases.

the spread between Italian and German 10-year government bond yields. Corradin et al. (2021) decompose daily changes in sovereign bond yields around policy announcements of the PEPP.

However, the announcements of these purchase programmes often contained information also about other types of policy measures. Therefore, changes in asset prices surrounding central bank announcements of a purchase programme may be the result of the simultaneous announcement of other policy measures and updates of their likelihood, or the result of concomitant non-policy news. The latter is especially important for this type of asset purchase programmes, which were often announced when markets were closed. For instance, the two announcements of the SMP included in the event-study literature quoted above are 10 May 2010 and 7 August 2011. However, on 10 May 2010 (it was Sunday) the ECB announced not only the SMP but also several other monetary policy measures (see Section 8 for details). The announcement on 7 August 2011 (it was Sunday) was surrounded by many other events, such as the pledge by the Italian government on Friday 5 August to adopt additional fiscal consolidation measures, the downgrade of the United States by Standard & Poor in the evening (after markets closed) of Friday 5 August 2011, the French-German communiqué over the weekend to support the euro area, and a statement by the G20 group of leading industrialised and developing nations in the morning of 8 August 2011 to reassure financial markets. This represents a challenge for the literature that assumes that daily asset price changes around the ECB announcement on 10 May 2010 and 7 August 2011 can correctly isolate the impact of the SMP. More generally, as argued by Gürkaynak et al. (2005), central bank's communication is multi-dimensional and it is not warranted to assume that asset price changes around a policy announcement are the result of one specific policy measure. We present a way to identify market-stabilization QE.

Turning to the channels of transmission of SPM, OMT and PEPP, similar considerations apply: prior literature on the relative importance of their channels has used event studies around specific policy announcements. We instead quantify the relative importance of the channels to identified policy surprises that are derived using a methodology that takes into account that a policy announcement may be multi-dimensional, and thus each dimension of policy may have different transmission channels. Also, we add to the literature by documenting the relative importance of the different channels over time rather than just on impact. For instance, Krishnamurthy et al. (2017) analyse the relative contribution of the channels on impact using an event study approach around SMP and OMT announcements, and find that credit risk and liquidity risk premia are the dominant channels for periphery yields while redenomination risk is of little importance. Corradin et al. (2021) employ an event-study methodology similar to

Krishnamurthy et al. (2017) to study the PEPP announcements. They find that on impact half of the decline in Italian sovereign yields is driven by the credit default premium while the decline in Spanish yields is largely driven by improved liquidity.

The decline in credit risk in periphery countries that we document is consistent with several non-mutually exclusive explanations, which however we do not attempt to identify separately. Expectations of asset purchases may compress credit spreads via the central bank's removal of the quantity of defaultable assets that the market must hold (see, Altavilla et al. (2021) and Costain et al. (2021) on the credit channel of asset purchases), or breaking a self-fulfilling debt crisis driven by investors' loss of confidence (see, Cole and Kehoe (2000), Bocola and Dovis (2019) and Lorenzoni and Werning (2019) on self-fulfilling debt crisis; Corsetti and Dedola (2016), on the central bank providing a backstop; Allen et al. (2006) on coordination risk). In support of the latter, several papers find that the increase in yields during the sovereign debt crisis is disconnected from underlying fiscal fundamentals (Di Cesare et al. (2012), De Grauwe and Ji (2013), Favero (2013), Dewachter et al. (2015)). The impact of central bank's purchases may also be amplified by a virtuous feedback loop whereby the easing of funding conditions created by asset purchases improves the economic outlook, which in turn makes default less likely, thus further compressing default risk, and so on. We do not separately assess the contribution of endogenous default, but we analyse below the systemic nature of the effects of our market-stabilization QE and its macroeconomic effects.

Studies on the SMP, OMT and PEPP have generally focused on the financial market impact and have not investigated the macroeconomic effects. One exception is Krishnamurthy et al. (2017), who argue that their event study showing that the euro area stock market improved on SMP and OMT announcement days suggests that these policies have beneficial macroeconomic effects. Another exception is Altavilla et al. (2016), who provide an estimate of the macroeconomic impact of OMT by computing a conditional forecast using a macro VAR. They assume that the decline in periphery-country 2-year yields found on impact in their event study lasts for three years while German yields are unaffected by the OMT. They identify the OMT shock by assuming a recursive approach whereby real activity and inflation do not react on impact to a change in the periphery yields. They find that the macroeconomic effect on periphery country is substantial while it is negligible on core countries. We instead quantify the macroeconomic effects using our identified high-frequency shock, we estimate the persistence rather imposing it and reach different conclusions about the effect on core countries.

While our results belong to the literature showing that high-frequency changes in risk-free interest rates around monetary policy events do not contain sufficient information for characterising all dimensions of monetary policy, we identify a specific dimension of policy that differs from other studies[5]. For instance, Jarociński and Karadi (2020) highlight the distinction between monetary policy shocks and information shocks, with the latter triggering an increase in risk-free rates and a boost in inflation expectations, equity prices and the macroeconomy. They argue that the sign of the comovement of risk-free rates and stock market index can be used to discriminate pure monetary policy shocks from information shocks. Our findings show that market-stabilization QE leads to a small increase in risk-free rates and a sizeable increase in stock prices, a decline in periphery-country sovereign yields and expansionary macroeconomic effects. A taxonomy based on the sign of the comovement of risk-free rates and the stock market may lead to conclude that our policy surprises are an information shock rather than "market-stabilization QE". But this does not seem plausible. It would imply that the boosting effect on the stock market and on the macroeconomy triggered by central bank announcements regarding measures such as the OMT and PEPP, which were announced to address the spiraling out of financial markets and are captured by our market-stabilization QE, are simply the market response to the revelation of central bank's inside information that the macroeconomic state is actually better than expected by markets. We see instead market-stabilization QE as a new and different dimension of monetary policy: a dimension aimed to stabilize markets and address flight-to-safety dynamics. Cieslak and Schrimpf (2019), on the basis of high-frequency comovement of risk-free interest rates and stock prices as well as on the basis of the effect of policy news across the term structure, propose a distinction between monetary and non-monetary policy shocks (economic growth shocks and risk premium shocks). They assume that growth shocks have a stronger effect on the short-to-intermediate segment of the yield curve, whereas risk premium shocks affect more strongly longer maturities. We show instead that our market-stabilization QE affects the yield curve equally at different maturities, while it is conventional QE the factor that influences more strongly longer maturities. Kroencke et al. (2021) show that surprises extracted from US risk-free rates can explain only a small share of the high-frequency reaction of the stock market to monetary policy surprises and identify an additional factor that they label risk shifts. They show that it generates short-lived effects to be reversed after about four weeks and thus they conclude that it is unlikely to be related to changes in fundamentals. We find instead that our market-stabilization QE generates persistent

[5] A complementary approach focusing on capturing an additional dimension of the ECB monetary policy is performed in an independent work by Mira Godinho (2021).

effects both on financial markets and the macroeconomy.

The distinction between conventional QE and market-stabilization QE may appear to apply to the euro area only, which has a single monetary policy and independent fiscal policies at the national level issuing sovereign debt. This may make the euro area more prone to fragmentation of sovereign debt markets and self-fulling debt crises. But the notion that large-scale asset purchase programmes can have different objectives and outcomes may apply also to the Fed. For instance, Vissing-Jorgensen (2021) argues that during the COVID-19 pandemic the US Federal Reserve announced a market-functioning QE that behaved differently compared to earlier QE programs announced during the Global Financial Crisis.[6] Vissing-Jorgensen (2021) shows that the Fed's market-functioning QE appears to have worked via effects materializing at the time of purchase (flow effects) rather than announcement effects, in contrast to earlier QE programs and in contrast to the Fed's corporate bond purchases announced during the COVID-19 pandemic. We instead focus on the announcement effects of our market-stabilization QE and find that they are substantial. One reason is that our market-stabilization QE captures programmes that target risk assets, thus making it more similar to the Fed's corporate bond purchase program launched during the pandemic, where indeed announcement effects were strong (see, among others, Haddad et al. (2021) and Kargar et al. (2021)).

3 Factor Identification

We use intra-daily asset price changes within a narrow window surrounding the policy events. We focus on Governing Council's scheduled meetings as they are one of the most anticipated news. Thus, the immediate financial markets' reaction can be considered to be caused by the policy announcement. While this choice implies that we omit from our baseline specification announcements of non-standard measures that took place at unscheduled meetings, they typically happened when markets were closed (evening or weekend) and in presence of several confounding news. In Section 8 we document the implications.

The ECB communication in scheduled meetings occurs in two distinct instances: a press release at 1:45pm CET announcing the monetary policy decision, and a press conference with the ECB President that begins at 2:30pm and lasts for about one hour. We focus on the market

[6] On 15 March 2020 the Fed announced that it would buy at least 500bn dollar of Treasuries and at least 200bn dollar of mortgage-backed securities. On 23 March 2020 the Fed announced that it would "purchase Treasury securities and agency mortgage-backed securities in the amounts needed to support smooth market functioning and effective transmission of monetary policy to broader financial conditions and the economy".

reaction to the press conference because prior to 2016 the press release referred to the decision on policy rates only, while non-standard measures were communicated by the ECB President at the press conference.

To identify the central bank's multidimensional communication we extend the approach of Gürkaynak et al. (2005), Swanson (2021) and Altavilla et al. (2019) in two directions. First, in addition to risk-free rates we include in the panel of asset prices also the high-frequency changes in sovereign yields of the largest euro area countries. In the euro area during the sovereign-debt crisis and in periods of financial stress sovereign yields of constituent countries have often moved in different direction. Therefore, risk-free rates may fall short of characterizing the effects of some of the ECB's policy measures. As proxy for risk-free rates we use the EONIA OIS rates and, before they become available for the long maturities, the German Bund. We include 1, 3, and 6-month and 1, 2, 5, and 10-year risk-free rates, to which we add 2, 5, and 10-year sovereign yields of Italy, France and Spain, totalling 16 assets.[7] Our sample is January 2002 to June 2020.

Second, we identify via factor rotation a dimension of the ECB policy that goes above and beyond what captured by risk-free rates. We call this dimension of the ECB policy "market-stabilization QE". Specifically, we estimate latent factors from the high-frequency changes in our 16 assets using principal components analysis. Statistical analysis of the total number of factors using Cragg and Donald (1997)'s rank test finds support for four or five factors. As the cross-section of the panel of asset prices from which we extract the factors is large compared to the length of the sample, the result of the rank test is not conclusive. We proceed assuming a four-factor model structure, and repeat the analysis with five factors.[8]

To identify the traditional risk-free rate factors we extend to our four-factor setup the restrictions employed by Swanson (2021) for the US and by Altavilla et al. (2019) for changes in risk-free rates during the ECB press conference window. Hence, as regards the risk-free rate factors, we obtain surprises that correspond to their Timing, Forward Guidance and QE (we refer to the latter as "conventional QE"). In particular, we impose that the second, third and fourth factors do not load on the 1-month OIS. This captures the notion that changes in the current-month policy rate are communicated in the press release published before the ECB press conference. Therefore, by the time the latter starts, the adjustment of the short-term rate has

[7] As the Bund is part of our measure of risk-free rates, we include only the other three largest countries in our panel of sovereign yields. We study explicitly the Bund in Section 4. We take the high-frequency data from the euro area monetary policy event-study database, EA-MPD (see Altavilla et al. (2019) for details).

[8] The extra factor does not contain any noteworthy information. Results are available from the authors upon request.

already taken place and no further communication during the press conference can change the current value of the policy rate. In addition, the third risk-free factor is assumed to have the smallest variance in the pre-crisis period (pre-August 2008).

As we have included an additional factor compared to the risk-free rate literature quoted above, we need two additional economic restrictions. As regards the first restriction, we impose that our new factor, i.e. the fourth factor, does not load on risk-free rates or generates opposite reaction of sovereign yields of periphery countries compared to risk-free rates. As discussed in Section 1, the latter implements the notion that some of the ECB non-standard measures have the aim of safeguarding the monetary policy transmission mechanism within the euro area and reversing flight-to-safety dynamics. In our baseline specification the comovement restriction is imposed on the 5-year Italian sovereign yield and the 5-year risk-free rate.

As regards the second restriction, we assume that the fourth factor has the smallest variance outside the sovereign-debt crisis (May 2010 - December 2012) and the COVID-19 pandemic period (December 2019 through the end of our sample).

Appendix A includes details on the rotation. Appendix B presents sensitivity analysis regarding the restrictions we have used to identify market-stabilization QE, in particular the impact of imposing weaker or stronger restrictions. Appendix C discusses an alternative methodology using sign and monotonicity restrictions. We show that our baseline results are robust to all these variations. In the remaining of the paper we focus on market-stabilization QE while drawing comparisons with the standard risk-free factors, especially coventional QE, when relevant.[9]

4 Estimated surprises and factor loadings

The factors are identified up to scale, thus we normalize the rotated factors such that market-stabilization QE and conventional QE have unit effect on the 5-year Italian sovereign yield and 10-year risk-free rate, respectively. Hence, negative values correspond to monetary policy easing and positive values stand for policy tightening.[10]

Figure 1 shows the time series of the estimated conventional QE and market-stabilization QE surprises. As expected due to our identifying restrictions, the variance of market-stabilization

[9] A discussion of the properties of euro area risk-free rate factors is in Altavilla et al. (2019) and Motto and Öztug (2020).

[10] A negative reading on conventional QE (market-stabilization QE) corresponds to an expansionary monetary policy in terms of risk-free rates (Italian sovereign yield). As market-stabilization QE has opposite effect on risk-free rates and periphery sovereign yields, the definition of expansionary and contractionary monetary policy may give rise to confusion. We show in Section 7 that the decline in periphery country yields leads to a macroeconomic expansion in both core and periphery countries.

QE is low with the exception of the sovereign-debt crisis and the COVID-19 pandemic period. The risk-free rate factors (see also Figure E.1 in Appendix E) are similar to the ones found in Altavilla et al. (2019) over the common sample. To build confidence that we have correctly identified an additional dimension of the ECB monetary policy and that it is meaningfully different from conventional QE, we assess the largest surprises against the content of the ECB announcements and market commentaries. We recall that our baseline analysis focuses on scheduled meetings. We analyse unscheduled meetings as well as policymakers' speeches and other policy events in Section 8. Reassuringly, the largest conventional QE surprises correspond to the policy meetings of January 2015, March 2016 and December 2016, which mark the launch and subsequent recalibrations of the APP programme. And we find that in these events market-stabilization QE is absent. The largest realisation of market-stabilization QE is on 2 August 2012 when ECB President Draghi said that the ECB could buy Spanish and Italian bonds. We find no conventional QE surprise on that occasion.

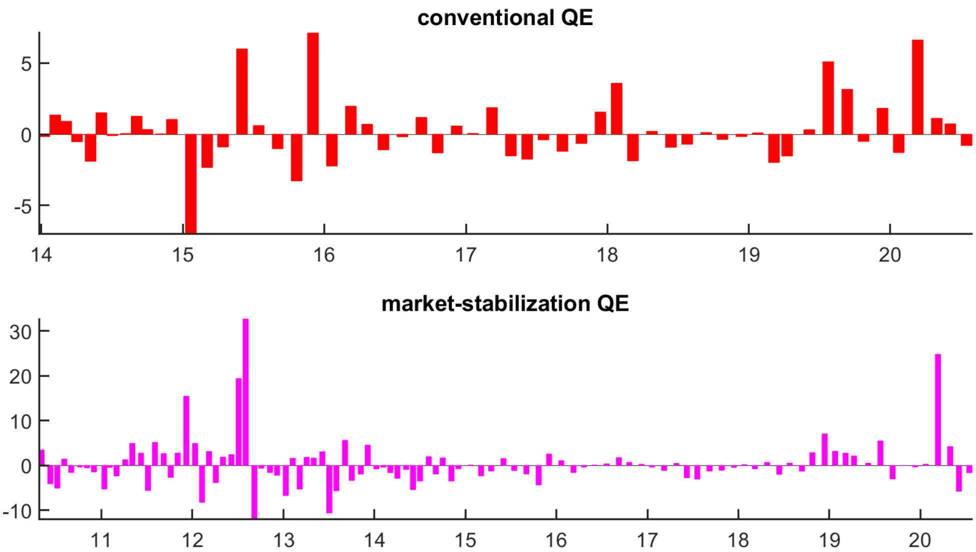

Figure 1: Estimated conventional QE and market-stabilization QE factors

Note: The figure shows the estimated factors in basis points. As the factors are identified up to scale, conventional QE and market-stabilization QE are scaled such that they have unit effect on the 10-year OIS and 5-year Italian sovereign yield, respectively. Negative values correspond to monetary policy easing and positive values stand for policy tightening. Data period covers Governing Council scheduled meetings from 3 January 2002 to 16 July 2020, both included.

The second largest realisation of market-stabilization QE is on 12 March 2020. It corresponds to markets' disappointment, with the Financial Times reporting that "*Markets had hoped that today would be [ECB President] Christine Lagarde's "Whatever it takes" moment. Those hopes* *have proven misplaced*". This coincides also with a large positive realization of conventional QE. This shows that markets were expecting policy support both in the form of an expansion of the APP programme as well as a targeted purchase programme supporting periphery countries of the kind announced during the sovereign-debt crisis. Large expansionary realizations of market-stabilization QE are also on 2 September 2012 when details of the OMT programme were announced, and on 4 June 2020 when a €600bn expansion of the PEPP was announced. Indeed, the Bloomberg Survey of market analysts carried out ahead of 4 June 2020 policy meeting shows that the majority of respondents expected an expansion by €500bn only. The contractionary surprise in market-stabilization QE on 8 December 2011 is interesting because the ECB announced a rate cut and the 3-year long-term refinancing operation (LTRO). But there were expectations for the announcement of large-scale purchases of government bonds to support euro area stressed countries. For instance, the Associated Press Newswires titled "*HOPES DASHED: ECB President Mario Draghi said there is no existing plan for large-scale ECB purchases of government bonds, as markets had been hoping.*" These episodes suggest that, among non-standard measures aimed to safeguard the transmission mechanism within the euro area, our market-stabilization QE captures news about large-scale purchase programmes aimed to stabilize markets. This motivates the name we give to the new factor. A detailed account of the largest surprises and their alignment with well-known dates and market commentaries is provided in Appendix D.

