

Euro area sovereign bond risk premia before and during the Covid-19 pandemic*

Stefano Corradin
ECB

Bernd Schwaab
ECB

November 17, 2022

Abstract

We provide a novel modelling framework to decompose euro area sovereign bond yields into five distinct components: *i*) expected future short-term risk-free rates and a term premium, *ii*) a default risk premium, *iii*) redenomination risk premium, *iv*) liquidity risk premium, and *v*) segmentation (convenience) premium. Identification is achieved by considering sovereign yields jointly with other rates, including sovereign credit default swap spreads with and without redenomination as a credit event trigger. We illustrate our model by studying yield components embedded in German, French, Italian, and Spanish sovereign bonds, before and after the onset of the Covid-19 pandemic in 2020, and by examining the impact of European Central Bank (ECB) monetary policy and European Union (EU) fiscal policy announcements in response to the pandemic. We find that all five risk premia became sizable following the onset of the pandemic, and that both monetary and fiscal policy announcements had a pronounced effect on yields, mostly through default, redenomination, and segmentation (convenience) premia.

Keywords: Sovereign bond yields, ECB, Kalman filter, event study.

JEL classification: *C22, G11.*

*Author information: Stefano Corradin, European Central Bank, email: stefano.corradin@ecb.europa.eu. Bernd Schwaab, European Central Bank, email: bernd.schwaab@ecb.europa.eu. Niklas Grimm, Leon Loidl and Maria Antonietta Viola provided excellent research assistance. We thank four anonymous referees, Svetlana Bryzgalova (discussant), and Athanasios Orphanides (discussant). We benefited from conversations with Pierre Collin-Dufresne, Philipp Hartmann, Urban Jermann, Peter Karadi, Manfred Kremer, Wolfgang Lemke, Simone Manganelli, and Peter Praet, and seminar and conference participants at the 8th International Conference on Sovereign Bond Markets 2022, the Bank of Spain, the Federal Reserve Bank of Boston, the CEBRA 2021 Annual Meeting, and the European Commission's 2021 Annual Research Conference. The views expressed in this paper are those of the authors and they do not necessarily reflect the views or policies of the European Central Bank.

1 Introduction

The outbreak of the novel Corona virus in the euro area in February 2020 had a pronounced impact on euro area sovereign bond yields. Some countries were hit earlier and harder by Covid-19 than others, and from different economic and fiscal positions, causing sovereign yields to diverge from previously more closely aligned levels. This divergence, in turn, created an obstacle to the even transmission of the European Central Bank (ECB)'s common monetary policy to all parts of the euro area, and to achieving favorable financing conditions for all firms, financial institutions, and households (Lane (2020)).¹ In response to the economic fallout of the pandemic, monetary and fiscal policy makers needed to step in to support the economy. Examples of such support include the ECB's Pandemic Emergency Purchase Programme (PEPP), as announced on 18 March 2020, and the European Union (EU)'s first recovery package, as announced on 23 April 2020.² How large-scale monetary and fiscal support measures impact sovereign yields, and through which channels (risk premia), is of considerable interest to researchers and policy makers. To our knowledge, however, there is currently no workable empirical framework to support such analysis.

To assess in detail how euro area sovereign bond yields were impacted by large-scale monetary and fiscal policies, we would like to know which bond premia are the most dominant at any time.³ This paper therefore addresses the following questions: Which underlying risk premia explain the bulk of the observed variation in sovereign yields across euro area countries during normal times? Which risk premia explain the evolution of sovereign yields following the onset of the Covid-19 pandemic? How successful were monetary and fiscal policy announcements in stabilizing yields? Finally, which channels explain most of the policy announcements' impacts?

As its main contribution, this paper proposes a novel empirical framework to decompose euro area sovereign bond yields into five distinct premia: *i*) expected future short-term risk-free rates

¹Eser, Carmona Amaro, Iacobelli, and Rubens (2012) and ECB (2014) document that private borrowing and lending rates are often calculated from national sovereign yields as the relevant benchmark.

²Similar quantitative easing and fiscal support measures have been implemented by central banks and governments in the United States, the United Kingdom, and Japan, among others, each affecting sovereign bond yields; see e.g. Hartley and Rebucci (2020).

³A vast literature has documented that sovereign bond yields comprise several components. See for example Duffie and Singleton (1999), Greenwood and Vayanos (2010), Manganelli and Wolswijk (2009), Renne and Monfort (2014), De Pooter, Martin, and Pruitt (2018), Krishnamurthy, Nagel, and Vissing-Jorgensen (2018), De Santis (2019), and Schwarz (2019).

and a term premium, *ii*) a default risk premium, *iii*) redenomination risk premium, *iv*) liquidity risk premium, and *v*) a segmentation (convenience) premium. This is non-trivial, as these components are unobserved and can be hard to ascertain. To our knowledge, our framework is the first to allow empirical researchers to robustly decompose sovereign yields into their main components for the largest euro area countries. We illustrate our novel approach for four countries: Germany, France, Italy, and Spain. Together, these countries represent approximately 75% of euro area gross domestic product (GDP) in 2019.⁴

Our starting point is the framework and empirical study of [Krishnamurthy, Nagel, and Vissing-Jorgensen \(2018\)](#), KNV hereafter). KNV estimate latent yield components for Italian, Spanish, and Portuguese yields during the euro area sovereign debt crisis between 2010 and 2012. They do so using an unobserved component model in state space form. They identify the redenomination and default risk premium by relying on corporate bonds that are assumed to have no exposure to their respective sovereign's default risk, and on foreign-law sovereign U.S. dollar (USD)-denominated bonds that are assumed to have only exposure to default risk. Unfortunately, the former are hard-to-impossible to find, and the latter are only available for only one euro area country.⁵ These two drawbacks render their framework infeasible in practice when studying more recent data.

We overhaul the KNV framework in (at least) two major ways. First, we identify the default risk and the redenomination risk premium relying on sovereign credit default swap spreads (CDS) with and without redenomination as a credit event feature. We identify the default risk premium from sovereign euro-denominated CDS spreads, and identify the redenomination risk premium using the so-called ISDA basis. The ISDA basis is the difference between sovereign CDS spreads under International Swaps and Derivatives Association (ISDA) contract terms (CT) CT2014 and CT2003. Following the euro area sovereign debt crisis, and particularly following the Greek credit event on 9 March 2012, the ISDA introduced new contract terms in September 2014. The new terms make a redenomination of debt securities issued by a country leaving the euro area into a new currency much more certain to trigger the new CDS contracts, as long as the redenomination is

⁴See e.g. <https://ec.europa.eu/eurostat/databrowser/view/tec00001/default/table?lang=en>.

⁵To our knowledge, only Italy issues (a few) USD-denominated bonds. Spain has stopped issuing such bonds since 2013, and, France and Germany only issue euro-denominated sovereign debt. Partly owing to these data availability issues, KNV end up relying on a different statistical model specification for each country, complicating the interpretation of their empirical results. These drawbacks render their framework of limited use in policy practice.

deemed detrimental to bondholders. The ISDA 2003 terms remained unchanged, and the CT2003 CDS contracts kept trading, at a discount to the CT2014 CDS contracts. A positive ISDA basis between ISDA CT2014 and CT2003 CDS spreads thus corresponds closely to risk perceptions that a government could, following a default, renounce the euro and redenominate its debt into a new currency at a depreciated exchange rate (see also [Visco \(2018\)](#), [Balduzzi, Brancati, Brianti, and Schiantarelli \(2020\)](#), [Kremens \(2021\)](#) and [Bonaccolto, Borri, and Consiglio \(2021\)](#)).⁶ ISDA 2014 CDS spreads became available in October 2014, and were therefore not available to KNV when they conducted their study.