Figure 2 shows the loadings of risk-free rates and Italian sovereign yields on conventional QE and market-stabilization QE. Figures E.2 and E.3 in Appendix E show the loadings also for the other risk-free rate factors. We make three observations.

First, loadings on the traditional risk-free rate factors display the familiar shape. Timing and FG are two forms of forward guidance and thus loadings display a hump-shaped pattern. Conventional QE loads stronger the longer the maturity, as intended by conventional large-scale asset purchase programmes aimed to extract duration risk.

Second, the loadings of risk-free rates on market-stabilization QE are small and have opposite sign compared to the ones of periphery country yields. This suggests that the reversal of flight-to-safety dynamics is a feature of the policy measures captured by market-stabilization QE.

Third, the loadings of Italian sovereign yields on market-stabilization QE have a peak at 5-year maturity, but are broadly comparable in size across maturities.[11] The empirical

[11] Loadings of Spanish yields are very similar to the ones of Italian yields, see Appendix E.

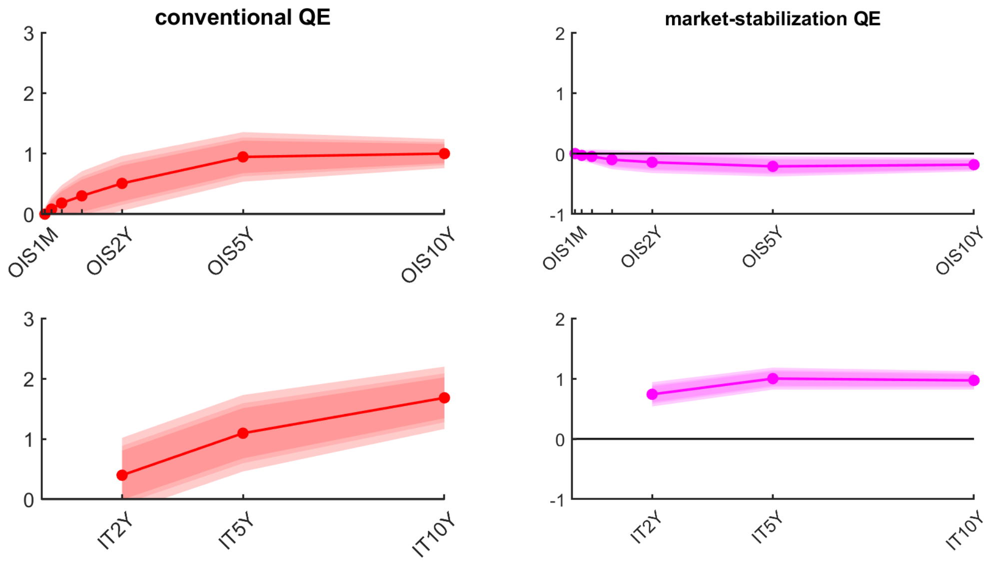

Figure 2: Factor loadings of risk-free rates and IT sovereign yields

Note: The figure shows the factor loadings, in basis points. For each maturity the loadings are obtained by regressing the surprises onto the factors and also controlling for the standardized surprise associated with the release of the US initial jobless claims. Conventional QE and market-stabilization QE have unit effect on 10-year OIS and 5-year Italian sovereign yield. The shaded areas indicate the 90%, 95% and 99% confidence intervals.

literature on the ECB asset purchases aimed to restore the transmission mechanism provides inconclusive evidence on the shape of the yield-curve response, depending on the set of events and frequency considered. For instance, as regards OMT announcements, using a two-day event-study approach Altavilla et al. (2016) and Krishnamurthy et al. (2017) find that some announcements exerted a stronger effect on longer maturities while others on short-medium maturities. As regards SMP announcements, using a two-day window, Krishnamurthy et al. (2017) find that one announcement exerted stronger effect at short-medium maturities while another produced a level shift. However, several announcements considered in the literature occurred over the weekend and were accompanied by other monetary policy as well as non-policy news, as we document in Section 8.[12]

One implication of the muted response of risk-free rates to a surprise in market-stabilization QE is that factors extracted only from a panel of risk-free rates may be insufficient to characterize

[12]From a theoretical perspective, unless market segmentation prevails, Altavilla et al. (2021) show that the direct effect of the credit-risk channel of asset purchases targeting defaultable bonds is to affect the whole term structure. Costain et al. (2021) show in a term-structure model that purchase programmes like the PEPP produce a level shift in the stressed-country yield curve. In Section 5 we present evidence on the channels through which market-stabilization QE effects sovereign yields.

the multi-dimensionality of ECB policies. To assess the relative contribution of market-stabilization QE in explaining the response of sovereign yields, we run regressions of the high-frequency changes in sovereign yields at different maturities on the identified surprises. We add in the regression the surprise in US initial jobless claims as an additional control (labelled in the tables IJC) given that the publication of jobless claims overlaps with the ECB press conference. The surprise in the initial jobless claims is computed with reference to Bloomberg's survey expectations. However, including this surprise does not affect our estimates.

To characterize the economic effects of the estimated factors across sub-periods, we divide the full sample into three periods: the pre-Lehman collapse sample (January 2002 - September 2008); the crisis period (September 2008 - January 2014), which includes the global financial crisis and the sovereign-debt crisis; the period extending until the end of the sample (January 2014 - July 2020), which includes the monetary policy measures launched in mid-2014 and shortly thereafter (negative interest rates, targeted long-term refinancing operations, QE and forward guidance) as well as the COVID-19 pandemic period. Tables 1 and 2 show the results for German and Italian sovereign yields, respectively. Results for Spain are in Table E.2 in Appendix E.

The top panels of the tables show regression results when market-stabilization QE is excluded while the bottom panels when included. The contribution of market-stabilization QE to periphery-country yields is striking. In the sample including the sovereign-debt crisis the adjusted R^2 on the 5-year Italian yield rises from 44% to 91%, and on the 10-year yield from 25% to 87%. In the sample including the COVID-19 pandemic it rises from 70% to 99%, and on the 10-year yield from 84% to 99%. Results for Spanish sovereign yields are similar to Italian yields and are shown in Appendix E.

In the sample including the sovereign debt crisis, market-stabilization QE contributes also to the German Bund. A comparison of the results shown in Table 1 for the Bund and Table E.2 in Appendix E for the OIS shows that the response of German yields and OIS rates share the same sign; but the size of the response of the former is larger. This is expected given that one of the aims of the ECB policies captured by our new factor is to reverse flight-to-safety flows. Although via arbitrage OIS rates and the German Bund are connected, flight-to-safety flows and their reversal would affect more directly the German Bund.[13]

These findings corroborate the relevance of our new factor for explaining monetary policy

[13] See also ECB (2014) for evidence on the stronger response of the Bund compared to OIS rates following an identified flight-to-safety shock.

Table 1: Estimated effects of monetary policy surprises on German sovereign yields

Panel (A): Conference window

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
		01/2002-09/2008			09/2008-01/2014			01/2014-07/2020	
VARIABLES	DE 2Y	DE 5Y	DE 10Y	DE 2Y	DE 5Y	DE 10Y	DE 2Y	DE 5Y	DE 10Y
Timing	1.10***	0.54***	0.19**	1.22***	0.90***	0.40***	1.03***	0.90***	-0.15
	(0.09)	(0.09)	(0.09)	(0.10)	(0.10)	(0.08)	(0.20)	(0.29)	(0.27)
FG	1.35***	1.35***	0.70***	0.89***	0.85***	0.53***	1.47***	1.56***	0.94***
	(0.05)	(0.14)	(0.16)	(0.12)	(0.13)	(0.11)	(0.18)	(0.19)	(0.21)
IJC	-0.27	0.43	0.48	-2.80	-3.66*	-2.14	0.46***	0.02	0.06
	(0.55)	(0.71)	(0.87)	(2.14)	(2.18)	(1.80)	(0.17)	(0.15)	(0.16)
conventional QE							0.32***	0.66***	1.19***
							(0.08)	(0.13)	(0.10)
Observations	70	70	70	62	62	62	57	57	57
R-squared	0.99	0.88	0.76	0.82	0.64	0.33	0.83	0.86	0.91

Panel (B): Conference window: with the new factor

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
		01/2002-09/2008			09/2008-01/2014			01/2014-07/2020	
VARIABLES	DE 2Y	DE 5Y	DE 10Y	DE 2Y	DE 5Y	DE 10Y	DE 2Y	DE 5Y	DE 10Y
Timing	1.10***	0.54***	0.19**	1.20***	0.87***	0.36***	1.25***	1.08***	0.13
	(0.09)	(0.09)	(0.09)	(0.08)	(0.08)	(0.06)	(0.12)	(0.21)	(0.17)
FG	1.35***	1.35***	0.70***	1.05***	1.07***	0.75***	1.21***	1.35***	0.63***
	(0.05)	(0.14)	(0.16)	(0.10)	(0.10)	(0.08)	(0.12)	(0.19)	(0.12)
IJC	-0.27	0.43	0.48	-2.58	-3.36**	-1.84	0.25*	-0.16	-0.20*
	(0.55)	(0.71)	(0.87)	(1.60)	(1.55)	(1.29)	(0.14)	(0.14)	(0.11)
market-stabilization QE				-0.22***	-0.31***	-0.31***	-0.23***	-0.19***	-0.29***
				(0.04)	(0.04)	(0.02)	(0.04)	(0.06)	(0.04)
conventional QE							0.53***	0.83***	1.43***
							(0.07)	(0.16)	(0.08)
Observations	70	70	70	62	62	62	57	57	57
R-squared	0.99	0.88	0.76	0.9	0.83	0.71	0.89	0.88	0.95

*Note: The table reports the reaction of German sovereign yields at different maturities to surprises in monetary policy using intra-daily data. Coefficients are expressed in percentage per annum per standard deviation change in the factors. Robust standard errors in parentheses; ***, **, and * denote statistical significance at the 1%, 5% and 10% levels, respectively.*

in the euro area. Excluding this factor gives a very partial view of the range of ECB policy measures perceived by markets. For instance, Leombroni et al. (2021) show that, using high-frequency data, in the pre-2009 sample the R^2 of the regression of sovereign yields on risk-free rate factors is similar for core and periphery countries; but it declines significantly for periphery countries in the 2009-2014 sample. They conclude that during the sovereign-debt crisis the reaction of peripheral sovereign yields to conventional monetary policy weakened significantly. Panel (A) of Table 2 shows that across sub-samples we similarly find a significant decline in the R^2 of a regression of periphery sovereign yields on risk-free rate factors. But Panel (B) of Table 2 and Table 3 suggest that it is not because the transmission of risk-free rate factors has ceased. It is because of the two-to-three- fold increase —depending on the maturity, see last row of Table 3— in the standard deviation of sovereign yields of periphery countries over the

Table 2: Estimated effects of monetary policy surprises on Italian sovereign yields

Panel (A): Conference window

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
		01/2002-09/2008			09/2008-01/2014			01/2014-07/2020	
VARIABLES	IT 2Y	IT 5Y	IT 10Y	IT 2Y	IT 5Y	IT 10Y	IT 2Y	IT 5Y	IT 10Y
Timing	1.15***	0.67***	0.17*	0.97***	0.49**	0.28	2.18***	1.90***	1.15*
	(0.06)	(0.10)	(0.09)	(0.21)	(0.19)	(0.20)	(0.49)	(0.69)	(0.63)
FG	1.22***	1.21***	0.65***	1.98***	1.88***	1.23***	0.54	-0.07	-0.37
	(0.05)	(0.10)	(0.16)	(0.27)	(0.35)	(0.28)	(0.39)	(0.57)	(0.49)
IJC	-0.45	-0.16	0.39	1.65	-2.66	-2.71	-1.69***	-0.91*	-0.48
	(0.48)	(0.66)	(0.86)	(2.38)	(2.97)	(2.48)	(0.34)	(0.48)	(0.36)
conventional QE							1.20***	1.85***	2.62***
							(0.17)	(0.26)	(0.18)
Observations	70	70	70	62	62	62	57	57	57
R-squared	0.99	0.96	0.72	0.61	0.43	0.24	0.75	0.73	0.86

Panel (B): Conference window: with the new factor

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
		01/2002-09/2008			09/2008-01/2014			01/2014-07/2020	
VARIABLES	IT 2Y	IT 5Y	IT 10Y	IT 2Y	IT 5Y	IT 10Y	IT 2Y	IT 5Y	IT 10Y
Timing	1.15***	0.67***	0.17*	1.05***	0.59***	0.39***	1.55**	0.79***	0.20
	(0.06)	(0.10)	(0.09)	(0.12)	(0.10)	(0.09)	(0.59)	(0.16)	(0.13)
FG	1.22***	1.21***	0.65***	1.51***	1.27***	0.62***	1.25***	1.19***	0.70***
	(0.05)	(0.10)	(0.16)	(0.11)	(0.16)	(0.17)	(0.29)	(0.10)	(0.09)
IJC	-0.45	-0.16	0.39	1.01	-3.50*	-3.54*	-1.09***	0.15*	0.42***
	(0.48)	(0.66)	(0.86)	(1.32)	(2.06)	(1.94)	(0.25)	(0.08)	(0.09)
market-stabilization QE				0.66***	0.86***	0.85***	0.66***	1.16***	0.99***
				(0.03)	(0.05)	(0.11)	(0.13)	(0.04)	(0.03)
conventional QE							0.63***	0.84***	1.76***
							(0.15)	(0.10)	(0.07)
Observations	70	70	70	62	62	62	57	57	57
R-squared	0.99	0.96	0.72	0.93	0.89	0.85	0.9	0.99	0.99

Note: The table reports the reaction of Italian sovereign yields at different maturities to surprises in monetary policy using intraday data. Coefficients are expressed in percentage per annum per standard deviation change in the factors. Robust standard errors in parentheses; ***, **, and * denote statistical significance at the 1%, 5% and 10% levels, respectively.

policy window during the crisis. In turn, this is due to the central bank's announcements of a new policy tool, i.e. our market-stabilization QE, affecting strongly periphery country yields and mildly core country yields.[14]

[14] There are many differences in the way we identify our market-stabilization QE compared to the risk premium shock in Leombroni et al. (2021). We use sovereign yields while they use the stock market, and we impose that the variance of the new factor is minimal outside the period of sovereign-debt crisis period and the pandemic, whereas they do not impose this restriction.

Table 3: Relative contribution of factors in explaining policy surprises

Panel (A): German sovereign yields

	01/2002-09/2008			09/2008-01/2014			01/2014-07/2020			
VARIABLES	DE 2Y	DE 5Y	DE 10Y	DE 2Y	DE 5Y	DE 10Y	DE 2Y	DE 5Y	DE 10Y	SD Factor (full sample)
Timing	29.6	8.1	3.2	56.4	35.4	12.9	25.5	13.4	0.1	2.5
FG	67.9	73.3	62.8	28.4	34.6	33.9	35.1	33.6	6.1	2.5
conventional QE							19.1	32.9	79.6	1.7
market-stabilization QE				6.6	15.2	30.5	7.9	3.4	6.3	4.3
Residual	2.4	18.6	34.0	8.5	14.7	22.8	12.6	16.8	8.0	NA
SD of sov. yields	5.6	4.8	2.5	4.8	4.4	3.1	2.4	3.1	3.7	NA

Panel (B): Italian sovereign yields

	01/2002-09/2008			09/2008-01/2014			01/2014-07/2020			
VARIABLES	IT 2Y	IT 5Y	IT 10Y	IT 2Y	IT 5Y	IT 10Y	IT 2Y	IT 5Y	IT 10Y	SD Factor (full sample)
Timing	35.8	15.8	2.7	24.4	8.4	4.9	16.9	3.6	0.2	2.5
FG	61.9	77.4	59.0	33.4	23.3	7.7	20.8	12.1	3.1	2.5
conventional QE							10.8	16.6	58.5	1.7
market-stabilization QE				35.1	55.3	69.8	30.6	64.3	36.3	4.3
Residual	2.3	6.8	38.3	7.0	13.0	17.6	20.9	3.4	1.9	NA
SD of sov. yields	5.3	4.5	2.4	7.2	7.8	6.7	4.4	5.8	6.8	NA

Note: The table reports, for the 2, 5 and 10 year maturity, the fraction of the variance (in percentage points) explained by risk-free factors in the conference window. The row labeled "Residual" reports the variance not explained by the factors. The last row in each panel shows the variance of yields at the relevant maturity measured in the press conference window. The last column reports the standard deviation of the factors.

5 Channels through which market-stabilization QE affects sovereign yields

This section examines the channels through which market-stabilization QE affects sovereign bond yields. There are in principle five channels that could be relevant, see Krishnamurthy et al. (2017).

We proxy the first two channels, "signalling" channel about future policy rates and "term (or duration-risk) premium" channel, with risk-free rates without disentangling them. As we have documented in the previous section, the response of risk-free rates to a surprise in market-stabilization QE is small and goes in the opposite direction compared to periphery-country sovereign yields. This suggests that these two channels do not play a relevant role in explaining how ECB policies captured by market-stabilization QE affect periphery-country sovereign yields. We provide further evidence below.

The third channel is the "credit-risk premium" channel. We proxy it with sovereign credit-default swap (CDS) spreads denominated in euro. They have become more liquid since the sovereign-debt crisis in 2011-2012.

The fourth channel is the "redenomination risk" channel. It captures the risk that a euro area government in addition or in alternative to defaulting on its obligations will exit the euro and redenominate its debt into a legacy currency at a depreciated exchange rate. We proxy this channel with the measure proposed by De Santis (2019). It is based on the quanto CDS, which is the yield difference of contracts issued in U.S. dollar and in euro. As contracts issued in different currencies amount to future exchange rate expectations, the difference between U.S. dollar and euro denominated contracts reflects to a large extent the risk associated with the depreciation of the euro against the U.S. dollar. But the depreciation can occur also with no break-up of the euro area. Hence, we obtain a clean measure of redenomination risk by expressing the quanto CDS of a euro area country (say, Italy) relative to the one of Germany, which acts as the benchmark euro area country. Data are available at daily frequency starting from September 2011, as the earlier sample is not reliable.[15]

The fifth channel is the "segmentation/illiquidity" channel. In the presence of markets segmentation, this channel operates via changes in investors' desire to sell bonds and changes in pressure on dealers' inventory-absorption capacity (see, for instance, Duffie et al. (2007), De Pooter et al. (2018), Goldberg and Nozawa (2020)). Central bank announcements about asset purchases can affect both of these elements because investors feel lower pressure to sell bonds knowing that the central bank is going to be present as a large and stable buyer, and because the central bank absorbs assets and frees-up arbitrageurs' balance sheet capacity.