Second, we modify the KNV framework by including a country-specific liquidity risk premium. Liquidity risk premia have become important for euro area sovereign yields particularly during times of financial turmoil (see e.g. [ECB \(2014\)](#), [Renne and Monfort \(2014\)](#), [Pelizzon et al. \(2016\)](#), [Eser and Schwaab \(2016\)](#), and [De Pooter, Martin, and Pruitt \(2018\)](#)). We identify liquidity risk premia from country-specific liquidity risk factors provided by Tradeweb, a leading electronic trading platform, and from the ten-year KfW-Bund spread. The former is a financial industry standard and a commercially-available measure of point-in-time market illiquidity (see e.g. [De Renzis, Guagliano, and Loiacono \(2018\)](#)), while the latter is a common measure of the price of liquidity risk at any time (see e.g. [ECB \(2009\)](#), [Renne and Monfort \(2014\)](#), and [Schwarz \(2019\)](#)).

Liquidity risk premia are not only of interest per se. Properly accounting for variation in liquidity risk premia also sharpens the interpretation of all other risk premia by removing an omitted variable. For example, turbulent times, such as the onset of the Covid-19 pandemic recession, imply sharply-rising liquidity risk premia, *increasing* yields. If liquidity risk premia are missing, this variation gets pushed into the dynamic residual. This dynamic residual is interpreted as a segmentation/convenience premium in both KNV's and our setup. Turbulent times, however, can also trigger flights-to-safety, pushing convenience premia into more negative territory, *decreasing* yields. Not accounting for liquidity risk premia means conflating both effects, allowing them to potentially offset each other.

We focus our empirical study on sovereign yields at the five-year maturity, owing to data availability and economic reasons discussed in the main text, and provide four main empirical

⁶Caveats apply, and are discussed in the main text.

results.

First, we find that all five yield components can become economically important, in the sense that their magnitudes reach double-digit basis points. The relative importance of each premium varies considerably across countries at any time, as well as within each country over time. For example, default and redenomination risk premia explain most of the Italian and Spanish yield, but are not as important for French and German yields. Instead, French and German yields are mostly explained by expectations about future short-term risk-free rates and a term premium, as well as segmentation premia. Liquidity risk premia increased considerably from before to after the onset of the Covid-19 pandemic, in all four countries.

Second, we document that all euro area sovereign bond yields in our sample contain a pronouncedly negative segmentation premium, which we interpret as a convenience yield. Convenience yields capture the extent to which investors value the non-pecuniary benefits of sovereign bonds (see e.g. [Krishnamurthy and Vissing-Jorgensen \(2012\)](#), [Greenwood, Hanson, and Stein \(2015\)](#), [Del Negro, Giannone, Giannoni, and Tambalotti \(2018\)](#), and [Brunnermeier, Merkel, and Sannikov \(2021\)](#)). Our segmentation premium estimates are most negative for German bonds, suggesting that these bonds are the most highly sought-after asset in our sample. We find that the segmentation premium became more negative following the ECB's PEPP announcement on 18 March 2020 for most countries. Our empirical results are in line with the theoretical predictions (see e.g. [Corradin and Maddaloni \(2020\)](#)) that the segmentation premium is pushed into more negative territory by a central bank purchasing large fractions of outstanding debt, thereby lowering yields (see also [Kojien, Koulischer, Nguyen, and Yogo \(2021\)](#) and [Eser, Lemke, Nyholm, Radde, and Vladu \(2019\)](#)). Examples for such central bank asset purchase programs are the ECB's Public Sector Purchase Programme (PSPP) between March 2015 and June 2022, and the ECB's PEPP between March 2020 and June 2022.⁷

Third, we find that the ECB's PEPP-related unconventional monetary policy announcements

⁷[Kojien, Koulischer, Nguyen, and Yogo \(2021\)](#) and [Eser, Lemke, Nyholm, Radde, and Vladu \(2019\)](#) investigate how the ECB's asset purchase programs work by looking jointly at sovereign yields and institutional investors' changes in bond portfolios. [He, Nagel, and Song \(2022\)](#) document an unusual rise of U.S. Treasury yields relative to overnight indexed swap rates in March 2020, which they refer to as an inconvenience yield. They relate this finding to selling pressure originating from large holders of Treasuries and to regulatory constraints, both affecting primary dealers' balance sheet capacity. In response, the Federal Reserve first offered short-term financing to primary dealers and then started buying significant amounts of Treasuries.

had a beneficial, and economically large, impact on some sovereign yields, benefitting vulnerable countries hard-hit by Covid-19. For example, the ECB's initial PEPP-related announcement on 18 March 2020 led to a large reduction in Italian yields, and to a moderate reduction in Spanish yields. Specifically, five-year Italian yields peaked at 196 bps before the 18 March announcement, and then decreased by 78 bps over a two-day event window. Our statistical model attributes this decrease to a lower default risk premium (by 35 bps), redenomination risk premium (by 14 bps), and segmentation premium (by 16 bps). Spanish yields decreased by 11 bps, owing to a decrease in the segmentation premium (by 10 bps). By contrast, French and German yields increased by 10 and 24 bps, respectively.⁸ As a second example, the ECB expanded its PEPP from €600 billion (bn) to €1,350 bn on 4 June 2020, decreasing Italian yields by an additional 17 bps, mainly owing to a lower default risk premium (by 18 bps) and redenomination risk premium (by 6 bps). Spanish yields decreased by 5 bps, mainly owing to a lower default risk premium (by 5 bps) and redenomination risk premium (by 3 bps).

The asymmetric impact on yields on both 18 March and 4 June 2020 (Italian and Spanish yields down, French and German yields up) is probably attributable to the unprecedented flexibility built into the PEPP, granting the ECB substantial latitude in implementing asset purchases across euro countries, across asset classes, and over time, as deemed appropriate. In particular, within the PEPP, the ECB can deviate from the strict limits set by the ECB's capital key that had guided its net purchases until then.⁹ Previous ECB asset purchase programs, including the PSPP, did not exhibit such flexibility.¹⁰ As a result, the ECB's PEPP may have been understood as a signal of its willingness to provide a backstop to a potential national sovereign debt crisis, wherever it were to occur. In addition, the PEPP intervention might have lowered self-reinforcing tail risks, reducing the market price of risk, and might thus have increased debt sustainability in vulnerable countries (see e.g. [Corsetti and Dedola \(2016\)](#), [Bocola and Dovis \(2019\)](#)).

Fourth, we find that the EU's main fiscal policy announcements also lowered sovereign yields,

⁸These increases can in part be explained by an increase in expected future short-term risk-free rates and term premium. Some market participants may have been expecting a cut in the ECB's deposit facility rate at the time, to counteract the economic fallout of the Covid-19 pandemic, which did not happen. Instead, asset purchases became the preferred monetary policy instrument.

⁹The ECB capital is held by euro area national central banks as shareholders. The capital key is set to reflect the member states' population and GDP.

¹⁰The announcement of the ECB's PSPP, on 22 January 2015, lowered sovereign yields more symmetrically for all four countries in our sample, including France and Germany.

and more uniformly so across countries. At first glance, this is surprising because the EU’s fiscal policies were all expansionary, adding new debt (guaranteed by EU member states) to the EU’s balance sheet. For example, on 23 April 2020, EU heads of state agreed to put together a significant recovery package initially worth €540 bn. The package comprised a €100 bn program to mitigate unemployment risks (SURE), a €200 bn pan-European guarantee fund for loans to non-financial firms through the European Investment Bank (EIB), and a €240 bn crisis support credit line issued by the European Stability Mechanism (ESM) to European governments (see Section 4.4.1 for a discussion). It also announced a recovery fund of a “sufficient magnitude,” with details to be worked out subsequently. Italian, Spanish, French, and German yields decreased by 23, 14, 11, and 5 bps, respectively, upon announcement. Our statistical model attributes the observed 23 bps decrease in Italian yields to lower risk premia across the board: the default risk premium (by 14 bps), the redenomination risk premium (by 3 bps), the segmentation premium (by 2 bps), the liquidity risk premium (by 1 bps), as well as expected future short-term risk-free rates and term premium (by 5 bps). A similar pattern is observed for Spanish yields: all yield components decreased, by approximately proportionate amounts. Later, on 21 July 2020, EU heads of state reached an agreement fleshing out the technical details of its NGEU program. Also this announcement led to a uniform reduction in all yields. Italian, Spanish, French, and German yields then decreased by 8, 2, 3, and 3 bps, respectively. We interpret the uniform decline in yields following EU fiscal policy announcements as potentially reflecting market participants’ assessment that expansive fiscal policy can play an important role in supporting monetary policy aimed at improving the economic outlook (see [Bartsch, Benassy-Quere, Corsetti, and Debrun \(2021\)](#)). In addition, the fiscal policy may have supported vulnerable countries by removing fiscal risk from weakened sovereign budgets onto shared budgets, facilitating lower default risk premia (in line with [Augustin, Sokolovski, Subrahmanyam, and Tomio \(2022\)](#)) and more negative convenience yields ([Jiang, Lustig, Van Nieuwerburgh, and Xiaolan \(2021\)](#)). Finally, the observed strong policy response at the European level may have contributed to lowering national political risks, rationalizing lower redenomination risk premia.

We proceed as follows. Section 2 presents our financial and statistical framework. Section 3 discusses our data. Section 4 presents our main empirical results. Section 5 concludes. A Web Appendix provides further technical and empirical results.

2 Financial framework

2.1 Sovereign yield components and identification

Following KNV, we consider the yield on a euro-denominated sovereign bond issued by country c observed at time t with remaining time-to-maturity τ ,

$$\begin{aligned} r_{t,t+\tau}^c &= \frac{1}{\tau} \int_t^{t+\tau} \mathbb{E}[i_s] ds + \text{Term Premium}_{t,t+\tau} \\ &\quad + \text{Default Risk Premium}_{t,t+\tau}^c + \text{Redenomination Risk Premium}_{t,t+\tau}^c \\ &\quad + \text{Liquidity Risk Premium}_{t,t+\tau}^c + \text{Segmentation Premium}_{t,t+\tau}^c + u_{t,t+\tau}^c. \end{aligned} \quad (1)$$

Equation (1) decomposes the bond yield $r_{t,t+\tau}^c$ into several distinct terms. We now address each in turn. The first and second term (top line) do not depend on the identity of the country (c). We denote by i_t the overnight interest rate at time t on a safe and liquid contract, such as the EONIA overnight rate. The first term thus reflects the expectation hypothesis of interest rates. The second term reflects a term (or duration risk) premium. Longer-term bonds carry interest rate risk, and therefore contain a term premium to compensate investors for bearing that risk. As in KNV, we do not separately identify the first two terms. Instead, we identify both terms as one latent component, from EONIA OIS rates.

The remaining four premia are country-specific, and unobserved, and therefore need to be inferred from additional financial instruments. We depart from KNV's analysis by using a different set of financial instruments to identify country-specific default, redenomination, and liquidity risk premia. Web Appendix A provides two tables that contrast KNV's approach with our approach.

The third term, Default Risk Premium $_{t,t+\tau}^c$, denotes the premium investors demand for bearing default risk. In bond pricing models, this premium is driven by the probability of default, the loss-given-default, and the economic market-price-of-risk associated with default states (see e.g. [Duffie and Singleton \(1999\)](#)). We identify the default risk premium based on sovereign CDS spreads denominated in euro under ISDA 2003 contract terms (CT2003). Such CDS contracts protect the insurance owner from a sovereign default, but not necessarily from a redenomination of sovereign debt into another currency (as explained below). In addition, such CT2003 CDS contracts denomi-

nated in euro do not protect the protection buyer from a devaluation of the euro should a sovereign credit event occur. In place of CDS spreads, KNV use USD-denominated sovereign bonds to identify the default risk premium, assuming that these cannot be redenominated through changes in domestic law (see [Chamon, Schumacher, and Trebesch \(2018\)](#)). KNV argue that the yields of these bonds, when adjusted by the USD OIS rate for the corresponding maturity, should contain the default risk premium.

A crippling limitation of KNV’s identification approach is that very few euro area countries actually issue USD-denominated bonds. We observe that, for the four countries in our sample, only Italy has two USD-denominated bonds outstanding for which daily price quotes are available. Spain has ceased issuing USD-denominated sovereign debt since 2012, and, to our knowledge, Germany and France never have.¹¹ As a result, KNV’s decomposition approach is not feasible for the largest euro area countries, particularly Germany and France. Web Appendix B attempts to tentatively compare the two approaches for Italian data. The two measures of the default risk premium are correlated, with a correlation coefficient of 0.83. The USD-denominated bond spread is larger on average than the CT2003 CDS spread, thus potentially overestimating the default risk premium. As acknowledged by KNV, the USD-denominated bond spread can embed other premia. For example, euro area sovereign USD-denominated bonds are substantially less liquid than euro-denominated ones. Finally, Web Appendix B reports that the Italian EUR CT2003 CDS contract is more liquid than the two USD-denominated sovereign bonds (with average bid-ask spreads of approximately 7.6 bps vs. 10.9 and 11.6 bps, respectively).

If investors are concerned that, in addition to defaulting on (all or parts of) its obligations, the government will also re-denominate its debt into a new local currency at a depreciated exchange rate, effectively exiting the euro area, then investors will demand a positive Redenomination Risk Premium $^c_{t,t+\tau}$ (our fourth term; see also [ECB \(2014\)](#), [De Santis \(2019\)](#), [Kremens \(2021\)](#) and [Bonaccolto, Borri, and Consiglio \(2021\)](#)). We identify the redenomination risk premium from the difference between five-year sovereign CDS spreads quoted in USD under ISDA CT2014 and CT2003 terms. This difference is also known as the ISDA basis among central bankers and academics (see e.g. [Visco \(2018\)](#), [Balduzzi, Brancati, Brianti, and Schiantarelli \(2020\)](#), [Kremens \(2021\)](#) and

¹¹We used the ECB’s Centralized Security Database (CSDB) to assess the availability of USD-denominated bonds issued by the central government. The CSDB contains all active debt securities issued by euro area issuers.

Bonaccolto, Borri, and Consiglio (2021)). In 2014, following the euro area sovereign debt crisis and the Greek credit event on 9 March 2012, the ISDA introduced new credit terms making a redenomination of debt much more likely to trigger the revamped CDS contracts. We here summarize the main distinctions, and refer to Web Appendix C for details about the differences between the ISDA 2014 and 2003 credit terms. The ISDA 2003 terms contain fine print that effectively removes protection against redenomination risk for countries belonging to the Group of 7 (G7) countries, including France, Germany, and Italy, as well as OECD countries with a AAA/Aaa rating. The ISDA 2014 terms, by contrast, removed any reference to G7 membership. The ISDA 2014 terms also removed the requirement that a restructuring event would be triggered “*only in the case of a deterioration in the creditworthiness or financial condition of the sovereign [that exits the euro]*”, which could be difficult to prove in practice. Finally, the ISDA 2014 terms remove discretion by introducing an explicit rule: the restructuring credit event is triggered by *any* redenomination into a new currency, as long as a haircut or market loss occurs to existing bondholders. This is a much more straightforward criterion, and easier to ascertain. Therefore, a positive ISDA basis between ISDA 2014 and ISDA 2003 CDS spreads, when quoted in the same currency¹² and referencing the same euro area sovereign, is indicative of a perceived risk that the sovereign could renounce the euro and subsequently redenominate its debt.¹³

Alternative measures of redenomination risk could also be used within our statistical model as introduced in Section 2.2 below. As a first example, KNV infer redenomination risk by relying on corporate bond yields and corporate CDS spreads. They argue that both the yield of euro-denominated local-law sovereign bonds and euro-denominated local-law corporate bonds of the same maturity should be equally affected by redenomination risk. As a result, the yields of the euro-denominated local-law corporate bonds, when adjusted by the euro OIS rate, and the corporate CDS spread for the corresponding maturity, should both contain the redenomination risk premium. A

¹²The ISDA basis computed from USD-denominated CDS spreads could also reflect a potential depreciation of the euro against the USD in the event of a return to a national currency of the underlying sovereign reference entity. The alternative would be to compute the ISDA basis on euro-denominated CDS spreads. We prefer the ISDA basis obtained from USD-denominated CDS spreads because of the higher market liquidity of the underlying contracts. In any case, the difference between the USD and euro-denominated ISDA basis is small in our sample: 2 bps for France on average, 1 bps for Germany, 10 bps for Italy, and 5 bps for Spain.