A common proxy for liquidity conditions is the CDS-bond basis. It is computed as the difference between the CDS premium and the yield spread of a corresponding bond over a risk-free bond. We use it in our baseline specification and adjust it for the redenomination risk. A small or negative CDS-bond basis means that the yield required on a risky bond is large relative to the premium payable on the corresponding CDS contract. We cross-check the results with other indicators of liquidity. First, we use the bid-ask spread from Reuters, which captures the cost to immediately purchase or sell. We compute it as (Ask-Bid)/((Ask+Bid)/2) for the 3-year sovereign yield. Second, we use the order-book illiquidity score from the electronic platform MTS (Mercato Telematico dei Titoli di Stato), which is the major wholesale market for euro-denominated sovereign bonds. It is computed using bid-ask spreads and quoted quantities from the limit order book.[16] Third, we consider the spread between the 5-year yield on

[15] Table E.3 in Appendix E complements the results presented in this section by showing the estimated effect of monetary policy surprises on the redenomination risk using regression analysis.

[16] Specifically, the indicator is computed as the sum of the five best quotes on both the ask and bid sides of the order book, divided by the sum of the corresponding quoted volumes. The indicator is computed for the

German government-guaranteed bonds issued by special-purpose banks like KfW (Kreditanstalt für Wiederaufbau) and RENTEN, sourced from Bloomberg, and the corresponding German sovereign bond, all guaranteed by the German government and thus carrying the same default risk. This type of spread is often used as a measure of liquidity and flight-to-safety flows (see, De Santis (2012), Monfort and Renne (2013)).

In the presence of market segmentation, local supply effects may become relevant (see, e.g., D'Amico and King (2013)). We assess it indirectly in the next section where we estimate whether surprises in market-stabilization QE transmit to other financial market segments that are not targeted by central bank's purchases.

To quantify the relative importance of the channels, we cannot use intra-daily data due to their unavailability for most of our proxy variables. Therefore, we employ a daily financial VAR, which allows us to assess both the impact response and the evolution over time. The model includes the proxies of the different channels we have described above. Following the methodology of Stock and Watson (2012) and Mertens and Ravn (2013), we achieve identification of the model by using our intra-daily market-stabilization QE as external instrument.

Let X_t be a vector of variables comprising, in the baseline specification, the 3-year OIS rate as well as the sovereign yield, the CDS spread and the quanto CDS for Italy and Spain and the sovereign yield and the CDS spread for Germany, all with 3-year maturity. We focus on the 3-year maturity because the quanto CDS is liquid at this maturity. The VAR can be written as:

$$X_t = c + \sum_{i=1}^{k} B_i X_{t-i} + A_0 u_t. \tag{1}$$

As we are only interested in the effects of the market-stabilization QE shock, our objective is to identify the column of the matrix A_0 corresponding to the contemporaneous effect of this shock. The instrument, Z_t, must be relevant for the structural shock of interest u_t^m, and be strictly exogenous to the other shocks, u_t^0. Formally:

$$\begin{aligned} \mathbb{E}(Z_t u_t^m) &\neq 0, \\ \mathbb{E}(Z_t u_t^0) &= 0. \end{aligned} \tag{2}$$

The estimation of the VAR covers September 2011 until the end of the sample in July

second-most recently issued ten-year sovereign bond of each country.

2020. The beginning of the sample is determined by the availability of redenomination risk data. When we redo the analysis starting the VAR and the first stage regression in May 2010 and excluding the proxy for redenomination risk, we find that results for the other variables are almost unchanged although the response of the German sovereign yield becomes more persistent (see Figure E.4 in Appendix E). We use the 3-year Italian sovereign yield as indicator variable in the first-stage regression of the residual on the external instrument.

Figure 3 shows the impulse response functions of the variables to an accommodative surprise in market-stabilization QE, i.e. a decline in the Italian sovereign yield. The impact response of the OIS rate (see Figure 3, third row, third column) is small and positive, consistently with our intra-daily analysis, and it is not persistent. This suggests that the signalling and duration-risk channels are not relevant for explaining how market-stabilization QE affects sovereign yields. Absence of the duration channel is a striking difference compared to conventional QE in the euro area where it is a dominant channel (see, e.g., Altavilla et al. (2021)).

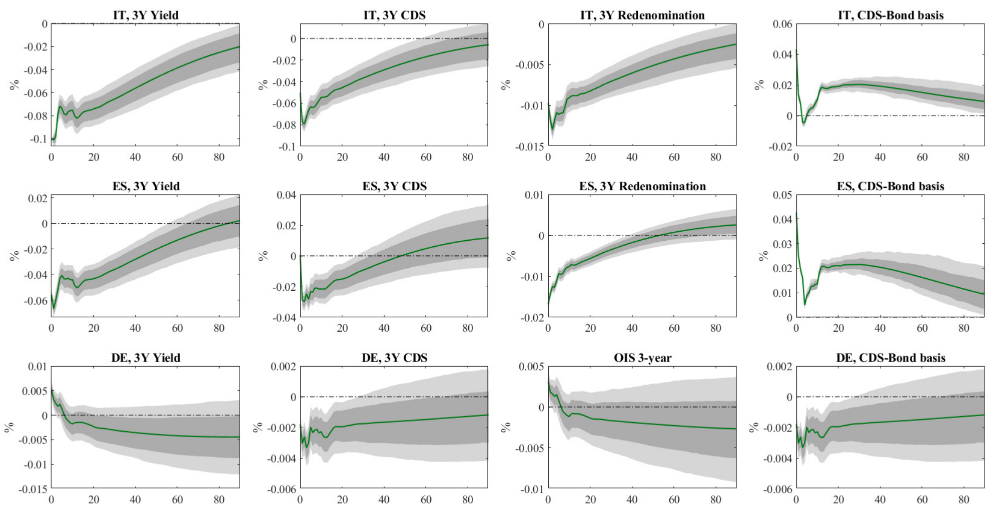

Figure 3: Channels through which market-stabilization QE affects sovereign yields

Note: The figure shows the impulse response functions of a daily proxy-VAR including the 3Y OIS rate as well as the sovereign yield, CDS spread and redenomination risk for Italy and Spain and the sovereign yield and CDS spread for Germany. The adjusted CDS-bond basis is computed after estimation as residual, i.e. as CDS premium - (sovereign yield - OIS rate - redenomination risk). The response is normalised to an impact decline of IT 3-year sovereign yield by 10 basis points. The shaded areas indicate the 68% and 90% posterior coverage bands. The x-axis units are business days. The y-axis units are percentage points per annum.

The relative importance of the other channels is different for Italy and Spain. Figure 3 shows that for Italy the credit-risk channel explains half of the change in the swap-adjusted

Italian yield (i.e. subtracting the OIS response to the response of the sovereign yield). The contribution of the redenomination-risk channel is small. The contribution of the liquidity channel can be gauged by computing the adjusted CDS-bond basis as a residual, and it is displayed for convenience in the figure. An increase means an improvement in liquidity. We find that its contribution is large on impact but declines over time. We report below robustness analysis for alternative proxies of liquidity.

The second row in Figure 3 shows that for Spain the largest contribution on impact comes from the liquidity channel. It remains important through time although the credit-risk channel gradually gains in importance. The redenomination-risk channel plays a relatively more important role than for Italy.

The results for Germany, displayed in the third row of Figure 3, confirm that the response is qualitative similar to the OIS in that it is positive on impact but it is stronger than the OIS response. The contribution of the segmentation channel has opposite sign compared to Italy and Spain. This can be interpreted as the reversal of the flight to safety and liquidity flows into Bunds.

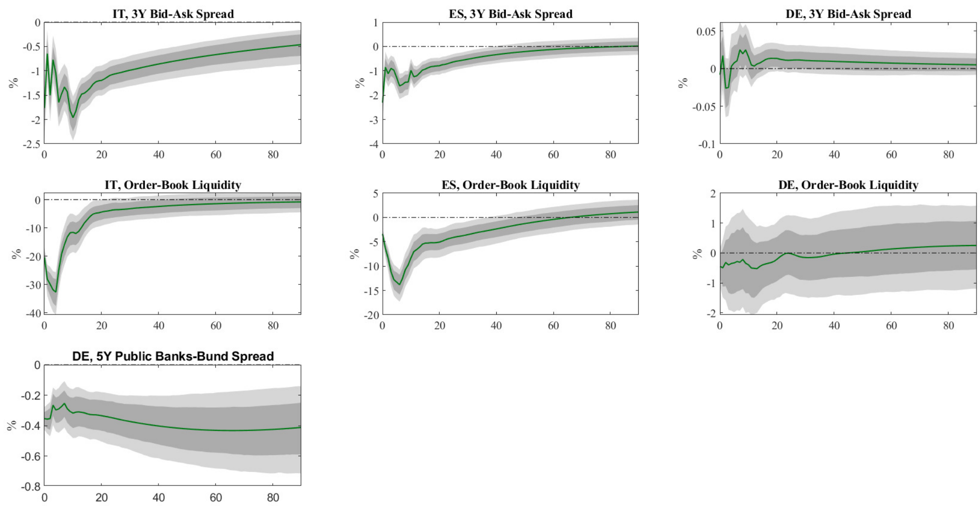

Figure 4: Effect of market-stabilization QE on alternative liquidity measures

Note: The figure shows the impulse response functions of a daily proxy-VAR including the variables listed in Figure 3 and a proxy for liquidity for IT, ES and DE. The response is normalised to an impact decline of IT 3-year sovereign yield by 10 basis points. Each type proxy for the three countries is introduced one at the time. The shaded areas indicate the 68% and 90% posterior coverage bands. The x-axis units are business days. The y-axis units are percent.

We cross-check the results for the liquidity channel using the alternative indicators described above. We exclude the proxy for redenomination risk and start the estimation and the first stage regression in May 2010.[17] Figure 4, first row, shows that the relative bid-ask spread declines for Italy and Spain, i.e. lower transaction costs and hence higher liquidity. The impact on Germany is badly estimated. The order-book illiquidity score, displayed in the second row of Figure 4, shows that liquidity strongly improves in Italy and Spain, while the impact on Germany is insignificant. Our findings for market-stabilization QE for Germany differ from what found by Schlepper et al. (2017) for the APP (i.e. conventional QE). They find that the latter generates a strongly adverse impact on liquidity conditions as measured by bid-ask spreads and order book depth. The third row of Figure 4 shows that the spread between the German bank guaranteed bonds and the Bund declines, meaning that flight-to-liquidity flows into the Bund are reversed. We conclude that the alternative indicators of liquidity we have considered confirm the results of our baseline specification.

6 Transmission of market-stabilization QE to other asset classes

In this section we analyse the transmission of market-stabilization QE to asset classes beyond sovereign bond markets. We start with documenting via regression analysis the high-frequency response of the stock market and the exchange rate, for which intra-daily data are available. We then build on the daily VAR developed in Section 5 and extend it to assess the effect of market-stabilization QE on the most important asset classes and its persistence.

Table 4 shows the high-frequency response of the euro area overall stock market index as well as the index comprising only banks.[18] The bottom panel shows that a contractionary surprise in market-stabilization QE, which leads to an increase in periphery-country sovereign yields, exerts a negative and significant impact on the stock market indices over the whole sample as well as sub-samples. The impact on the banking index is twice as large compared to the overall index.

Comparing the adjusted R^2 of the regression including market-stabilization QE (bottom panel in Table 4) with the one excluding it (top panel) shows the strong explanatory power of our new factor. Over the sovereign-debt crisis the adjusted R^2 for the overall stock market index rises from 10% to 46% and for the bank index from 15% to 65%. Sizeable improvement in the fit appears also in the pandemic period, in the order of almost 20 percentage points.

[17] Results are robust to starting in 2011 and including the proxy for redenomination risk. Results are available upon request.

[18] Data are from the EA-MPD.

Table 4: Estimated effects of monetary policy surprises on stock prices

Panel (A): Conference window

VARIABLES	(1) 01/2002-07/2020 STOXX50E	(2) 01/2002-07/2020 SX7E	(3) 01/2002-09/2008 STOXX50E	(4) 01/2002-09/2008 SX7E	(5) 09/2008-01/2014 STOXX50E	(6) 09/2008-01/2014 SX7E	(7) 01/2014-07/2020 STOXX50E	(8) 01/2014-07/2020 SX7E
Timing	-0.02	-0.05	-0.05***	-0.04*	0.01	-0.02	-0.29***	-0.43**
	(0.02)	(0.04)	(0.02)	(0.02)	(0.03)	(0.05)	(0.10)	(0.18)
FG	-0.05**	-0.06	-0.02	-0.04	-0.06*	-0.16**	-0.16**	0.05
	(0.02)	(0.05)	(0.03)	(0.03)	(0.04)	(0.07)	(0.08)	(0.14)
conventional QE	-0.08**	-0.06					-0.16***	-0.20***
	(0.04)	(0.08)					(0.03)	(0.05)
IJC	-0.28***	-0.46***	-0.83***	-0.78**	-0.27	-0.54	-0.13*	-0.12
	(0.08)	(0.16)	(0.25)	(0.31)	(0.37)	(0.62)	(0.06)	(0.15)
Observations	189	189	70	70	62	62	57	57
R-squared	0.12	0.07	0.15	0.13	0.1	0.15	0.43	0.33

Panel (B): Conference window: with the new factor

VARIABLES	(1) 01/2002-07/2020 STOXX50E	(2) 01/2002-07/2020 SX7E	(3) 01/2002-09/2008 STOXX50E	(4) 01/2002-09/2008 SX7E	(5) 09/2008-01/2014 STOXX50E	(6) 09/2008-01/2014 SX7E	(7) 01/2014-07/2020 STOXX50E	(8) 01/2014-07/2020 SX7E
Timing	-0.02	-0.05**	-0.05***	-0.04*	-0.00	-0.04	-0.17**	-0.20
	(0.01)	(0.02)	(0.02)	(0.02)	(0.02)	(0.03)	(0.07)	(0.14)
FG	-0.05***	-0.06**	-0.02	-0.04	-0.02	-0.05	-0.30***	-0.21*
	(0.02)	(0.03)	(0.03)	(0.03)	(0.03)	(0.04)	(0.07)	(0.11)
conventional QE	-0.08***	-0.06*					-0.05*	0.00
	(0.03)	(0.03)					(0.03)	(0.07)
market-stabilization QE	-0.08***	-0.18***			-0.07***	-0.16***	-0.12***	-0.24***
	(0.01)	(0.01)			(0.01)	(0.03)	(0.03)	(0.05)
IJC	-0.25***	-0.38***	-0.83***	-0.78**	-0.20	-0.39	-0.24***	-0.33**
	(0.09)	(0.11)	(0.25)	(0.31)	(0.39)	(0.59)	(0.07)	(0.14)
Observations	189	189	70	70	62	62	57	57
R-squared	0.39	0.54	0.15	0.13	0.46	0.65	0.58	0.52

*Note: The table reports the reaction of the euro area overall stock market index and bank stock market index over different samples, using intra-day data. Coefficients are expressed in percentage points per standard deviation change in the factors. Robust standard errors in parentheses; ***, **, and * denote statistical significance at the, 1%, 5% and 10% levels, respectively.*

Table 5 reports the high-frequency response of the euro-US dollar exchange rate. As shown in the bottom panel, a contractionary surprise in market-stabilization QE, which leads to an increase in periphery-country sovereign yields, triggers a highly statistically significant depreciation of the euro. Rogers et al. (2014) uncovered this apparently puzzling effect of monetary policy during the sovereign crisis (see also Wright (2019)). They argue that ECB policy measures taken during the sovereign crisis can support confidence in the euro area and lead to an appreciation of the euro. We show that it leads to a reversal of flight-to-safety dynamics. In the sub-sample including the sovereign-debt crisis the R^2 of the regression rises from 29% (top panel in Table 5) to 49% when market-stabilization QE is included (bottom panel). In the sub-sample including the pandemic the response of the exchange rate has similar sign as in the sovereign-debt crisis period but it is not significant.

To estimate the transmission of market-stabilization QE to other asset classes whose prices are available only at daily frequency and to assess persistence we extend the proxy-VAR employed in Section 5. Given the large number of assets we consider, we keep the model of Section 5 as the core specification, we exclude the proxy for redenomination risk so that we can start the VAR and the first stage regression in May 2010, and we add one at the time a set of variables pertaining to a segment of financial markets. For each segment, we include country data for Italy, Spain and Germany. Specifically, we consider the following segments: investment-grade (IG) non-financial corporate (NFC) bond spreads; high-yield (HY) NFC bond spreads; IG financial corporate (FC) bond spreads; HY financial corporate bond spreads; covered bond spreads (limited to ES and DE as data for IT is not available over a long sample, and we replace it with the EA aggregate); stock market price index; exchange rate; and finally two indicators of global and systemic risk, specifically the US stock market implied volatility from the Chicago Board Options Exchange Volatility Index (VIX), and the CISS. The CISS is a measure of euro area systemic stress (see, Holló et al. (2012)). Stock market and exchange rate are in log level. The data on spreads come from Markit iBoxx.[19] As in Section 5, we use our intra-daily market-stabilization QE as external instrument and the 3-year Italian sovereign yield as indicator variable, and we use the same estimation sample.

Figure 5 shows impulse response functions of fixed-income markets to an accommodative surprise in market-stabilization QE, i.e. periphery-country sovereign yields go down. The first row shows results for Italy, the second for Spain and the third for Germany. We make five observations.

First, corporate bond spreads decline across all segments and countries, including Germany. This is noteworthy because German sovereign yields go up, as shown in the previous section.

Second, IG corporate bond spreads (Figure 5, first column) display a hump-shaped pattern peaking after a couple of weeks. Financial and non-financial bond spreads react differently: non-financials tend to react more slowly, and over the initial months less strongly. These results support theories of gradual adjustment of IG corporate bond markets due for instance to slow-moving capital as suggested by Mitchell et al. (2007).