¹³Investors may not wish to continue to trade “old” ISDA 2003 CDS contracts indefinitely into the future. There is some reason to be hopeful in this regard, however, as both 2014 and 2003 contracts are needed to hedge G7-country redenomination risk in isolation. Both CDS contracts are reasonably liquid; see Section 3.

major limitation here is that the corporate bonds should be issued by a non-financial corporation for which the default risk is very low and, crucially, not linked to the default risk of the sovereign. Such bonds are difficult to find, and their yields are in any case subject to company-specific pricing effects. Similarly, euro-denominated single-name CDS referencing euro area non-financial corporations are rare and illiquid. Second, [De Santis \(2019\)](#)'s measure of redenomination risk could be used. This measure is based on the difference between a country's Quanto CDS spread and the Quanto CDS spread for Germany. This measure, however, risks conflating states of the world with default scenarios that involve and do not involve debt redenomination,¹⁴ and is not available for Germany.

A Liquidity Risk Premium $_{t,t+\tau}^c$ (fifth term) arises from the potential difficulty that investors may have in selling the bond before its redemption. Such difficulties typically arise in distressed market conditions, when it is harder to find a counterparty for a trade. While liquidity risk premia are typically small in deep sovereign bond markets, they became economically significant during the global financial crisis between 2008 and 2010 and the euro area sovereign debt crisis between 2010 and 2012 (see e.g. [Renne and Monfort \(2014\)](#), [Pelizzon, Subrahmanyam, Tomio, and Uno \(2016\)](#) and [De Pooter, Martin, and Pruitt \(2018\)](#)). We identify the liquidity risk premium as $LRP_t^c = \beta_L \times (\text{KfW-Bund spread}_t \times \text{TradeWeb liquidity}_t^c)^{\frac{1}{2}}$, where β_L is a coefficient to be estimated, and the term in round brackets is the geometric average of the ten-year KfW-Bund spread on the one hand and a country- and market-segment-specific proprietary liquidity measure provided by Tradeweb markets on the other hand. The scaling by β_L is necessary to map the units of the liquidity factor into percentage points (yields). The KfW-Bund spread is a common measure of the price of liquidity risk (see e.g. [ECB \(2009\)](#) and [Renne and Monfort \(2014\)](#)). Tradeweb liquidity indicators are commercially available and measure the point-in-time market illiquidity of a small basket of similar bonds relative to ten-year German sovereign bonds (see e.g. [De Renzis, Guagliano, and Loiacono \(2018\)](#), and [Web Appendix D](#) for time series data plots). Ten-year Bunds are considered the most liquid bond in the euro area, and are therefore a natural point of comparison.¹⁵

¹⁴Quanto CDS spreads are differences in CDS spreads associated with the same reference entity but denominated in different currencies (e.g., USD and euro). Quanto CDS spreads reflect the expected depreciation of the exchange rate in the event that CDSs are triggered (a sovereign default) and the covariance between the exchange rate and default risk (see [Augustin, Chernov, and Song \(2020\)](#) and [Monfort, Pegoraro, Renne, and Roussellet \(2021\)](#)).

¹⁵Other, more involved, specifications for the liquidity risk premium are, of course, possible. For example, the geometric average could be tilted towards the country-specific (Tradeweb) measurement at the expense of the common

We identify a Segmentation Premium $u_{t,t+\tau}^c$ as the remaining persistent component (sixth term). It is called a segmentation premium because it can arise with some limits to arbitrage (see e.g. [Gromb and Vayanos \(2002\)](#), [Duffie \(2010\)](#)) and in the presence of a large buyer such as a central bank ([Corradin and Maddaloni \(2020\)](#)). In [Gromb and Vayanos \(2002\)](#)'s setting, the bond price reflects the valuation of only a subset of investors because some investors are constrained from fully participating in the market, for example owing to country-specific regulatory hurdles or home biases. The bond yield can then embed a segmentation premium relative to its frictionless price. This segmentation premium is negative if the first set of investors benefit from owning the bond above and beyond the utility they derive from receiving its cash flows ([Krishnamurthy and Vissing-Jorgensen \(2012\)](#), [Del Negro, Giannone, Giannoni, and Tambalotti \(2017\)](#), and [Brunnermeier, Merkel, and Sannikov \(2021\)](#)). The segmentation premium can therefore also be referred to as a convenience yield. In the euro area setting, investors could be willing to pay a premium to hold government bonds instead of central bank reserves, particularly when large-scale central bank asset purchase programs are active and the latter are subject to penalty (negative) interest rates. In addition, current banking sector liquidity regulations compel banks to hold sovereign bonds, as so-called high-quality liquid assets.

Finally, independently-distributed noise terms $u_{t,t+\tau}^c$ capture one-off effects. Such one-off effects are transitory (non-autocorrelated), and typically small. Trading around key policy announcements can lead to transitory market pressures related to dealer inventory effects (see e.g. [Greenwood and Vayanos \(2010\)](#), [Eser, Carmona Amaro, Iacobelli, and Rubens \(2012\)](#), and [Eser and Schwaab \(2016\)](#)). In addition, one-off effects could be present when a newly-issued bond becomes the new benchmark bond.

We focus our analysis on the five-year maturity throughout this paper for two main reasons. First, the sovereign CDS contracts used to identify default and redenomination risk premia are the most liquid at this maturity. Second, the weighted average maturity of the outstanding sovereign debt for the euro area countries in our sample is approximately six years. This is closer to the five year maturity than, say, the two or ten year maturity, and therefore the most relevant economically.

(KfW-Bund spread) measurement. Experimenting with different weighting schemes does not affect the empirical results presented in Section 4 in a major way. Taking the geometric (rather than arithmetic) average takes advantage of the fact that both liquidity measurements are strictly positive at all times, and that the geometric average takes slightly higher values when both input measures are high simultaneously.

2.2 Statistical model

This section presents our statistical model in state space form. The measurement and state equations are given, respectively, by

$$y_t = Z\alpha_t + \epsilon_t, \quad \epsilon_t \sim \text{i.d.}(0, H_t), \quad (2)$$

$$\alpha_{t+1} = d + T\alpha_t + \eta_t, \quad \eta_t \sim \text{i.d.}(0, Q), \quad (3)$$

where y_t is the data vector, $t = 1, \dots, T$, Z is a loading matrix, α_t is the state vector, ϵ_t is the measurement error, H_t is the measurement error covariance matrix, d is a vector of state equation intercepts, T is the state transition matrix, η_t is the state equation error, and Q is the state equation error covariance matrix. Matrices H_t and Q are symmetric and positive definite. The error terms ϵ_t and η_t are assumed to have zero mean, finite second moments, and to be independent at all leads and lags, but not necessarily normally distributed.¹⁶

The $[7 \times 1]$ -dimensional data vector y_t contains bond yields, CDS spreads, and a liquidity risk factor. The $[6 \times 1]$ -dimensional state vector α_t contains the unobserved risk premia of interest. Section 2.1 explained in detail which data in y_t are used to identify which risk premium in α_t , given by

$$y_t = \begin{bmatrix} 5y \text{ benchmark bond yield, Bloomberg} \\ 5y \text{ benchmark bond yield, Reuters} \\ 5y \text{ OIS EUR rate} \\ 5y \text{ CDS EUR ISDA CT2003} \\ 5y \text{ CDS USD ISDA CT2014} \\ 5y \text{ CDS USD ISDA CT2003} \\ 5y \text{ Tradeweb liquidity indicator} \\ \times \text{KfW-Bund spread} \end{bmatrix}, \quad \alpha_t = \begin{bmatrix} \text{expected future average short-rate} \\ \text{and term premium} \\ \text{default risk premium} \\ \text{redenomination risk premium} \\ \text{filtered CDS USD CT2003} \\ \text{liquidity risk premium} \\ \text{segmentation premium} \end{bmatrix};$$

see also Section 3 for details on the data.