Third, the pattern of the response of HY corporate bond spreads is different from the one of IG. The peak effect occurs more quickly both for financials and non-financials.

Fourth, the size of the response of HY corporate bond spreads is larger than the one of IG. A comparison of the decline in country-based HY spreads with the decline in the corresponding sovereign bond spreads (i.e. the difference between the sovereign yield and OIS rate in Figure 3) shows that the pass-through of the latter into the former is complete for Spain and almost

[19]They are asset swap spread computed as a weighted average of asset swap spread weighted by base market value.

complete for Italy.

For IG corporate bonds the pass-through is more limited especially for non-financials, and quantitatively similar to the unconditional and conditional pass-through found in the literature on the euro area bond markets. For instance, using an event study approach to measure the impact of the APP (i.e. conventional QE), Altavilla et al. (2021) find that a decrease in euro area sovereign bond spreads by 100 basis points triggered by the APP leads to a decrease in euro area corporate bond spreads by 63 and 50 basis points for financial and non-financial, respectively.

The stronger decline in HY compared to IG bond spreads is consistent with our finding of Section 5 that the credit-risk channel is dominant for periphery countries. For one, HY bonds were not expected to be a target of ECB asset purchases. If segmentation were a dominant channel, spillovers across asset classes would be weak; and thus we should not observe that bond spreads in the HY segment decline by more than in IG segment, which was potentially a target of purchases. On the contrary, if the credit-risk channel is dominant, a larger effect on HY compared to IG bonds is to be expected given that the former have higher probability of default and thus are more sensitive to a decline in the premium per unit of default risk.

Fifth, covered-bond spreads do not react on impact but follow a hump-shaped pattern peaking a few weeks after the shock. The response is relatively small.

Figure 6 shows the transmission to other market segments and the effect on global and systemic risk. We find that the stock market reaction, shown in the first column, to an accommodative surprise in market-stabilization QE is expansionary in all countries. This is consistent with our results based on the high-frequency reaction that we have documented above. Figure 6 adds to it by documenting the cross-country dimension and showing that the response is persistent. The exchange rate reaction is shown in the second column. Following an accommodative surprise in market-stabilization QE the euro appreciates against the dollar in a persistent manner.

To provide further insights on the determinants of the transmission of market-stabilization QE, Figure 6 shows the response of three proxies of global and systemic risk to a shock in market-stabilization QE that leads to a decline in periphery yields. We find that the Swiss franc, which typically behaves as safe-haven currency, depreciates against the euro. The VIX, which is often used as a proxy for global investors' risk aversion (see among others, Longstaff et al. (2011)), and the CISS decline significantly and persistently. These results stand in contrast to the evidence on the impact of conventional QE shocks in the euro area. Specifically, Wieladek

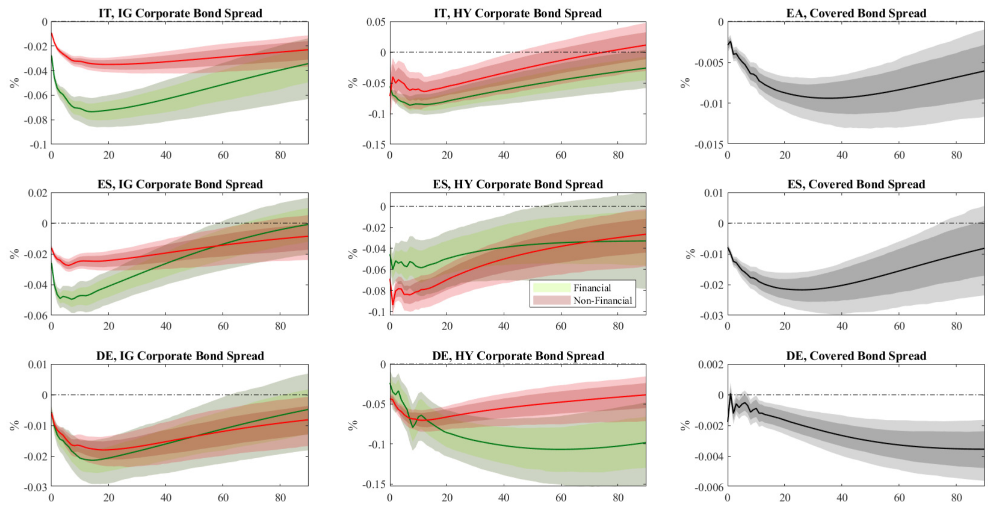

Figure 5: Transmission to other asset classes: fixed income

Note: The figure shows the impulse response functions of a daily proxy-VAR similar to the one shown in the previous section and augmented with additional variables as explained in the text. The response is normalised to an impact decline of IT 3-year sovereign yield by 10 basis points. The shaded areas indicate the 68% and 90% posterior coverage bands. The x-axis shows business days. The y-axis units are in percentage points per annum.

and Garcia Pascual (2016) show that the VIX slight increase following an expansionary APP shock, and Lewis and Roth (2019) document a similar finding for the CISS.

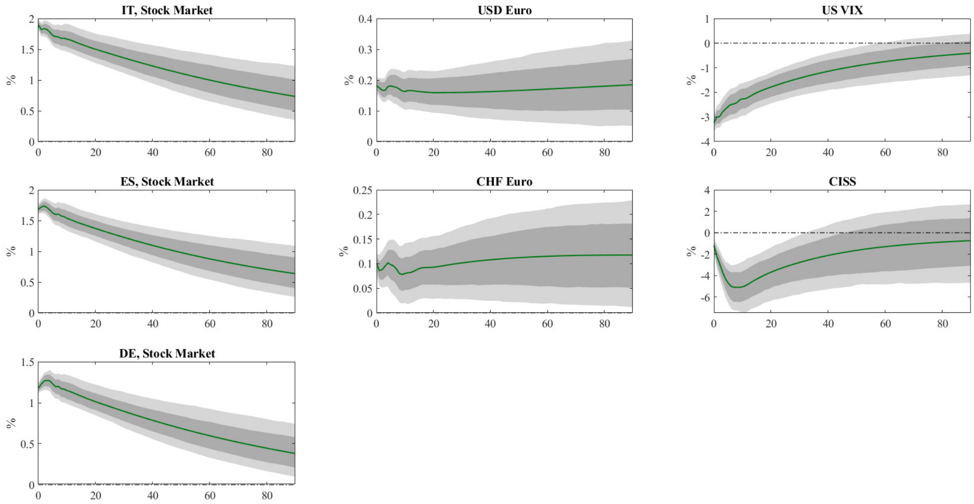

Figure 6: Transmission to stock market, exchange rate and global risk indicators

Note: The figure shows the impulse response functions of a daily proxy-VAR similar to the one shown in the previous section and augmented with additional variables as explained in the text. The response is normalised to an impact decline of IT 3-year sovereign yield by 10 basis points. The shaded areas indicate the 68% and 90% posterior coverage bands. The x-axis shows business days. The y-axis units are in percentage points per annum.

Table 5: Estimated effects of monetary policy surprises on the exchange rate

Panel (A): Conference window

VARIABLES	(1) 01/2002-07/2020 EUR/USD	(2) 01/2002-09/2008 EUR/USD	(3) 09/2008-01/2014 EUR/USD	(4) 01/2014-07/2020 EUR/USD
Timing	0.06***	0.08***	0.07***	0.15**
	(0.01)	(0.01)	(0.02)	(0.06)
FG	0.06***	0.02	0.05***	0.24***
	(0.01)	(0.02)	(0.01)	(0.05)
conventional QE	0.08***			0.09***
	(0.03)			(0.02)
IJC	0.05	0.56***	-0.02	0.06
	(0.08)	(0.21)	(0.30)	(0.04)
Observations	189	70	62	57
R-squared	0.3	0.38	0.29	0.58

Panel (B): Conference window: with the new factor

VARIABLES	(1) 01/2002-07/2020 EUR/USD	(2) 01/2002-09/2008 EUR/USD	(3) 09/2008-01/2014 EUR/USD	(4) 01/2014-07/2020 EUR/USD
Timing	0.06***	0.08***	0.07***	0.18**
	(0.01)	(0.01)	(0.02)	(0.07)
FG	0.06***	0.02	0.07***	0.22***
	(0.01)	(0.02)	(0.02)	(0.05)
conventional QE	0.08***			0.11***
	(0.03)			(0.03)
market-stabilization QE	-0.02***		-0.03***	-0.02
	(0.01)		(0.00)	(0.02)
IJC	0.06	0.56***	0.01	0.04
	(0.08)	(0.21)	(0.28)	(0.05)
Observations	189	70	62	57
R-squared	0.35	0.38	0.49	0.58

*Note: The table reports the reaction of euro-dollar exchange rate over different samples to surprises in monetary policy, using intra-day data. Coefficients are expressed in percentage points per standard deviation change in the factors. Robust standard errors in parentheses; ***, **, and * denote statistical significance at the 1%, 5% and 10% levels, respectively.*

7 Macroeconomic effects

In this section we provide an assessment of the macroeconomic relevance of market-stabilization QE. Given the heterogeneity of the impact of market-stabilization QE on sovereign yields across euro area countries that we have documented, we use a two-country-block VAR model with periphery and core countries, respectively. The core-country block is the average of Germany and France, while the periphery-country block is the average of Italy and Spain. The weights assigned to each country in the aggregation are based on GDP. Overall the model accounts for more than 70% of the euro area GDP. The model is monthly. Each block includes: sovereign bond yields, (log) industrial production, unemployment, (log) Harmonised Index of Consumer Prices excluding food and energy prices as a measure of inflation, and (log) stock market price index. The model includes also the (log) euro/dollar exchange rate.

We adapt to the monthly frequency the proxy-VAR approach we employed in the previous sections. We use our intra-daily market-stabilization QE as external instrument by allocating the high-frequency surprise to the month in which it occurs; in case more than one surprise occurs in a month we sum them up. In the first stage regression we instrument the periphery sovereign yield. The estimation sample is March 2000 to June 2020, and we include 12 lags. The first stage regression on the instrument is over the sample starting in May 2010.

Figure 7 shows impulse responses to a shock in market-stabilization QE. The initial impulses are normalized to generate a 10 basis point decline in periphery-country yields. Consistently with the higher-frequency results reported in the previous sections, core-country yields go up. The stock market improves, with similar size and pattern over time across the two country blocks. The euro exchange rate appreciates against the dollar.

The shock leads to a macroeconomic expansion both in core and periphery countries. Industrial production increases, unemployment declines, inflation increases. The peak response in periphery countries is stronger than the one in core countries.

It is noteworthy that macroeconomic conditions improve also in core countries notwithstanding they experience an increase in their sovereign yields. In analysis not displayed here, we run a specification of the model in which we replace the core-country block with separate variables for Germany and France. Although uncertainty becomes larger due to the expanded set of variables, Germany behaves similarly to the core-country block.[20] This shows that in Germany,

[20] Results are available upon request.

which is the main recipient of flight-to-safety flows during times of financial tensions and hence benefits from the associated lower sovereign yields, macroeconomic conditions improve when the ECB announced policy measures that had the effect of reversing such flows and increasing German sovereign yields.

The positive impact on macroeconomic conditions in all countries has a bearing for the understanding of the channels of market-stabilization QE. The improvement in financial conditions we have documented may create a favourable feedback loop by strengthening the economy, which in turn feedbacks into lower credit-risk premia, and so on.

In comparison to conventional QE, the macroeconomic effect of market-stabilization QE on the euro area is stronger. For instance, Rostagno et al. (2021a) find that 100 basis points decline in the 5-year euro area sovereign yield leads to a decline in euro area unemployment by 0.5 percent. Wieladek and Garcia Pascual (2016) and Gambetti et al. (2017) find that a decline by 100 basis points in the 10-year euro area sovereign yield leads to an increase in euro area GDP by 0.9 and 1.2 percent, respectively. Using Okun's law to convert these values into unemployment, they correspond to a decline in unemployment by about 0.4 and 0.6 percent, respectively. We find that 100 basis points decline in 5-year *periphery* sovereign yields due to market-stabilization QE leads to a decline of euro area unemployment (computed as the weighted average of core- and periphery-country blocks) by 0.7 percent. And this does not consider that in our results the decline in the sovereign yield for the euro area as a whole is lower than 100 basis points given that the sovereign yield in the core-country block goes up following a shock to market-stabilization QE.

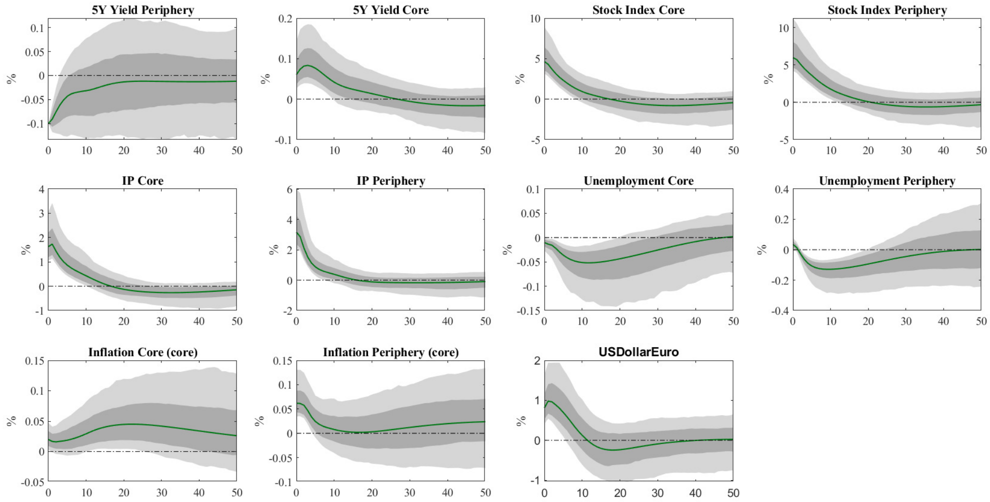

Figure 7: Macroeconomic effects

Note: The figure shows the impulse response functions of a monthly proxy-VAR. The Core block includes Germany and France while the Periphery block includes Italy and Spain. GDP weights are used in the aggregation. The shaded areas indicate the 68% and 90% posterior coverage bands. The x-axis units are months. The y-axis units are percent.

8 Unscheduled policy events

Several ECB announcements related to policy measures aimed to safeguard the transmission mechanism and market functioning took place at night or during the weekend in dramatic circumstances. This compromises the very idea of high-frequency identification, which is based on using a narrow window around the policy announcement under the presumption that nothing else has occurred over such a window. Also, such announcements were often surrounded by non-monetary news. This represents a challenge for the literature that has analysed ECB policy measures using event studies with one or two-day window and considered the change in asset prices over such a time-span as the response to a specific monetary policy measure (e.g. SMP or OMT). This has motivated our choice of not including in our baseline estimation policy announcements made in unscheduled meetings.

To at least partly address these challenges, in this section we follow the approach of Altavilla et al. (2019) and we treat non-scheduled policy announcements as if they are Governing Council policy dates. In practice this amounts to use the factor loadings we have estimated using scheduled meetings and finding the combination of factors that best fit the change in yields around the window surrounding an unscheduled policy announcement.

Three considerations can be made regarding this analysis. First, it allows to measure how markets interpreted the unscheduled policy events we consider, and in particular whether market-stabilization QE is present. Second, it has a bearing on the literature that assumes that some unscheduled ECB announcements contain exclusively information about the SMP, or OMT and PEPP. Our analysis allows to measure whether ECB communication was interpreted as multi-dimensional. Third, the decomposition provides an out-of-sample assessment of our identification strategy. If our identification were to suggest that market-stabilization QE is consistently absent in unscheduled policy events in which there were announcements of measures aimed to address the malfunctioning of bond markets while it dominates in other policy events when only risk-free rates policy measures were announced, or the other way around, this may rise concerns about our methodology described in Section 4 for factor identification.

Consider the econometric model:

$$\boldsymbol{Y} = \boldsymbol{\Lambda}^{*}\boldsymbol{\beta} + \boldsymbol{\eta} \tag{3}$$

where the $\boldsymbol{Y}$ vector contains in its rows daily change in 1, 3, and 6-month and 1, 2, 5, and 10-year risk-free rates and 2, 5, and 10-year sovereign yields of Italy, France and Spain for the corresponding policy event; $\boldsymbol{\Lambda}^{*}$ is the 16×5 unscaled loading matrix computed as explained in Appendix A; $\boldsymbol{\eta}$ is an idiosyncratic shock. $\boldsymbol{\beta}$ is estimated using OLS, and each row contains factor values for the corresponding policy event. We estimate Eq. 3 for each unscheduled event.[21]

We set the width of the window depending on the announcement. If it occurs when markets are closed, we set the window from the end of the last business day to the first two hours of the first business day in which markets reopen after the announcement. In case of other policy events such as speeches or statements we use a window of two hours. This strikes a balance between the desire to set a window as narrow as possible to strengthen identification and the need to allow for sufficient time to absorb a news that comes in an unscheduled policy meeting. Details for each event and the window are provided in Appendix F.

To make the estimated factors comparable to what we have shown for the scheduled meetings in the previous sections, we scale the factors as explained in Appendix A and we display them as

[21] For completeness, in the analysis we include also a target factor that we estimate in the press-release window following the methodology of Altavilla et al. (2019). To recall, the press release is published by the ECB before the press conference. We include target because in principle market participants may update their beliefs about the ECB's policy rate decision that will be taken in the policy meeting within the month and therefore this would show up as a reaction interpretable as target surprise. We find that target is insignificant in all unscheduled events we consider; results are available upon request.

a fraction of the average absolute value of the in-sample surprise of each type that we computed in Section 4. Therefore, as in Section 4, the scaling implies that magnitudes are comparable across different dates for the same type of surprise.

Figure 8 presents results for policy events that triggered large market changes while Figure 9 focuses on moderate market changes. Several results are noteworthy.