¹⁶The Kalman filtering and smoothing recursions can provide optimal (i.e., minimum-variance linear unbiased) estimates of the state vector α_t even if ϵ_t and η_t are not normally distributed; see e.g. Durbin and Koopman (2001, Ch. 4.3).

The loading matrix Z in (2) relates the observations y_t to the latent risk premia in α_t . This correspondence allows us to identify the latent risk premia from the data.¹⁷ The measurement error variance matrix H_t can be made time-varying as suggested by KNV. Both matrices are then given by

$$Z = \begin{bmatrix} 1 & \beta_D & \beta_R & 0 & \beta_L & 1 \\ 1 & \beta_D & \beta_R & 0 & \beta_L & 1 \\ 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \end{bmatrix}, \quad H_t = \begin{bmatrix} \gamma_1^2 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & \gamma_2^2 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & \gamma_3^2 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & \gamma_4^2 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & \gamma_5^2 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & \gamma_6^2 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & \gamma_7^2 \end{bmatrix} \cdot \begin{pmatrix} 1 \\ 1 \\ 1 \\ y_{4,t-1} \\ y_{5,t-1} \\ y_{6,t-1} \\ y_{7,t-1} \end{pmatrix},$$

where $\beta = (\beta_D, \beta_R, \beta_L)'$ and $\gamma = (\gamma_1, \dots, \gamma_7)'$ collect deterministic loading and standard deviation parameters.¹⁸ The time-varying covariance matrix H_t allows measurement errors to be more dispersed if the lagged data are higher. This specification requires the respective elements of y_{t-1} to be non-negative, however. While CDS spreads and liquidity measures are always non-negative, sovereign yields and euro area OIS rates are not. We therefore use time-varying measurement error variances only for the CDS spreads and the liquidity measure, and use time-invariant ones for sovereign yields and OIS rates.¹⁹

The state equation system matrices are given by d , T , and Q . An important special case is given by $d = 0$ and $T = I_6$, where I_6 denotes the $[6 \times 6]$ identity matrix. In this case, each risk premium evolves as a random walk, in line with what could be expected from assets trading in

¹⁷The fourth element of α_t (“filtered CDS USD CT2003”) is not of primary interest. Including it permits our model to obtain the ISDA basis as the difference between the *filtered* CDS USD CT2014 spread and *filtered* CDS USD CT2003 spread; see the fifth row of matrix Z below. Each CDS spread $y_{4,t}$, $y_{5,t}$, and $y_{6,t}$ is subject to its own measurement error.

¹⁸The default risk premium $\alpha_{2,t}$ could, in principle, also be made sensitive to the two CDS spreads $y_{5,t}$ and $y_{6,t}$. We do not do so because the latter two CDS contracts also insure against a devaluation of the euro against the U.S. dollar should a sovereign credit event occur; see Section 2.1. These contract spreads are thus sensitive to risks beyond “pure” default risk.

¹⁹The empirical results reported in Section 4 are not particularly sensitive to adopting an entirely time-invariant measurement error variance matrix H_t because the estimated measurement errors are small. Our results are also not sensitive to making all diagonal elements of H_t time-varying, using an exponential link function for sovereign yields and OIS rates. If only a part of H_t is time-varying, then the lagged data y_{t-1} can be re-scaled to a unit mean to facilitate the interpretation of all elements of γ as standard deviation parameters. We do so for our empirical work in Section 4.

approximately efficient financial markets. The random walk specification for latent components is a common choice in the applied literature using time-varying parameter models (see e.g. [Primiceri \(2005\)](#), [Eickmeier, Lemke, and Marcellino \(2015\)](#), [Krishnamurthy, Nagel, and Vissing-Jorgensen \(2018\)](#), and references therein). Each latent component can then evolve flexibly, conditional on the data at hand, to match a multitude of potential patterns. The state error variance matrix is given by $Q = \mathbb{E}[\eta_t \eta_t'] = DCD$, where $D = \text{diag}(\delta_1, \dots, \delta_6)$ is a diagonal matrix containing state error volatility parameters $\delta = (\delta_1, \dots, \delta_6)'$, and C is a symmetric and positive-definite correlation matrix with ones on the diagonal and correlation parameters $\rho = (\rho_1, \dots, \rho_{15})'$ off the diagonal. Non-zero on-diagonal elements in D imply time-variation in risk premia. Non-zero off-diagonal elements in C allow for contemporaneous correlation between the state errors η_t .

The state vector α_t is initialized with a diffuse prior distribution.²⁰ This reflects the unit random walk character of the unobserved components in α_t (see e.g. [Durbin and Koopman \(2001, Ch. 5.2\)](#)), in line with KNV's approach.

2.3 Parameter and state vector estimation

All deterministic parameters are stacked into $\psi = (\beta', \gamma', \delta', \rho)'$ to be estimated numerically by (quasi-)maximum likelihood methods (see [Hamilton \(1994, Ch. 13.4\)](#) and [Durbin and Koopman \(2001, Ch. 7\)](#)), or to be calibrated to fixed values based on non-sample information (see Section 4.1 below). For parameter estimation, we assume that the measurement and state errors are normally distributed, and maximize the average (or sum) over all four country-specific log-likelihoods. This implies that the loading, volatility, and correlation parameters in ψ are restricted to be the same across countries. The state space of each model remains $[6 \times 1]$ -dimensional. In this way, a large amount of time series data is brought to bear for inference on ψ , facilitating precise estimates and a robust convergence to the global maximum. The pooling of country-specific parameters is advantageous because, for example, our German or French data are fairly uninformative about default, redenomination, and liquidity risk premia. The pooling restriction does not imply that the estimated random walk components in α_t are in any way similar across countries; see Section

²⁰This means that, roughly, $\alpha_1 \sim N(0, \kappa \cdot I_6)$ with $\kappa \rightarrow \infty$. [Koopman \(1997\)](#) provides exact Kalman filtering and smoothing recursions for non-stationary time series models with diffuse initial conditions, which we use. State initialization with a finite $\kappa = 10$, however, lead to virtually identical parameter and state vector estimates.

4. Full-sample estimates of the state vector $\hat{\alpha}_t = \mathbb{E}[\alpha_t | y_1, \dots, y_T; \psi^{(\text{common})}]$ are obtained from the Kalman filter and smoother as in KNV.²¹

Interestingly, the model parameters can alternatively be estimated using simple least squares regression methods. The loading parameters β could be estimated by a (restricted) regression of sovereign yields on the other financial instruments' rates. Estimates of the state vector α_t , and of the remaining parameters in ψ , could then be obtained in a second step conditional on β . Web Appendix E provides the details of such a regression-based approach to decomposing euro area sovereign yields, and demonstrates that the empirical outcomes are very similar.²²

While slightly more involved, Kalman filtering is our preferred estimation approach, however, for three reasons. First, all variables in y_t could be subject to at least some measurement error. If so, errors-in-variables (see e.g. Davidson and MacKinnon (2004, Ch. 5.1)) could imply that the least squares estimator is subject to a bias of unknown sign and magnitude. By contrast, measurement errors are explicitly taken into account in a filtering approach, leading to reliable, one-step, and consistent parameter and state vector estimates. Second, the filtering approach allows us to put full-sample standard error bands around each filtered component. Finally, the regression-based approach implicitly pushes the segmentation premium into the regression residual, effectively merging the last two terms in Equation (1). This decreases the precision with which the segmentation premium is measured.

3 Data

We focus on Germany (DE), France (FR), Italy (IT), and Spain (ES) because they constitute the four largest euro area countries, representing approximately three quarters of euro area GDP at any time. Five-year sovereign benchmark bond yields for Germany, France, Italy, and Spain are obtained from Bloomberg and Thomson Reuters. Bloomberg and Thomson Reuters data can differ

²¹We omitted country superscripts to indicate country data in (2) – (3) for compactness. To clarify, when estimating French yield components, say, the state vector estimate is $\hat{\alpha}_t^{\text{FR}} = \mathbb{E}[\alpha_t^{\text{FR}} | y_1^{\text{FR}}, \dots, y_T^{\text{FR}}; \psi]$. This quantity does not necessarily coincide with $\hat{\alpha}_t^{\text{FR}} = \mathbb{E}[\alpha_t^{\text{FR}} | y_1^{\text{DE}}, \dots, y_T^{\text{DE}}, y_1^{\text{FR}}, \dots, y_T^{\text{FR}}, y_1^{\text{ES}}, \dots, y_T^{\text{ES}}, y_1^{\text{IT}}, \dots, y_T^{\text{IT}}; \psi]$ that a much larger, unwieldy, model (that we do not estimate) would produce. In practice, if the measurement error variances are small, then each state vector is almost perfectly observed, and the smoothing recursions are only minimally influenced by other countries' data.

²²The least squares approach does not pool over γ , δ , and ρ parameters. The fact that the empirical outcomes are close suggests that pooling these parameters across countries is not restrictive.

at times in their assessment which bond (ISIN) is the relevant five-year benchmark bond to track.²³

Sovereign CDS spreads are obtained from Thomson Reuters between January 2015 and April 2018 and Credit Market Analysis (CMA) DataVision from May 2018 onwards. Thomson Reuters takes CDS spread quotes each day from several contributors and combines them into end-of-day data. CMA collects its data from a slightly larger consortium of hedge funds, asset managers, and major investment banks. Thus, we prefer the CMA data for our study at hand, but splice them with Thomson Reuters data for the earlier years for data availability reasons. CMA reports bid, ask, and mid quotes allowing us to cross-check the CDS market liquidity. The average bid-ask spread for the five-year CT2014 CDS is 6 bps for Italy, and 5 bps for Spain, 3 bps for France, and 3 bps for Germany. The average bid-ask spread for the five-year CT2003 CDS is 8 bps for Italy, and 7 bps for Spain, 4 bps for France, and 4 bps for Germany. As a result, the 2003 contracts are only marginally less liquid than their 2014 counterparts.

Our country-specific liquidity risk factors combine data from Tradeweb and Bloomberg. Tradeweb liquidity indicators use executed prices and trade volumes collected from Tradeweb’s online trading platforms,²⁴ comparing execution prices to previously-indicated mid prices for a given security. The distance between execution and mid prices is used to compute a bond market (il)liquidity measure: execution prices further away from mid prices indicate a less liquid market. Tradeweb liquidity measures are available at different maturity buckets. We consider the 2 – 5.5 year bucket for our sample of Italian, Spanish, French and German sovereign bonds.

Web Appendix F reports unit-root and cointegration testing outcomes for our input data at hand. Most of our input data is non-stationary, particularly most sovereign yields and CDS spreads.

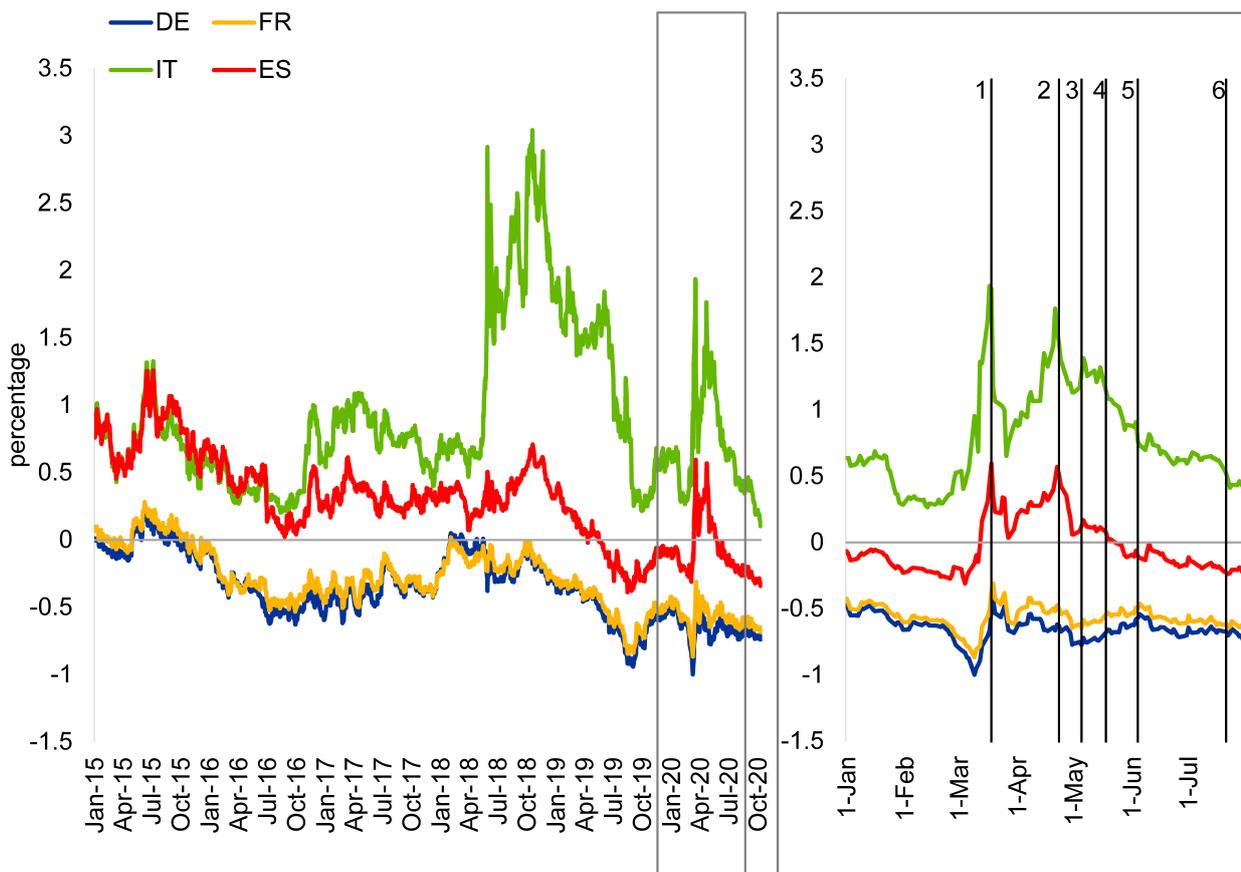
Figure 1 plots our sample of five-year sovereign bond yields between 2 January 2015 and 9 October 2020. The figure suggests a gradual downward trend for all countries. A potential contributor to this trend may have been purchases of euro area sovereign bonds within the ECB’s PSPP that started in March 2015. The severity of the economic and financial implications from the Covid-19 pandemic has become increasingly apparent since February 2020 (see the right panel of Figure 1). All four sovereign yields stabilized, however, from May 2020 onwards. We discuss the monetary

²³Including both data sources into our statistical model allows us to be robust to such differences. Replacing the two bond yield measurements with their average value leads to comparable parameter and state vector estimates for our data at hand.