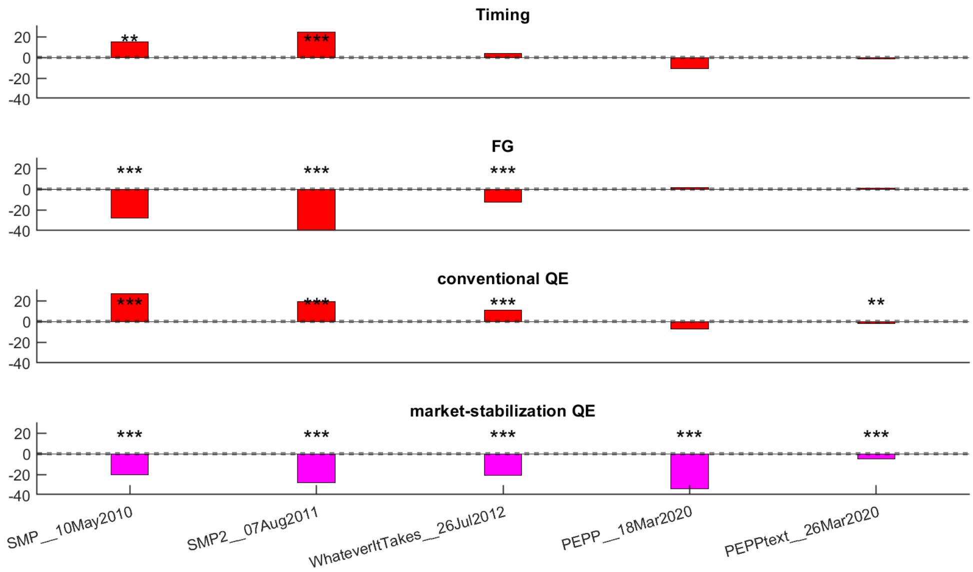

Figure 8: Estimated factors for selected policy events (large market changes)

*Note: The figure shows the estimated factor decomposition for several "out-of-sample" policy events. Dashed lines indicate average absolute in-sample value for each factor. Robust standard errors are calculated and ***, **, and * denote statistical significance at the 1%, 5% and 10% levels, respectively. Timing, FG, conventional QE and market-stabilization QE have unit effect on 6-month, 2-year, 10-year risk-free rates, and 5-year Italian sovereign yield respectively.*

We find that on 18 March 2020 (fourth event in Figure 8), which corresponds to the first announcement of PEPP, there is a large realisation of market-stabilization QE. The announcement took place at night. Interestingly, on this event all other risk-free rate factors are insignificant.

We find that the first and second SMP announcements on 10 May 2010 and 7 August 2011, both of which occurred on Sunday, are multi-dimensional (see first two events in Figure 8). In both events there is a large contribution of market-stabilization QE but also other types of policy measures are present. It should be noted that on 10 May 2010 the ECB announced "several measures to address the severe tensions".[22] Specifically, it announced the reactivation of the fix-rate-full allotment in the three-month operations (i.e. central bank's term liquidity offered on demand without quantity restrictions), the conduct of a new six-month refinancing

[22] See press release, https://www.ecb.europa.eu/press/pr/date/2010/html/pr100510.en.html

operation, and the SMP. As some of these measures relate to the money markets, this may explain why we find the presence of multi-dimensional policy. Regarding the announcement on 7 August 2011, we have reported in Section 1 the numerous dramatic news regarding the euro area and the US surrounding that event, making thus unsurprising that the event is interpreted as multi-dimensional. The famous "whatever it takes" speech by ECB President Mario Draghi on 26 July 2012 is interpreted as a surprise in market-stabilization QE, but other factors are present as well.

As the sample of scheduled policy events that we use to estimate the factors and their loadings in Section 3 contains only a few events taking place during the COVID-19 pandemic period, we analyse several unscheduled policy events during 2020 as a way to validate our identification approach and assess how PEPP has been perceived by financial markets over time. Using a narrative approach, we review daily market commentaries searching for significant market reaction reported to have been triggered by ECB communication. This leads us to consider the publication of the PEPP legal framework on 26 March 2020 (last event in Figure 8), the publication on 6 April 2020 of the first press release displaying the allocation of assets actually purchased under the PEPP, and several statements in 2020 by Governing Council members commenting on policy intentions (see Figure 9 and details for each event in Appendix F). We find that they all contain a significant PEPP surprise, with the sign of the response in line with the conclusions drawn by real-time markets commentaries, as well as a conventional QE surprise. These results are consistent with the stated dual roles of PEPP. Specifically, the ECB has motivated PEPP as having two roles: stabilizing markets across euro area countries and easing the general policy stance similarly to the APP (i.e. conventional QE). And it has stated that the relative importance of the two roles changes over time. In practice, the market-stabilization role is implemented via a flexible allocation regarding the targeted countries and assets in deviation from capital key.

An interesting event is 5 May 2020 when the German Constitutional Court ruled on the legitimacy of the APP and imposed some constraints for the Bundesbank in order to participate to asset purchase programmes. Market analysts commented on the significant uncertainty the ruling created for euro area government bond markets because it could constrain also the ECB's PEPP. Indeed, although the ruling was on the APP rather than the PEPP, Figure 9 shows that this event is interpreted by our methodology as a large contractionary market-stabilization QE with no other factor being significant.

Finally, for comparison we consider a speech by President Mario Draghi on 27 June 2017 at the ECB Forum on Central Banking in Sintra, as this event is analysed in Altavilla et al. (2019) and they find that it is explained by a contractionary (conventional) QE surprise. This speech triggered strong market reaction because, after three years of aggressive policy accommodation and asset purchases, it was interpreted by market commentaries as announcing the start of policy normalisation. When we add both conventional QE and market-stabilization surprises to the regression, we find a strong role for conventional QE while, as it may be expected given the content of the communication, our market-stabilization QE is absent.

We conclude that the out-of-sample analysis carried out in this section supports the main finding of this paper that market-stabilization QE is a distinct and meaningful dimension of the ECB monetary policy. As a further robustness exercise, we show in Appendix F that our main results based on the proxy VAR are robust to computing impulse responses using as external instrument a time series of surprises that combines our baseline market-stabilization QE surprises with the market-stabilization QE surprises we have estimated via equation 3.

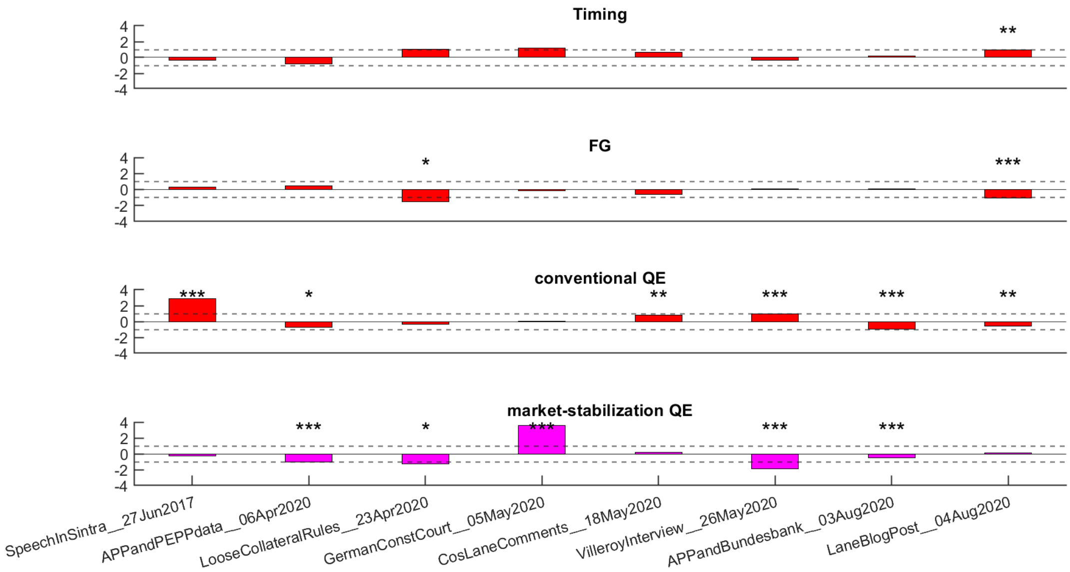

Figure 9: Estimated factors for selected policy events (moderate market changes)

*Note: Note: The figure shows the estimated factor decomposition for several "out-of-sample" policy events. Dashed lines indicate average absolute in-sample value for each factor. Robust standard errors are calculated and ***, **, and * denote statistical significance at the 1%, 5% and 10% levels, respectively. Timing, FG, conventional QE and market-stabilization QE have unit effect on 6-month, 2-year, 10-year risk-free rates, and 5-year Italian sovereign yield respectively.*

9 Conclusion

We identify a dimension of monetary policy, market-stabilization QE, that goes above and beyond risk-free interest rate factors. It captures asset purchase programmes aimed to safeguard the transmission mechanism and reverse flight-to-safety dynamics. Such programmes have been announced during the sovereign-debt crisis and the COVID-19 pandemic period. We are one of the first papers to study the ECB policy measures taken during the pandemic.

We show that monetary policy communication is multi-dimensional and this is a challenge for prior literature based on event studies around policy announcements related to the SMP, OMT and PEPP. We propose an identification approach based on high-frequency data, and we study the properties of market-stabilization QE.

We document the channels through which market-stabilization QE affects sovereign yields and transmits to other asset classes. Our results point to the relevance of the compression of credit risk. An interesting question for future research is the extent to which market-stabilization QE works as a coordination device in the presence of multiple equilibria. An additional extension is to analyze US data to test whether a similar factor emerges during the COVID-19 pandemic when the Fed has purchased risk assets.

We find that market-stabilization QE lowers periphery-country sovereign yields and, while it rises core-country sovereign yields, it generates an accommodative response of risk assets (e.g. stock market and corporate bonds) both in core and periphery countries. We also find that it strengthens macroeconomic conditions in all countries and it lowers global risk.

The out-of-sample analysis we carry out provides support for our identification strategy and the meaningfulness of the results.

Appendices

Appendix A. Factor Identification Methodology

We extend the identification methodology of Swanson (2021) and Altavilla et al. (2019) in two directions. First, we consider not only changes in risk-free rates at 1, 3, and 6-month and 1, 2, 5, and 10-year horizon but also changes in 2, 5, and 10-year sovereign yields of Italy, France and Spain. Thus, 16 assets in total. Second, and as a result of including those additional assets, we consider four factors in the ECB press conference window rather than three, and thus we need additional identifying restrictions.

Consider the $\boldsymbol{Y}$ matrix, with the aforementioned assets in its sixteen columns and each row containing price changes for Governing Council meetings. The length of each column is R. The factor structure is:

$$\boldsymbol{Y} = \boldsymbol{F}\boldsymbol{\Lambda} + \boldsymbol{\epsilon} \tag{A.1}$$

where $\boldsymbol{F}$ is the common latent factors, with the n-th column equal to $\boldsymbol{F}_n = \begin{bmatrix} F_{1,n} & \dots & F_{R,n} \end{bmatrix}'$, $n = 1, \dots, 4$, $\boldsymbol{\Lambda}$ is the 4×16 factor loadings matrix, and $\boldsymbol{\epsilon}$ is the idiosyncratic part of yield changes at different maturities. Factors are estimated with principal components.

Latent factors in their raw forms have no apparent economic meaning. We impose identifying restrictions so that each factor represents one dimension of monetary policy. We do this via factor rotation. Consider a 4×4 rotation matrix, $\boldsymbol{U}$, satisfying $\boldsymbol{U}\boldsymbol{U}' = I$, where I is an identity matrix. Also let $\{u_{ij}\}$ be the corresponding entry at column-j row-i of the rotation matrix. One can reformulate Eq. A.1 as follows:

$$\boldsymbol{Y} = \tilde{\boldsymbol{F}}\tilde{\boldsymbol{\Lambda}} + \boldsymbol{\epsilon}, \text{where } \tilde{\boldsymbol{F}} = \boldsymbol{F}\boldsymbol{U}, \text{and } \tilde{\boldsymbol{\Lambda}} = \boldsymbol{U}'\boldsymbol{\Lambda}. \tag{A.2}$$

Factor rotation is equivalent to determining the entries of the $\boldsymbol{U}$ matrix such that rotated, i.e. identified, factors $\boldsymbol{F}^*$ are given by the equation:

$$\boldsymbol{F}^* = \boldsymbol{F}\boldsymbol{U}^*, \tag{A.3}$$

where $\boldsymbol{U}^*$ is the uniquely identified matrix. To identify $\boldsymbol{U}$, one needs sixteen restrictions in total. For a given matrix $\boldsymbol{X}$, let $\boldsymbol{X}_{\cdot,j}$ denote the j-th column and $\boldsymbol{X}_{i,\cdot}$ the i-th row of $\boldsymbol{X}$. Four restrictions come from the columns of $\boldsymbol{U}$ being equal to one:

$$\boldsymbol{U}'_{.,1}\boldsymbol{U}_{.,1} = 1,\ \boldsymbol{U}'_{.,2}\boldsymbol{U}_{.,2} = 1,\ \boldsymbol{U}'_{.,3}\boldsymbol{U}_{.,3} = 1,\ \boldsymbol{U}'_{.,4}\boldsymbol{U}_{.,4} = 1, \tag{A.4}$$

and six restrictions come from the columns of $\boldsymbol{U}$ being orthogonal:

$$\begin{aligned} &\boldsymbol{U}'_{.,1}\boldsymbol{U}_{.,2} = 0,\ \boldsymbol{U}'_{.,1}\boldsymbol{U}_{.,3} = 0,\ \boldsymbol{U}'_{.,1}\boldsymbol{U}_{.,4} = 0, \\ &\boldsymbol{U}'_{.,2}\boldsymbol{U}_{.,3} = 0,\ \boldsymbol{U}'_{.,2}\boldsymbol{U}_{.,4} = 0, \\ &\boldsymbol{U}'_{.,3}\boldsymbol{U}_{.,4} = 0. \end{aligned} \tag{A.5}$$

We need six additional restrictions. These come from economic considerations. Three of them come from the assumption that in the press conference window the rotated factors do not load on the 1M risk-free rate:

$$\boldsymbol{U}'_{.,2}\boldsymbol{\Lambda}_{.,1} = 0,\ \boldsymbol{U}'_{.,3}\boldsymbol{\Lambda}_{.,1} = 0,\ \boldsymbol{U}'_{.,4}\boldsymbol{\Lambda}_{.,1} = 0. \tag{A.6}$$

Up to here, the restrictions are the same as in Altavilla et al. (2019). The remaining three economic restrictions are specifically introduced to identify our market-stabilization QE. One restriction exploits the notion that some ECB measures are aimed to restore a more homogeneous transmission mechanism and reverse flight-to-safety flows rather than providing policy accommodation by lowering risk-free rates. Therefore, we assume that market-stabilization QE does not load on risk-free rates or move them in opposite direction compared to periphery sovereign yields. The latter captures the reversal of flight-to-safety dynamics. In the baseline specification this is implemented by focusing on the Italian sovereign yield at 5-year maturity and imposing that the product of the effect of the fourth factor on the 5-year Italian sovereign yield (which is located in the *ninth* column of $\boldsymbol{\Lambda}$) and on the 5-year risk-free rate (which is located in the *sixth* column of $\boldsymbol{\Lambda}$) is zero or negative:

$$(\boldsymbol{U}'_{.,4}\boldsymbol{\Lambda}_{.,6})(\boldsymbol{U}'_{.,4}\boldsymbol{\Lambda}_{.,9}) \leq 0. \tag{A.7}$$

We carry out an extensive sensitivity analysis in Appendix B along several dimensions: we replace Italian yields with Spanish yields; we adopt the stronger restriction that market-stabilization QE does not load on risk-free rates; we adopt the weaker restriction that the (absolute) change in risk-free rates is smaller than the one in periphery yields.

Finally, the remaining two restrictions draw from and extend Swanson (2021)'s approach. Similar to Swanson (2021), we require that the QE factor variance during the pre financial-crisis period (in our sample this is January 2002 - Aug 2008) is minimised. And we extend this approach by imposing that the variance of our market-stabilization QE factor is minimised prior to the sovereign-debt crisis as well as in the period that runs from the end of the sovereign debt crisis to the start of the COVID-19 pandemic. Our dating of the sovereign debt crisis brackets the period spanning from the first announcement of the SMP in May 2010 to December 2012 when the crisis to a large extent normalised (see, De Santis (2019)). Our dating of the pandemic reflects that in January 2020 the World Health Organization declared the outbreak a Public Health Emergency of International Concern. We assume that the pandemic extends until the end of our sample. We carry out sensitivity analysis about different starting and ending dates of the sovereign-debt crisis and about the start of the pandemic, with details presented in Appendix B.

Formally, we require that the variance of conventional QE in the pre financial-crisis period and the variance of our market-stabilization QE in the selected periods are minimised. Let $\boldsymbol{F}^{preFC}$, $\boldsymbol{F}^{preDC}$, $\boldsymbol{F}^{postDC}$ denote the factor matrix prior to the financial crisis, prior to the debt crisis and after the debt crisis until the start of the pandemic period, respectively. Then, the solution to the following optimization problem gives the rotation matrix, $\{u_{ij}\}$:

$$\begin{aligned}
\boldsymbol{U}^* = \arg\min_{\{u_{ij}\}} \quad & \underbrace{\sum_{t=1}^{T_{preFC}} (\boldsymbol{F}_{t,\cdot}^{preFC}\boldsymbol{U}_{\cdot,3})^2/T_{preFC}}_{\text{variance of rotated_F3 before the financial crisis}} \\
+ \quad & \underbrace{\sum_{t=1}^{T_{preDC}} (\boldsymbol{F}_{t,\cdot}^{preDC}\boldsymbol{U}_{\cdot,4})^2/T_{preDC}}_{\text{variance of rotated_F4 before the debt-crisis}} \\
+ \quad & \underbrace{\sum_{t=1}^{T_{postDC}} (\boldsymbol{F}_{t,\cdot}^{postDC}\boldsymbol{U}_{\cdot,4})^2/T_{postDC}}_{\substack{\text{variance of rotated_F4 after the debt-crisis} \\ \text{until the start of Covid-19 Pandemic}}} \\
& \text{subject to} \\
& \text{Eq. A.4, A.5, A.6, and A.7,}
\end{aligned} \tag{A.8}$$

where T_{preFC}, T_{preDC}, and T_{postDC} represent total data points in the corresponding periods. Thus, the last two restrictions can be obtained from the first-order conditions of the optimization problem.

$\boldsymbol{U}^*$ is unique up to a rotation. For convenience, we scale the rotated factors, $\boldsymbol{F}^*$, such that the resulting factors, namely Timing, FG, and conventional QE are positively correlated with the 6-month, 2-year, 10-year risk-free rate, respectively. Moreover, we scale market-stabilization QE such that it is positively correlated with the 5-year Italian sovereign yield.

Appendix B. Robustness of Factors to Different Identifying Assumptions

As explained in Appendix A, we make use of two main identifying assumptions for market-stabilization QE, as embedded in Eq. A.7 and Eq. A.8. The first imposes that it does not load on risk-free rates or does it with opposite sign on risk-free rates and periphery sovereign yields. The second imposes minimum variance of market-stabilization QE over specific sample periods. In this section we carry out sensitivity analysis about these two assumptions while keeping the other equations unchanged.

Table B.1 presents the alternatives we consider. They are marked in the rows of the Table as $rob_{i,j}$. The index $i \in$\{1, 2, ..., 6\} stands for the following alternatives regarding the restriction for market-stabilization QE (MSQE): (1) MSQE does not load on 5-year risk-free rate or it does it with opposite sign compared to the 5-year Italian sovereign yield;[23] (2) as in the previous case, but we use the Spanish sovereign yield in place of Italian yields; (3) MSQE loads with opposite sign on the risk-free rate and the Italian sovereign yield; (4) MSQE does not load on the 5-year and 10-year risk-free rates;[24] (5) the (absolute) change in risk-free rates is arbitrarily smaller than the one in periphery yields, and we carry out sensitivity analysis about the size of this differential, k;[25] (6) we leave it unrestricted by simply imposing that the sign of the impact of MSQE on periphery sovereign yields is positive. The index $j \in$\{A, B, C, D, E, F\} stands for different sample periods over which the minimisation of the variance is computed, as described in the third column of Table B.1 and specified in Table B.2.

Our baseline case used in the paper corresponds to the first row of Table B.1, $rob_{1,A}$, i.e. we use the 5-year Italian sovereign yield, and we minimise the variance over the debt-crisis period defined as May 2010 - December 2012 as well as over the Covid-19 period assumed to start in December 2019. For instance, in the alternative case $rob_{1,B}$ we minimize the variance of the fourth factor over a sample that excludes only the sovereign-debt crisis. This means that under the case $rob_{1,B}$, $\boldsymbol{F}^{postDC}$ in Eq. A.8 contains the period after the debt crisis until the beginning of the COVID-19 pandemic for the case $rob_{1,A}$ while it contains the period until the end of the whole sample. The case $rob_{2,j}$ is similar to $rob_{1,j}$ with the exception that we use the Spanish

[23] Strictly speaking, if MSQE loading is different from zero it loads on the 5-year risk-free rate with opposite sign compared to the 5-year Italian sovereign yield.

[24] Although we impose the zero restriction only on the 5-year and 10-year maturities, we find that the estimated loadings are numerically approximately zero (and statistically not different from zero) on all maturities. However, imposing the zero restriction on all maturities makes the optimisation routine harder to converge.

[25] Average overreaction of 5-year Italian sovereign yields from the start of our data sample until 2008 implies that k is around 1.2. We also run a sensitivity analysis for $k \in \{1.2, 2, 10, 100\}$. Results are virtually the same and available upon request.

yield rather than the Italian yield, and so on. As shown in Table B.2, we consider alternatives in which the pandemic period starts in March 2020 and the sovereign debt crisis in July 2011, which marks the beginning of the most acute phase of the crisis when Italian sovereign spreads increased above 300 basis points.

Figure B.1 shows impulse responses using the alternative specifications of market-stabilization QE listed in Table B.1, see thin lines. The impulse responses for most variables are virtually indistinguishable from the baseline specification, see green line. The response of the German Bund yield and the exchange rate differs somewhat across specifications but does not alter the conclusions derived on the basis of our baseline specification.

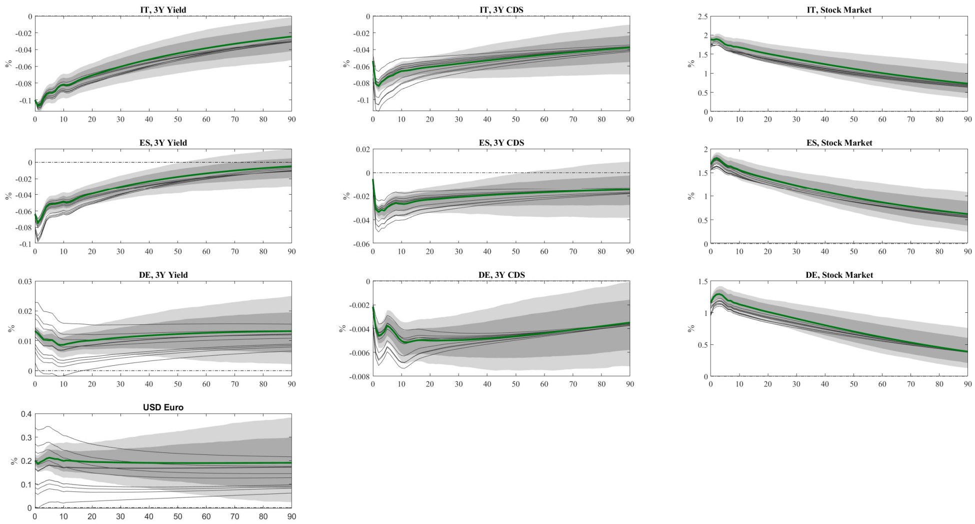

Figure B.1: Impulse responses to market-stabilization QE: alternative specifications

Note: The figure shows the impulse response functions of a daily proxy-VAR. The sample starts in May 2010. The response is normalised to an impact decline of IT 3-year sovereign yield by 10 basis points. Thin lines represent the different specifications described in Table B.1. The solid green line and the shaded areas are computed using the baseline specification. The shaded areas indicate the 68% and 90% posterior coverage bands for the baseline specification. The grey thin lines indicate alternative specifications. The x-axis units are business days. The y-axis units are percent.

Table B.1: Alternative assumptions for identifying market-stabilization QE

Robustness Scenarios	Eq. A.7	Eq. A.8
$rob_{1,A}$(baseline)	$(\boldsymbol{U}'_{.,4}\boldsymbol{\Lambda}_{.,6})(\boldsymbol{U}'_{.,4}\boldsymbol{\Lambda}_{.,9}) \leq 0$	debt-crisis + covid-19
$rob_{1,B}$	$(\boldsymbol{U}'_{.,4}\boldsymbol{\Lambda}_{.,6})(\boldsymbol{U}'_{.,4}\boldsymbol{\Lambda}_{.,9}) \leq 0$	debt-crisis
$rob_{1,C}$	$(\boldsymbol{U}'_{.,4}\boldsymbol{\Lambda}_{.,6})(\boldsymbol{U}'_{.,4}\boldsymbol{\Lambda}_{.,9}) \leq 0$	debt-crisis* + covid-19
$rob_{1,D}$	$(\boldsymbol{U}'_{.,4}\boldsymbol{\Lambda}_{.,6})(\boldsymbol{U}'_{.,4}\boldsymbol{\Lambda}_{.,9}) \leq 0$	debt-crisis*
$rob_{1,E}$	$(\boldsymbol{U}'_{.,4}\boldsymbol{\Lambda}_{.,6})(\boldsymbol{U}'_{.,4}\boldsymbol{\Lambda}_{.,9}) \leq 0$	debt-crisis* + covid-19*
$rob_{1,F}$	$(\boldsymbol{U}'_{.,4}\boldsymbol{\Lambda}_{.,6})(\boldsymbol{U}'_{.,4}\boldsymbol{\Lambda}_{.,9}) \leq 0$	debt-crisis + covid-19*
$rob_{2,A}$	$(\boldsymbol{U}'_{.,4}\boldsymbol{\Lambda}_{.,6})(\boldsymbol{U}'_{.,4}\boldsymbol{\Lambda}_{.,15}) \leq 0$	debt-crisis + covid-19
$rob_{2,B}$	$(\boldsymbol{U}'_{.,4}\boldsymbol{\Lambda}_{.,6})(\boldsymbol{U}'_{.,4}\boldsymbol{\Lambda}_{.,15}) \leq 0$	debt-crisis
$rob_{2,C}$	$(\boldsymbol{U}'_{.,4}\boldsymbol{\Lambda}_{.,6})(\boldsymbol{U}'_{.,4}\boldsymbol{\Lambda}_{.,15}) \leq 0$	debt-crisis* + covid-19
$rob_{2,D}$	$(\boldsymbol{U}'_{.,4}\boldsymbol{\Lambda}_{.,6})(\boldsymbol{U}'_{.,4}\boldsymbol{\Lambda}_{.,15}) \leq 0$	debt-crisis*
$rob_{2,E}$	$(\boldsymbol{U}'_{.,4}\boldsymbol{\Lambda}_{.,6})(\boldsymbol{U}'_{.,4}\boldsymbol{\Lambda}_{.,15}) \leq 0$	debt-crisis* + covid-19*
$rob_{2,F}$	$(\boldsymbol{U}'_{.,4}\boldsymbol{\Lambda}_{.,6})(\boldsymbol{U}'_{.,4}\boldsymbol{\Lambda}_{.,15}) \leq 0$	debt-crisis + covid-19*
$rob_{3,A}$	$(\boldsymbol{U}'_{.,4}\boldsymbol{\Lambda}_{.,6})(\boldsymbol{U}'_{.,4}\boldsymbol{\Lambda}_{.,9}) < 0$	debt-crisis + covid-19
$rob_{3,B}$	$(\boldsymbol{U}'_{.,4}\boldsymbol{\Lambda}_{.,6})(\boldsymbol{U}'_{.,4}\boldsymbol{\Lambda}_{.,9}) < 0$	debt-crisis
$rob_{3,C}$	$(\boldsymbol{U}'_{.,4}\boldsymbol{\Lambda}_{.,6})(\boldsymbol{U}'_{.,4}\boldsymbol{\Lambda}_{.,9}) < 0$	debt-crisis* + covid-19
$rob_{3,D}$	$(\boldsymbol{U}'_{.,4}\boldsymbol{\Lambda}_{.,6})(\boldsymbol{U}'_{.,4}\boldsymbol{\Lambda}_{.,9}) < 0$	debt-crisis*
$rob_{3,E}$	$(\boldsymbol{U}'_{.,4}\boldsymbol{\Lambda}_{.,6})(\boldsymbol{U}'_{.,4}\boldsymbol{\Lambda}_{.,9}) < 0$	debt-crisis* + covid-19*
$rob_{3,F}$	$(\boldsymbol{U}'_{.,4}\boldsymbol{\Lambda}_{.,6})(\boldsymbol{U}'_{.,4}\boldsymbol{\Lambda}_{.,9}) < 0$	debt-crisis + covid-19*
$rob_{4,A}$	$\lvert(\boldsymbol{U}'_{.,4}\boldsymbol{\Lambda}_{.,6})\rvert + \lvert(\boldsymbol{U}'_{.,4}\boldsymbol{\Lambda}_{.,7})\rvert = 0$	debt-crisis + covid-19
$rob_{4,B}$	$\lvert(\boldsymbol{U}'_{.,4}\boldsymbol{\Lambda}_{.,6})\rvert + \lvert(\boldsymbol{U}'_{.,4}\boldsymbol{\Lambda}_{.,7})\rvert = 0$	debt-crisis
$rob_{4,C}$	$\lvert(\boldsymbol{U}'_{.,4}\boldsymbol{\Lambda}_{.,6})\rvert + \lvert(\boldsymbol{U}'_{.,4}\boldsymbol{\Lambda}_{.,7})\rvert = 0$	debt-crisis* + covid-19
$rob_{4,D}$	$\lvert(\boldsymbol{U}'_{.,4}\boldsymbol{\Lambda}_{.,6})\rvert + \lvert(\boldsymbol{U}'_{.,4}\boldsymbol{\Lambda}_{.,7})\rvert = 0$	debt-crisis*
$rob_{4,E}$	$\lvert(\boldsymbol{U}'_{.,4}\boldsymbol{\Lambda}_{.,6})\rvert + \lvert(\boldsymbol{U}'_{.,4}\boldsymbol{\Lambda}_{.,7})\rvert = 0$	debt-crisis* + covid-19*
$rob_{4,F}$	$\lvert(\boldsymbol{U}'_{.,4}\boldsymbol{\Lambda}_{.,6})\rvert + \lvert(\boldsymbol{U}'_{.,4}\boldsymbol{\Lambda}_{.,7})\rvert = 0$	debt-crisis + covid-19*
$rob_{5,A}$	$k * \lvert(\boldsymbol{U}'_{.,4}\boldsymbol{\Lambda}_{.,6})\rvert - \lvert(\boldsymbol{U}'_{.,4}\boldsymbol{\Lambda}_{.,9})\rvert < 0$	debt-crisis + covid-19
$rob_{5,B}$	$k * \lvert(\boldsymbol{U}'_{.,4}\boldsymbol{\Lambda}_{.,6})\rvert - \lvert(\boldsymbol{U}'_{.,4}\boldsymbol{\Lambda}_{.,9})\rvert < 0$	debt-crisis
$rob_{5,C}$	$k * \lvert(\boldsymbol{U}'_{.,4}\boldsymbol{\Lambda}_{.,6})\rvert - \lvert(\boldsymbol{U}'_{.,4}\boldsymbol{\Lambda}_{.,9})\rvert < 0$	debt-crisis* + covid-19
$rob_{5,D}$	$k * \lvert(\boldsymbol{U}'_{.,4}\boldsymbol{\Lambda}_{.,6})\rvert - \lvert(\boldsymbol{U}'_{.,4}\boldsymbol{\Lambda}_{.,9})\rvert < 0$	debt-crisis*
$rob_{5,E}$	$k * \lvert(\boldsymbol{U}'_{.,4}\boldsymbol{\Lambda}_{.,6})\rvert - \lvert(\boldsymbol{U}'_{.,4}\boldsymbol{\Lambda}_{.,9})\rvert < 0$	debt-crisis* + covid-19*
$rob_{5,F}$	$k * \lvert(\boldsymbol{U}'_{.,4}\boldsymbol{\Lambda}_{.,6})\rvert - \lvert(\boldsymbol{U}'_{.,4}\boldsymbol{\Lambda}_{.,9})\rvert < 0$	debt-crisis + covid-19*
$rob_{6,A}$	$\lvert(\boldsymbol{U}'_{.,4}\boldsymbol{\Lambda}_{.,9})\rvert > 0$	debt-crisis + covid-19
$rob_{6,B}$	$\lvert(\boldsymbol{U}'_{.,4}\boldsymbol{\Lambda}_{.,9})\rvert > 0$	debt-crisis
$rob_{6,C}$	$\lvert(\boldsymbol{U}'_{.,4}\boldsymbol{\Lambda}_{.,9})\rvert > 0$	debt-crisis* + covid-19
$rob_{6,D}$	$\lvert(\boldsymbol{U}'_{.,4}\boldsymbol{\Lambda}_{.,9})\rvert > 0$	debt-crisis*
$rob_{6,E}$	$\lvert(\boldsymbol{U}'_{.,4}\boldsymbol{\Lambda}_{.,9})\rvert > 0$	debt-crisis* + covid-19*
$rob_{6,F}$	$\lvert(\boldsymbol{U}'_{.,4}\boldsymbol{\Lambda}_{.,9})\rvert > 0$	debt-crisis + covid-19*

Note: The table reports different assumptions used to identify market-stabilization QE, with each case labeled as $rob_{i,j}$, while $j \in \{A, B, C, D, E, F\}$ stands for different sample periods over which the minimization of the variance is computed, as described in Table B.2. The asterisk in some entries in the last column stands for different sample periods as explained in Table B.2. $(\boldsymbol{U}'_{.,4}\boldsymbol{\Lambda}_{.,6})$, $((\boldsymbol{U}'_{.,4}\boldsymbol{\Lambda}_{.,7}))$, refers to the effect of the fourth factor on 5-year and 10-year OIS, $(\boldsymbol{U}'_{.,4}\boldsymbol{\Lambda}_{.,9})$, and $(\boldsymbol{U}'_{.,4}\boldsymbol{\Lambda}_{.,15})$ refers to the effect of the fourth factor on 5-year, Italian, and Spanish yield, respectively. k-parameter stands for the scaling factor to correct for the reaction of OIS yield.

Table B.2: Periods for variance minimization in Eq. A.8

Period	Covered Dates
debt-crisis	06 May 2010 - 06 Dec 2012
covid-19	12 Dec 2019 - 16 Jul 2020
debt-crisis*	07 Jul 2011 - 06 Dec 2012
covid-19*	12 Mar 2020 - 16 Jul 2020

Note: The table reports different sample periods over which the variance of market-stabilization QE is minimised.

Appendix C. Identification by sign restrictions

This Appendix assesses the robustness of our baseline identification by using an alternative identification via sign and monotonicity restrictions. It draws from the approach of Cieslak and Schrimpf (2019).[26] Let $u_t = (\tilde{y}_t^{OIS6M}, \tilde{y}_t^{OIS2Y}, \tilde{y}_t^{OIS10Y}, \tilde{y}_t^{IT1OY})'$ and $\varepsilon_t = (\varepsilon_t^{Timing}, \varepsilon_t^{FG}, \varepsilon_t^{QE}, \varepsilon_t^{MSQE})'$ be the reduced form and structural shocks, respectively, where $\tilde{y}_t$ is the change in the yields for the corresponding bond in the press conference window and MSQE stands for market-stabilization QE, and the remaining notation is consistent with the paper. The structural shocks are our usual factors, i.e., Timing, FG, QE and market-stabilization QE. The reduced form and structural shocks are related such that:

$$u_t = A^{-1}\varepsilon_t \tag{C.1}$$

where A^{-1} is the matrix of the contemporaneous relationships. In extensive form:

$$\begin{bmatrix} \tilde{y}_t^{OIS6M} \\ \tilde{y}_t^{OIS2Y} \\ \tilde{y}_t^{OIS10Y} \\ \tilde{y}_t^{IT1OY} \end{bmatrix} = \underbrace{\begin{bmatrix} a_{OIS6M,Ti} & a_{OIS6M,FG} & a_{OIS6M,QE} & a_{OIS6M,MSQE} \\ a_{OIS2Y,Ti} & a_{OIS2Y,FG} & a_{OIS2Y,QE} & a_{OIS2Y,MSQE} \\ a_{OIS10Y,Ti} & a_{OIS10Y,FG} & a_{OIS10Y,QE} & a_{OIS10Y,MSQE} \\ a_{IT10Y,Ti} & a_{IT10Y,FG} & a_{IT10Y,QE} & a_{IT10Y,MSQE} \end{bmatrix}}_{A^{-1}} \begin{bmatrix} \varepsilon_t^{Timing} \\ \varepsilon_t^{FG} \\ \varepsilon_t^{QE} \\ \varepsilon_t^{MSQE} \end{bmatrix} \tag{C.2}$$

where $a_{OIS6M,Ti}$ represents the effect of Timing on OIS6M and similarly the other entries follow. We impose sign and monotonicity assumptions to A^{-1}.