²⁴See www.tradeweb.com for details on Tradeweb’s electronic marketplaces.

Figure 1: Sovereign bond yields and major policy events

Yields-to-maturity of five-year sovereign benchmark bonds for France (FR), Germany (DE), Italy (IT) and Spain (ES). Data are daily between 2 January 2015 and 9 October 2020. The right panel magnifies the period between 31 January 2020 and 31 July 2020. Vertical time lines indicate the following policy announcements: 1) On 18 March 2020 the ECB announced its Pandemic Emergency Purchase Programme (PEPP); 2) on 23 April 2020 the EU announced a recovery package worth €540 bn; 3) on 5 May 2020 the German Federal Constitutional Court addressed the compatibility of the Public Sector Asset Purchase Program (PSPP) launched by the ECB in March 2015 with German constitutional law; 4) on 18 May 2020 German Chancellor Angela Merkel and French President Emmanuel Macron announced their joint proposal for a €500 bn European recovery fund; 5) on 4 June 2020 the ECB announced the expansion of the PEPP from €750 bn to €1,350 bn; and 6) on 21 July 2020 EU leaders reached an agreement on details regarding its NGEU program.



and fiscal policy announcements that contributed to stabilizing sovereign yields in Section 4.4.1 below.

4 Empirical results

Our empirical study is structured around five interrelated questions. Which underlying risk premia explain the bulk of the observed variation in euro area sovereign bond yields? How do these premia vary across countries and time? Which risk premia explain the observed divergence of sovereign yields at the onset of the Covid-19 pandemic recession? How successful were monetary and fiscal policy announcements in stabilizing yields in the first half of 2020? Finally, which “channels” (yield components) explain most of the policy announcements’ impacts?

4.1 Model specification and parameter estimates

This section discusses model choice and the resulting parameter estimates. We first discuss parameter restrictions that we use when fitting the statistical model proposed in Section 2.2 to the data as discussed in Section 3 and Web Appendix D. We then turn to the parameter estimates.

We chose the loading coefficients $\beta_D = \beta_R = 1$ following our discussion in Section 2.1 and in line with preliminary data analyses. This implies that the default risk premium is approximately equal to the CDS EUR CT2003 rate, and that the redenomination premium is approximately equal to the ISDA basis (the difference between CT2014 and CT2003 CDS spreads; see Section 2.1 for details). The equality is approximate since all yields and CDS spreads can be subject to measurement error. Second, we chose $\gamma_1 = \gamma_2$, implying that the yield data obtained from Bloomberg and Thomson/Reuters are equally informative. This implies that the model seeks to fit the midpoint between the two yield measurements, facilitating the economic interpretation of the estimation outcomes. We also set $\gamma_3 = 0$. This choice implies that the first, euro-area-wide component (the expected future short-term risk-free rates and term premium) is numerically identical for all four countries in our sample. We chose $\gamma_4 = \gamma_5 = \gamma_6 = \gamma_7 = 4$ bps. These values are approximately in line with the observed bid-ask spreads for CDS spreads and German KfW bonds, but the exact calibration is immaterial, as other choices yield similar risk premium estimates.²⁵ Third, we simplify the state equation dynamics by choosing $d = 0$ and $T = I_6$, implying that each

²⁵The empirical results discussed in Sections 4.2 – 4.4 remain virtually identical if, say, $\gamma_4 = \gamma_5 = \gamma_6 = \gamma_7 = 8$ bps is chosen instead. If estimated, these measurement error variance parameters converge to zero, increasing the noise in the two residual terms (the segmentation premium and the one-off effects); there are no material effects on the other parameters.

risk premium component evolves as a random walk.²⁶ The off-diagonal elements of the state error correlation matrix C are not restricted in our baseline specification. This allows the innovation terms to all risk premia (η_t in Equation (3)) to be mutually correlated. Using this specification, we combine model parsimony with the ability to study the impact of a rich set of monetary and fiscal policy announcements on sovereign yields empirically given all the financial data at hand.

We now discuss our parameter estimates. All estimates discussed below are statistically significant at the 5% level.

The state error standard deviation parameters δ indicate how volatile each risk premium component is. The δ parameters are estimated to be, in ascending order, 0.8 bps (for the liquidity risk premium), 1.0 bps (redenomination risk premium), 1.8 bps (segmentation premium), 1.9 bps (default risk premium), and 2.1 bps (expected future short-term risk free rates and term premium). All δ parameters are estimated with small standard errors (below 1 bps). These estimates suggest pronounced time series variation for all risk premia.²⁷ The yield measurement error standard deviation parameter γ_1 is estimated at 3.6 bps, implying a moderate-to-small role for the noise term in (1). The loading on the country-specific liquidity risk factor (β_L) is estimated at approximately 0.25, implying country-specific liquidity risk premium estimates that are, on average over time, in line with those reported in [Renne and Monfort \(2014\)](#) and [De Pooter, Martin, and Pruitt \(2018\)](#).

Likelihood-based information criteria (AIC, BIC) prefer a full specification of the state covariance matrix Q over a more parsimonious diagonal specification.²⁸ Seven statistically significant correlation estimates in C point to, in descending absolute magnitude, plausible correlations between the innovations to the default and redenomination risk premium (0.58), redenomination and liquidity risk premium (0.27), default and liquidity risk premium (0.23), redenomination risk premium and segmentation premium (-0.21), expected rates and redenomination risk premium

²⁶We experimented with a model specification that uses an unrestricted vector of intercepts $d \neq 0$ and an unrestricted diagonal transition matrix $T = \text{diag}(t_1, \dots, t_6) \neq I_6$. If the additional (twelve) coefficients are estimated, then $T \approx I_6$, and $d \approx 0$, suggesting that random walks without drift are a sensible choice for our data at hand. The minimum estimated diagonal element in T is $0.992 \approx 1$, and the maximum estimated entry in d is $0.003 \approx 0$. The difference in maximal log-likelihood is small, suggesting that the joint restriction $d = 0$ and $T = I_6$ is appropriate. In addition, model selection criteria (AIC, BIC) prefer the more parsimonious specification.

²⁷If $\delta_i = 0$, then the corresponding risk premium would be constant; see (3). Standard t- and LR-tests are not appropriate for these parameters ([Andrews and Ploberger \(1994\)](#)), but likelihood-based information criteria (AIC, BIC) strongly prefer a model specification with $\delta > 0$.

²⁸Restricting Q to be diagonal is costly in terms of the model's log-likelihood fit, but is of little consequence for the empirical results as discussed in Sections 4.2 – 4.4, given that most measurement errors are small (in the single digit basis points) and each country's state vector is thus almost fully observed.

(-0.14), expected rates and default risk premium (-0.13), and expected rates and liquidity risk premium (-0.09). Overall, the moderate-to-small magnitudes, and intuitive signs, of the correlation estimates suggest that each risk premium captures a distinct source of economic risk.

The bond pricing errors implied by our fitted statistical model are small and visibly close to white noise processes. Figure F.1 in Web Appendix F.2 presents the respective time series. The mean absolute pricing error is at 1.5 bps, 1.0 bps, 0.6 bps, and 0.5 bps for IT, ES, FR, and DE bonds, respectively. We conclude that our statistical model is able to closely fit the sovereign yields, and is appropriate for the data at hand.

Finally, a country's risk premia could, in principle, be subject to a nonlinear dependence structure. In particular, euro area sovereign yields and CDS spreads could be subject to multiple equilibria, as discussed by e.g. Calvo (1988), Corsetti and Dedola (2016), and Bocola and Dovis (2019). We leave such a study for future research, but note that our sample covers the time following the introduction of the ECB's Outright Monetary Purchases program in 2012, which is widely credited for having reduced the risk of self-fulfilling bad equilibria; see ECB (2014) and Bocola and Dovis (2019).