Sign restrictions: To identify the structural shocks we require that A^{-1} fulfills sign restrictions as given below:

$$\begin{bmatrix} \tilde{y}_t^{OIS6M} \\ \tilde{y}_t^{OIS2Y} \\ \tilde{y}_t^{OIS10Y} \\ \tilde{y}_t^{IT1OY} \end{bmatrix} = \underbrace{\begin{bmatrix} + & + & + & - \\ + & + & + & - \\ + & + & + & - \\ + & + & + & + \end{bmatrix}}_{A^{-1}} \begin{bmatrix} \varepsilon_t^{Timing} \\ \varepsilon_t^{FG} \\ \varepsilon_t^{QE} \\ \varepsilon_t^{MSQE} \end{bmatrix} \tag{C.3}$$

[26] Cieslak and Schrimpf (2019) rely on the high frequency changes of 2Y, 10Y yields and stock prices (reduced form shocks) around FOMC decisions to compute growth, monetary and risk premium shocks (structural shocks) for the US data. They combine sign restrictions on the comovement of stocks and yields with differential effects of shocks across the maturity structure of the yield curve. Sign restrictions on high-frequency asset prices movements are applied also in Andrade and Ferroni (2021) to disentangle information shocks from pure monetary policy surprises. Further references include Matheson and Stavrev (2014); Nakamura and Steinsson (2018); Jarociński and Karadi (2020).

These restrictions capture that:

(**sign-i**) a positive Timing, FG and conventional QE shock increases risk-free rates and periphery yields,

(**sign-ii**) a positive market-stabilization QE increases periphery yields while decreases risk-free rates.

These two assumptions disentangle Timing, FG and QE from market-stabilization QE, but they are inconclusive in identifying the first three from each other as they all affect reduced form shocks in the same direction. Therefore, we impose additional restrictions.

Monotonicity restrictions:

Monotonicity assumptions capture the effects of risk-free policy measures on the term structure. Altavilla et al. (2019) show that effect of Timing on six-month OIS yields is stronger than the effect on other maturities. Similarly, the effect of FG and conventional QE is stronger on OIS2Y and OIS10Y, respectively, than their effect on other maturities.[27] This evidence can be used to impose monotonicity restrictions to separately identify Timing, FG and QE:

(**mon-i**) $|a_{OIS6M,Ti}| > |a_{OIS6M,FG}|$; $|a_{OIS6M,Ti}| > |a_{OIS6M,QE}|$

(**mon-ii**) $|a_{OIS2Y,FG}| > |a_{OIS2Y,Ti}|$; $|a_{OIS2Y,FG}| > |a_{OIS2Y,QE}|$

(**mon-iii**) $|a_{OIS10Y,QE}| > |a_{OIS10Y,Ti}|$; $|a_{OIS10Y,QE}| > |a_{OIS10Y,FG}|$

Let $var(u_t) = \Sigma_u$ and $var(\varepsilon_t) = I_{4\times4}$, where I is an identity matrix. Consider a Cholesky decomposition of Σ_u:

$$\Sigma_u = PP' \tag{C.4}$$

where P is the lower triangular matrix. This implies:[28]

$$u_t = P\varepsilon_t^{chol} \tag{C.5}$$

where ε_t^{chol} represents a candidate structural shocks.[29] Eq. C.5 holds for any orthogonal matrix, Q, such that $QQ' = Q'Q = I$:

$$u_t = PQ'Q\varepsilon_t^{chol} = P^Q\varepsilon_t^Q \tag{C.6}$$

where ε_t^Q is the structural shocks that correspond to the matrix Q. Q is a rotation matrix that

[27] That is why in our identification we use OIS6M, OIS2Y, OIS1OY as reduced form shocks.

[28] Notice that $var(u_t) = E[u_t u_t'] = E[P\varepsilon_t\varepsilon_t' P'] = PP'$.

[29] Here we only use the fact that P is a lower triangular matrix. Hence the Cholesky decomposition is by no means necessary but only sufficient. Indeed, any lower triangular matrix that satisfies Eq. C.4 is sufficient.

attaches economic interpretation to the shocks. It follows from Eq. C.1 and Eq. C.6 that:

$$PQ' = A^{-1} \tag{C.7}$$

We generate a large number of rotation matrices, Q, such that PQ' satisfies the sign and monotonicity restrictions given above. Following Kilian and Lütkepohl (2017), we implement this step using the Householder's algorithm (Rubio-Ramírez et al. (2010)). This procedure is implemented in the following way:

(i) Generate a 4×4 matrix M by drawing each column of M at random from a multivariate standard normal distribution $N(0, I_{4\times 4})$.

(ii) For each draw, apply a QR decomposition of the matrix M. Rubio-Ramírez et al. (2010) show that if we choose Q by a QR decomposition with diagonal entries of R normalized to be positive, this amounts to choosing Q from the space of orthogonal matrices (Kilian and Lütkepohl (2017)).[30]

(iii) Check whether PQ' satisfies (sign-i-ii) and (mon-i-ii-iii), otherwise discard the Q matrix.

(iv) Repeat this procedure until we have N Q matrices that satisfy the restrictions, where we set $N = 2000$.

As the algorithm delivers a large number of matrices that satisfy the restrictions, we choose the optimal rotation matrix that characterizes the identification procedure by implementing the penalty function approach of Kilian and Lütkepohl (2017). It allows to take into account relevant information for identification that is not reflected in the sign and monotonicity restrictions. We compute variances of the estimated time series for different rotation matrices and among them we choose the one associated with the smallest variance before the 2008 Global Financial Crisis for QE and the one that has the smallest variance outside the debt-crisis period and COVID-19 pandemic for market-stabilization QE. This is implemented in the following step:

(v) Use the Q matrix, and via Eq. C.1 and Eq. C.7 compute structural shock series. In other words, obtain N different series for Timing, FG, QE and market-stabilization QE. For each series compute the variance before the 2008 Global Financial Crisis for QE and the variance outside the debt-crisis period and COVID-19 pandemic for the market-stabilization QE. Sum these two objects for each series and choose the series for which the result is the smallest and the rotation matrix associated with it. For robustness, we consider also an alternative selection

[30] Normalization of diagonal entries of R matrix is implemented such that if the (i, i) element on the diagonal of R is negative, set $Q(:, i) = -Q(:, i)$.

criterion of the rotation matrix, the median.

Figure C.1 shows impulse responses using as external instrument the market-stabilization QE computed via sign restrictions. We consider the selection criterion of the rotation matrix based on the penalty function approach, as described above, and alternatively based on the median. The impulse responses are very similar to the ones reported in the paper for our baseline specification, providing further support to the robustness of our findings.

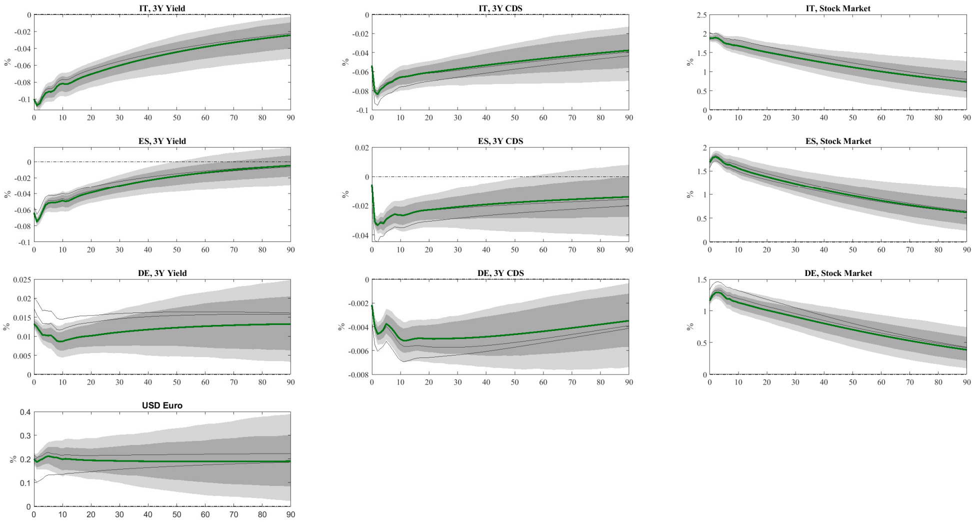

Figure C.1: Impulse responses to market-stabilization QE computed using sign restrictions

Note: The figure shows the impulse response functions of a daily proxy-VAR. The sample starts in May 2010. The response is normalised to an impact decline of IT 3-year sovereign yield by 10 basis points. The thin line represents the responses computed using sign restrictions. The solid green line and the shaded areas are computed using the baseline specification. The shaded areas indicate the 68% and 90% posterior coverage bands for the baseline specification. The grey thin lines indicate impulse responses computed using market stabilization QE obtained via alternative specifications of sign restrictions. The x-axis units are business days. The y-axis units are percent.

Appendix D. Matching policy surprises with ECB communication

In this appendix we complement our discussion of the largest policy surprises in market-stabilization QE of Section 4 and report on how market commentaries interpreted policy communication in real time. Note that a positive reading of market-stabilization QE implies an increase in the periphery sovereign yields.

On 4 August 2011 there is a positive large realisation. The Financial Times commented that there was a disappointment due investors realizing that the ECB was not buying sovereign bonds of Italy and Spain. Dow Jones Newswires reported "*In the ECB's post rate announcement press conference, traders noted the central bank intervened in the secondary market to buy Portuguese and Irish sovereign bonds, a decision that was not "unanimous" says ECB chief Trichet. This led to speculation the ECB may not be fully committed to the program and its involvement and impact may be limited, says IHS Global Insight. The move also suggests the bar for intervention remains high for the beleaguered Spanish and Italian economies, traders noted.*"

The surprise on 6 October 2011 corresponds to the announcement of the second Covered Bond Purchase Programme (CBPP2), which was a response to the intensification of the sovereign debt crisis given that covered bond markets were under significant pressure.

On 8 December 2011 there is positive large realisation. The ECB cut key interest rates and launched a 3-year lending programme (LTRO). But there were expectations for the announcement of large-scale purchases of government bonds to support euro area stressed countries. For instance, as reported by Reuters News, President Draghi's comments in the previous week on a fiscal compact were interpreted "*as being a hint the bank could commit to more bond buying if European leaders tighten budget rules.*" During the press conference President Draghi stated that the ECB's only mandate is to control inflation and EU Treaties contain a prohibition of financing governments outright. The Associated Press Newswires titled "*HOPES DASHED: ECB President Mario Draghi said there is no existing plan for large-scale ECB purchases of government bonds, as markets had been hoping. Stocks and the euro sold off.*" The Dow Jones Business News wrote "*The European Central Bank responded Thursday to pressure for radical action to stop the rot in the euro zone's financial markets, but stopped well short of giving any commitment to increased purchases of government bonds.*"

On 5 July 2012 there is a large realization due to disappointment of market expectations. The ECB reduced the deposit rate to zero but did not announce any measure to support stressed bond markets. Holger Schmieding, chief economist at Berenberg Bank, was reported by CNN to comment the measures announced by the ECB as follows: "*These moves were highly necessary and widely expected, but are insufficient to turn the euro zone economy around. The ECB would have to do more to intervene to calm market anxiety.*". The FT pointed out that "*The ECB neither announced any new liquidity initiative nor dropped any hint that it may intervene again in the sovereign bond markets to break the cycle of fear that is engulfing Spain and Italy.*"

On 2 August 2012 President Draghi said the ECB could buy Spanish and Italian bonds, but commentaries at the time stressed that markets were expecting a more explicit bond buying commitment. This shows up in our analysis as a positive large surprise. Reuters reported that "*Spanish 10-year yields topped 7 percent on Thursday and were seen testing their euro-era highs in the near term after ECB President Mario Draghi quashed expectations of an immediate resumption of the bank's bond-buying programme.*" The Wall Street Journal reported that "*Lack of fireworks from Mr. Draghi has seen a strong safety bid back into German paper. [...] Hard to believe the ECB came to this conference with so little – given market moves since the now infamous London comments last week.*"

A large expansionary surprise is on 6 September 2012. Yields on Spanish and Italian bonds fell sharply. The Wall Street Journal reported "*The unveiling of the European Central Bank's long-promised bond-buying program helped push up stocks around the Continent on Thursday, despite cuts by the central bank to its economic-growth forecast. In his monthly news conference, ECB President Mario Draghi said what many in financial markets had expected: The central bank is ready to buy unlimited quantities of government bonds that it perceives to be unreservedly weak.*"

To show that our identification procedure successfully separates conventional QE from market-stabilization QE, we draw attention to the surprise on 22 January 2015 which corresponds to the announcement of the APP. This shows up in our analysis as the largest conventional QE surprise, and a negligible market-stabilization QE surprise. Similar pattern is visible for the recalibrations of the APP in 2016.

During the COVID-19 pandemic period, on 12 March 2020 there is a large positive surprise for market-stabilization QE as well as a contractionary conventional QE surprise. Consistently with our tightening surprise, the Financial Times reported that "*...Markets had hoped that today would be Christine Lagarde's "Whatever it takes" moment. Those hopes have proven misplaced...*". The policy communication on 30 April 2020 disappointed market expectations, with the Financial Times writing that "*Some economists had predicted that the ECB would expand its plans to buy more than €1tn of assets this year to counter the threat that the countries* *hit hardest by coronavirus, such as Italy and Spain, could suffer a surge in borrowing costs — but it held off on any such announcement.*"

On 4 June 2020, there is a policy easing surprise for market-stabilization QE. The ECB announced a stimulus package worth €600 billion. In a Bloomberg Survey carried out ahead of the policy meeting, the vast majority of analysts had predicted an envelope of €500 billion.

Appendix E. Additional results

This section provides additional estimation results.

Figure E.1 shows the time series of the identified surprises.

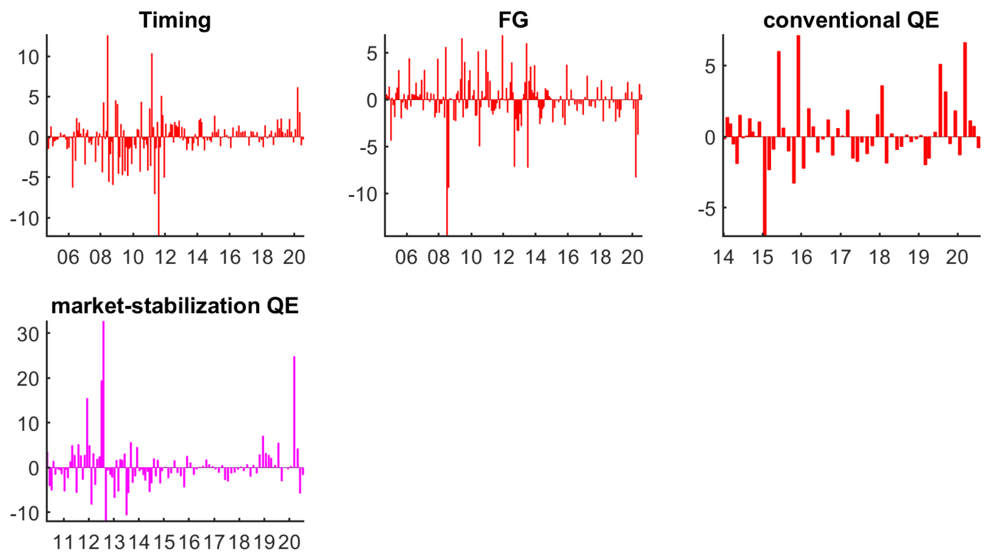

Figure E.1: Estimated factors during the ECB press conference window

Note: The figure shows the estimated factors in basis points. As the factors are identified up to scale, Timing, FG, QE and market-stabilization QE are scaled such that they have unit effect on 6-month, 2-year, 10-year OIS and 5-year Italian sovereign yield, respectively. Negative values correspond to monetary policy easing and positive values stand for policy tightening. Data period covers scheduled Governing Council meetings from 3 January 2002 to 6 June 2019, both included.

Figures E.2 and E.3 show the factor loadings of risk-free rates and Italian sovereign yields, respectively.

Table E.1 reports the estimated effects of the factors on risk-free rates.

Table E.2 reports the estimated effects of the factors on Spanish sovereign yields.

Figure E.4 shows impulse response functions for a sample starting in May 2010. The figure is similar to Figure 3 in Section 5, but it starts in May 2010 (both the VAR and the first stage regression), and therefore it excludes the proxy for redenomination risk which is available in a consistent manner only since 2011.

Table E.3 reports the estimated effects of monetary policy surprises on redenomination risk. The results suggest that a contractionary shock in market-stabilization QE leads to an increase of redenomination risk.

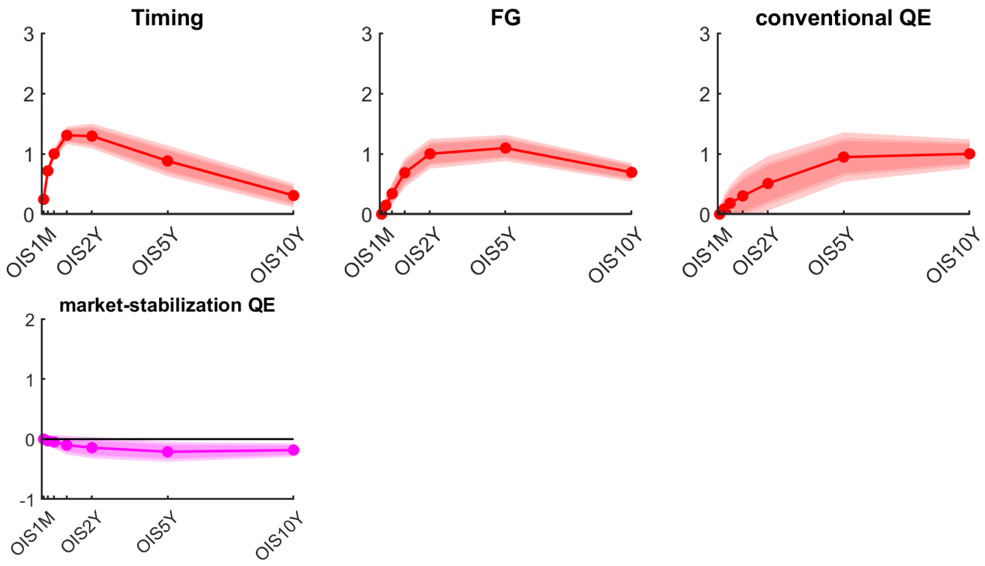

Figure E.2: Factor loadings of risk-free rates

Note: The figure shows the factor loadings, in basis points. For each maturity the loadings are obtained by regressing the surprises onto the factors and also controlling for the standardized surprise associated with the release of the US initial jobless claims. Timing, FG, conventional QE and market-stabilization QE have unit effect on 6-month, 2-year, 10-year OIS and 5-year Italian sovereign yield. The shaded areas indicate the 90%, 95% and 99% confidence intervals.

Table E.1: Estimated effects of monetary policy surprises on risk-free rates, full sample

Panel: Conference window

VARIABLES	(1) OIS 1M	(2) OIS 3M	(3) OIS 6M	(4) OIS 1Y	(5) OIS 2Y	(6) OIS 5Y	(7) OIS 10Y
Timing	0.24***	0.72***	1.00***	1.31***	1.29***	0.88***	0.31***
	(0.06)	(0.05)	(0.04)	(0.03)	(0.02)	(0.02)	(0.03)
FG	-0.00	0.14**	0.34***	0.69***	1.00***	1.09***	0.69***
	(0.03)	(0.06)	(0.06)	(0.04)	(0.03)	(0.04)	(0.05)
conventional QE	-0.00	0.08	0.18***	0.30***	0.51***	0.95***	1.00***
	(0.04)	(0.06)	(0.06)	(0.04)	(0.03)	(0.06)	(0.06)
market-stabilization QE	0.00	-0.03	-0.05*	-0.10***	-0.14***	-0.21***	-0.18***
	(0.02)	(0.03)	(0.03)	(0.03)	(0.01)	(0.02)	(0.02)
IJC	-0.01	-0.23	-0.06	0.12	0.13	-0.06	0.01
	(0.16)	(0.17)	(0.12)	(0.09)	(0.11)	(0.13)	(0.10)
Observations	189	189	189	189	189	189	189
R-squared	0.34	0.79	0.94	0.98	0.98	0.95	0.92

*Note: The table reports the reaction of risk-free rates at different maturities to surprises in monetary policy using intraday data. Coefficients are expressed in percentage per annum per standard deviation change in the factors. Robust standard errors in parentheses; ***, **, and * denote statistical significance at the 1%, 5% and 10% levels, respectively.*

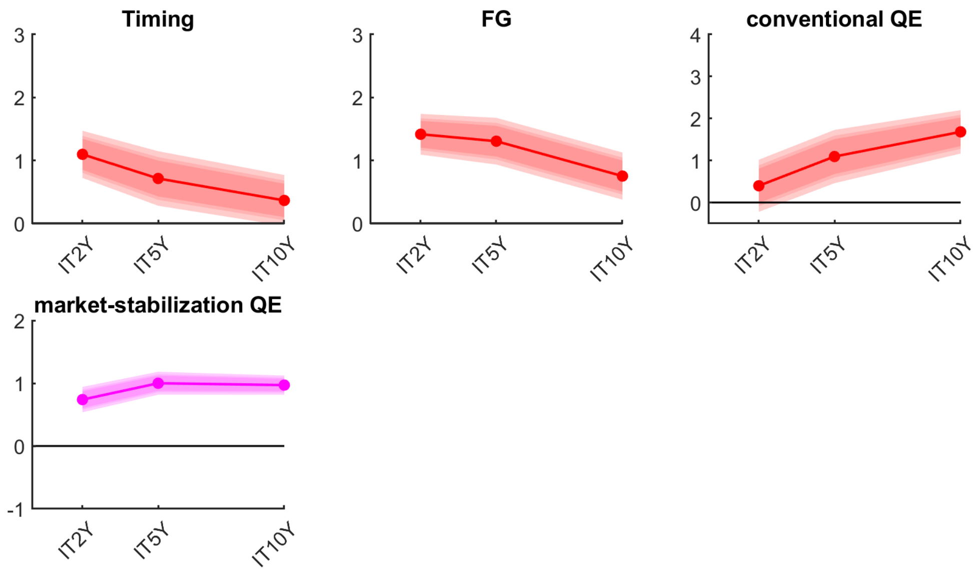

Figure E.3: Factor loadings of Italian sovereign yields

Note: The figure shows the factor loadings, in basis points. For each maturity the loadings are obtained by regressing the surprises onto the factors and also controlling for the standardized surprise associated with the release of the US initial jobless claims. Market-stabilization QE is scaled to have unit effect on the 5-year Italian sovereign yield. The shaded areas indicate the 90%, 95% and 99% confidence intervals.

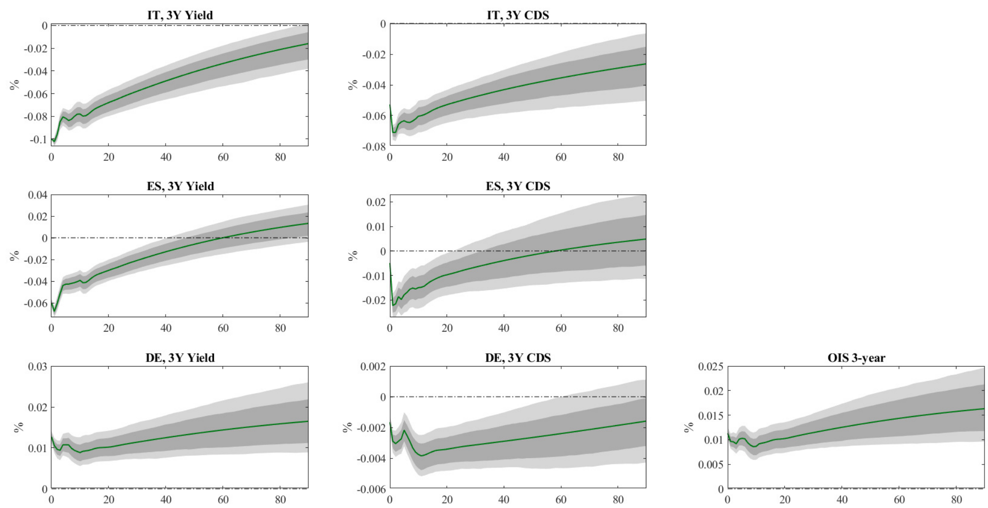

Figure E.4: Effects of market-stabilization QE on sovereign yields

Note: The figure shows the impulse response functions of a daily proxy-VAR including the 3Y OIS rate as well as the sovereign yield and CDS spread for Italy and Spain and Germany. The sample starts in May 2010. The response is normalised to an impact decline of IT 3-year sovereign yield by 10 basis points. The shaded areas indicate the 68% and 90% posterior coverage bands. The x-axis units are business days. The y-axis units are percentage points per annum.

Table E.2: Estimated effects of monetary policy surprises on Spanish sovereign yields

Panel (A): Conference window

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
		01/2002-09/2008			09/2008-01/2014			01/2014-07/2020	
VARIABLES	ES 2Y	ES 5Y	ES 10Y	ES 2Y	ES 5Y	ES 10Y	ES 2Y	ES 5Y	ES 10Y
Timing	0.88***	0.62***	0.18**	0.80***	0.46***	0.22	0.62	1.28***	0.31
	(0.05)	(0.05)	(0.08)	(0.08)	(0.12)	(0.15)	(0.43)	(0.34)	(0.41)
FG	1.29***	1.22***	0.68***	1.78***	1.65***	1.37***	1.05***	1.24***	0.57*
	(0.04)	(0.09)	(0.16)	(0.11)	(0.19)	(0.22)	(0.31)	(0.29)	(0.31)
IJC	0.14	0.41	0.33	1.39	-2.64	-3.63	0.58***	-0.82***	-0.17
	(0.38)	(0.55)	(0.84)	(1.64)	(2.10)	(2.30)	(0.16)	(0.26)	(0.18)
conventional QE							0.39***	0.87***	1.65***
							(0.07)	(0.13)	(0.09)
Observations	70	70	70	62	62	62	57	57	57
R-squared	0.98	0.97	0.74	0.82	0.56	0.38	0.7	0.77	0.87

Panel (B): Conference window: with the new factor

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
		01/2002-09/2008			09/2008-01/2014			01/2014-07/2020	
VARIABLES	ES 2Y	ES 5Y	ES 10Y	ES 2Y	ES 5Y	ES 10Y	ES 2Y	ES 5Y	ES 10Y
Timing	0.88***	0.62***	0.18**	0.83***	0.53***	0.31***	0.31	0.75***	-0.16
	(0.05)	(0.05)	(0.08)	(0.07)	(0.06)	(0.09)	(0.38)	(0.12)	(0.22)
FG	1.29***	1.22***	0.68***	1.57***	1.26***	0.87***	1.39***	1.84***	1.10***
	(0.04)	(0.09)	(0.16)	(0.08)	(0.09)	(0.14)	(0.18)	(0.11)	(0.18)
IJC	0.14	0.41	0.33	1.09	-3.18**	-4.30***	0.86***	-0.31**	0.28**
	(0.38)	(0.55)	(0.84)	(1.17)	(1.24)	(1.48)	(0.20)	(0.15)	(0.13)
market-stabilization QE				0.30***	0.55***	0.69***	0.32***	0.55***	0.49***
				(0.03)	(0.03)	(0.08)	(0.09)	(0.04)	(0.06)
conventional QE							0.11	0.39***	1.22***
							(0.11)	(0.06)	(0.10)
Observations	70	70	70	62	62	62	57	57	57
R-squared	0.98	0.97	0.74	0.93	0.87	0.88	0.83	0.95	0.96

*Note: The table reports the reaction of Spanish sovereign yields at different maturities to surprises in monetary policy using intraday data. Coefficients are expressed in percentage per annum per standard deviation change in the factors. Robust standard errors in parentheses; ***, **, and * denote statistical significance at the 1%, 5% and 10% levels, respectively.*

Table E.3: Estimated effects of monetary policy surprises on euro redenomination risk

Panel (A): Conference window

VARIABLES	(1) 10/2011-07/2020 Rdn IT 3Y	(2) 10/2011-07/2020 Rdn ES 3Y	(3) 10/2011-01/2014 Rdn IT 3Y	(4) 10/2011-01/2014 Rdn ES 3Y
Timing	0.58**	0.63	0.88**	0.54
	(0.25)	(0.40)	(0.33)	(0.49)
FG	0.36*	0.31	0.45	0.54
	(0.19)	(0.35)	(0.29)	(0.43)
conventional QE	-0.12	0.12		
	(0.10)	(0.22)		
IJC	-0.02	-0.19	0.15	-3.88
	(0.26)	(0.46)	(2.59)	(5.63)
Observations	84	84	28	28
R-squared	0.15	0.05	0.2	0.05

Panel (B): Conference window: with the new factor

VARIABLES	(1) 10/2011-07/2020 Rdn IT 3Y	(2) 10/2011-07/2020 Rdn ES 3Y	(3) 10/2011-01/2014 Rdn IT 3Y	(4) 10/2011-01/2014 Rdn ES 3Y
Timing	0.44	0.28	0.82**	0.44
	(0.28)	(0.34)	(0.32)	(0.48)
FG	0.26	0.07	0.22	0.21
	(0.17)	(0.30)	(0.27)	(0.44)
conventional QE	-0.13	0.09		
	(0.10)	(0.16)		
market-stabilization QE	0.09**	0.23***	0.13***	0.19***
	(0.04)	(0.05)	(0.03)	(0.05)
IJC	-0.05	-0.25	-0.09	-4.22
	(0.24)	(0.29)	(2.32)	(5.81)
Observations	84	84	28	28
R-squared	0.23	0.25	0.3	0.13

*Note: The table reports the reaction of the 3-year maturity euro redenomination risk over different samples to surprises in monetary policy. Rdn IT 3Y stands for 3-year maturity euro redenomination risk for Italy and Rdn ES 3Y for Spain. Coefficients are expressed in basis points per standard deviation change in the factors. Robust standard errors in parentheses; ***, **, and * denote statistical significance at the, 1%, 5% and 10% levels, respectively.*

Appendix F. Unscheduled policy events

Table F.1 displays the list of unscheduled events used in the analysis of Section 8, providing a brief account of their content and the time window we use.

Figure F.1 shows impulse responses computed using as external instrument a time series of surprises that combines our baseline market-stabilization QE surprises with the market-stabilization QE surprises we have estimated via equation 3 in Section 8. To ease comparison, the figure shows the results based on this alternative specification (thin line) as well as the results computed using our baseline specification. Results are very similar, providing further support to the robustness of our findings.

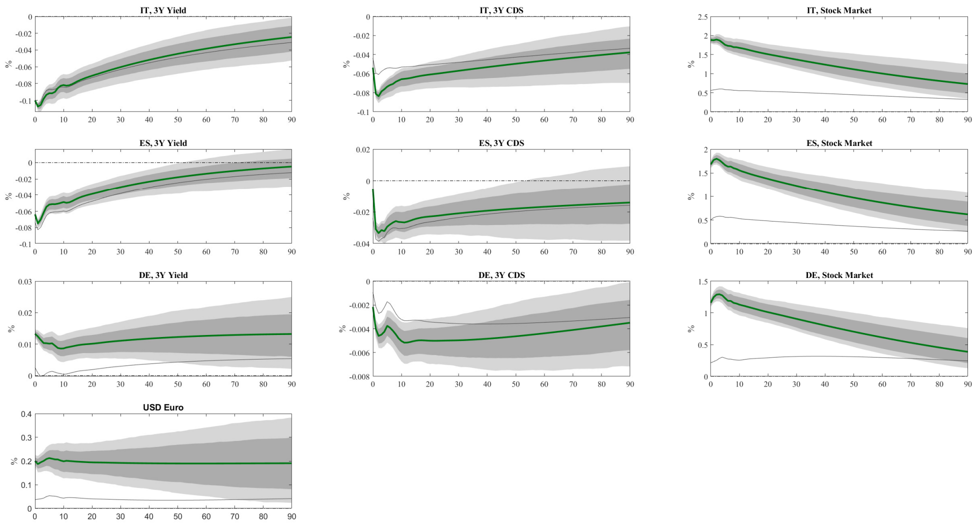

Figure F.1: Impulse responses to market-stabilization QE making use also of the surprises estimated in Section 8

Note: The thin line represents impulse responses computed using as external instrument a time series of surprises that combines the baseline market-stabilization QE surprises with the market-stabilization QE surprises estimated via equation 3 in Section 8. The solid green line and the shaded areas are computed using the baseline specification. The shaded areas indicate the 68% and 90% posterior coverage bands. The response is normalised to an impact decline of IT 3-year sovereign yield by 10 basis points. The The x-axis units are business days. The y-axis units are percentage points per annum.

Table F.1: Unscheduled policy events

	Date	Window-start	Window-end	Event
Large Surprises	10/05/2010	7 May 2010, closing	10 May, closing	SMP announcement
	07/08/2011	5 August 2011, 18:00-18:10	7 August 2011, 10:00-10:10	SMP announcement
	26/07/2012	26 July 2012, 12:00-12:10	27 July 2012, 14:00 - 14:10	'Whatever it takes' speech in London
	18/03/2020	19 March 2020, 8:00-8:10	19 March 2020, 10:00-10:10	PEPP Announcement
	26/03/2020	26 March 2020, 8:00-8:10	26 March 2020, 10:00-10:10	Legal details of PEPP are released: flexibility around the use of capital key, issuer limits and maturities
Smaller Surprises	27/06/2017	27 June 2017, 9:45-9:55	27 June 2017, 12:00-12:10	Speech Sintra
	06/04/2020	6 April 2020, 15:30-15:40	6 April 2020, 17:45-17:55	First publication of APP and PEPP data for March
	23/04/2020	23 April 2020, 8:00-8:10	23 April 2020, 10:00-10:10	ECB loosens collateral rules to accept bonds that lose their investment grade credit rating
	05/05/2020	5 May 2020, 9:45-9:55	5 May 2020, 12:00-12:10	German Constitutional Court ruling on PSPP
	18/05/2020	18 May 2020, 11:30-11:40	18 May 2020, 13:45-13:55	ECB Chief Economist Lane says that ECB will increase PEPP if bonds spreads widen significantly
	26/05/2020	26 May 2020, 08:56-9:06	26 May 2020, 11:11-11:21	Banque de France Governor Villeroy says that the capital key is an "uncalled-for constraint" for the PEPP
	26/05/2020	26 May 2020, 15:13-15:23	26 May 2020, 17:28-17:38	ECB Chief Economist Lane says that the whole point of having flexibility is that deviation from the capital key allocation are possible
	03/08/2020	3 August 2020, 14:50-15:00	3 August 2020, 17:45-17:55	German Bundesbank says that will continue to take part in purchases under the framework of the PSPP
	03/08/2020	3 August 2020, 15:30-15:40	3 August 2020, 17:45-17:55	Publication of APP and PEPP data
	04/08/2020	4 August 2020, 10:00-10:10	4 August 2020, 12:00-12:10	ECB Chief-Economist Lane Blogpost: "...the overall envelope of PEPP purchases is a core determinant of the ECB's overall monetary stance"

Note: The table reports the list of unscheduled policy events presented in Section 8, as well as their date and the time window over which asset price changes are computed. The start and end of the window is reported as a time interval of 10 minutes over which we compute the median, so as to reduce the possibility of selecting an outlier.

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