4.2 Risk premia before the Covid-19 pandemic

This section discusses longer-term developments in euro area sovereign yields, with a focus on which underlying premia explain most of the observed variation. We first discuss the variation in risk premia across countries and over time. We then turn to discussing redenomination risk and segmentation premia in more detail.

Figures 2 – 3 plot five-year sovereign bond yields for Italy, Spain, France, and Germany, along with full-sample estimates of each bond's default risk, redenomination risk, liquidity risk, and segmentation premium. Table 1 provides summary statistics (sample means and standard deviations) for all five risk premium estimates. Our empirical results are presented and discussed in the order that each country's yields were negatively affected by the Covid-19 pandemic (Italy first, Germany last).

All five above-mentioned risk premia are economically important, in the sense that their magnitudes lie in the double-digit basis points at least once in our sample. Their relative importance,

however, varies considerably over time and across countries. As a key finding, default and redenomination risk premia explain the bulk of variation in Italian and Spanish yields, but are less important for French and German yields. This is immediately visible: the predominant colours in Figure 2 are red and brown (for default and redenomination risk premia), while the predominant colours in Figure 3 are green and beige (for expected future short-term risk-free rates and term premium, and the segmentation premium).

Figure 2 suggests that default and redenomination risk premia are the main drivers of Italian bond yields during our sample. This is intuitive, given a relatively high level of outstanding sovereign debt (at approximately 138% of GDP at the end of 2019, compared to approximately 86% for the euro area), and a relatively low average annual nominal GDP growth rate (of 1.1% between 2010 and 2019, compared to 2.4% for the euro area over the same period). This finding is also in line with the evidence provided by KNV that Italian yields can be explained to a large extent by default and redenomination risk premia (although their study covers a different period, January 2010 to January 2013). Liquidity risk premia are lowest on average in Germany, and highest in Italy, with France and Spain as intermediate cases; see Table 1. This is in line with [Renne and Monfort \(2014\)](#) and [De Pooter, Martin, and Pruitt \(2018\)](#). Finally, all countries exhibit an economically significant negative segmentation premium.

Continuing with Figure 2 and Italian yields, significant fluctuations can occur in redenomination risk premia as a result of domestic political developments. Specifically, the redenomination risk premium displays a pronounced spike in mid-2018, ultimately reaching values of approximately 90 bps. The upward jump coincides with the start of a coalition government between the Lega and Movimento Cinque Stelle ([Balduzzi, Brancati, Brianti, and Schiantarelli \(2020\)](#), [Tholl, Schwarzbach, Pittalis, and von Mettenheim \(2020\)](#)). This coalition government was widely perceived as in contempt of the European Stability and Growth Pact and fundamentally euro-sceptical. In mid-2018 the redenomination risk premium accounts for approximately one third of the Italian five-year yield.

The bottom panel of Figure 2 suggests that, overall, Spanish yields share common dynamics with Italian yields, in the sense that both tend to rise and fall together. Time-variation in the redenomination risk premium, however, plays a less pronounced role for Spanish yields than for Italian yields.

Figure 2: Yield decomposition results for Italy (top) and Spain (bottom)

Yield decomposition results for Italian and Spanish five-year sovereign benchmark bonds. Data are daily between 2 January 2015 and 9 October 2020. The right panel magnifies the period between 31 January and 31 July 2020. The rightmost bars visualize the relative importance of each risk premium between 31 January and 31 July 2020. The reported percentages refer to the share of each component in the sum over (the absolute value of) all risk premia, averaged over all trading days between 31 January and 31 July 2020.

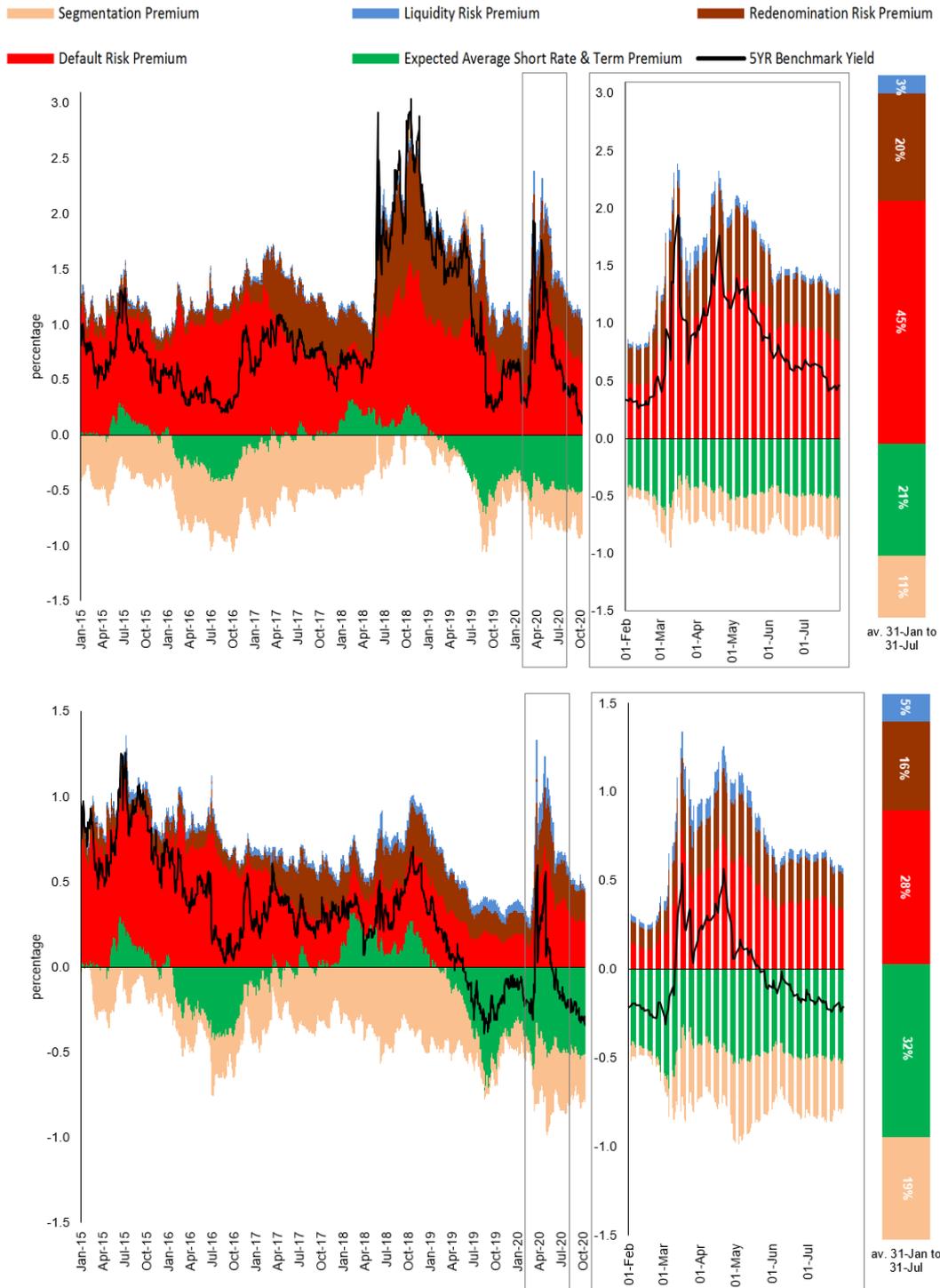


Figure 3: Yield decomposition results for France (top) and Germany (bottom)

Yield decomposition results for French and German five-year sovereign benchmark bonds. Data are daily between 2 January 2015 and 9 October 2020. The right panel magnifies the period between 31 January and 31 July 2020. The rightmost bars visualize the relative importance of each risk premium between 31 January and 31 July 2020. The reported percentages refer to the share of each component in the sum over (the absolute value of) all risk premia, averaged over all trading days between 31 January and 31 July 2020.

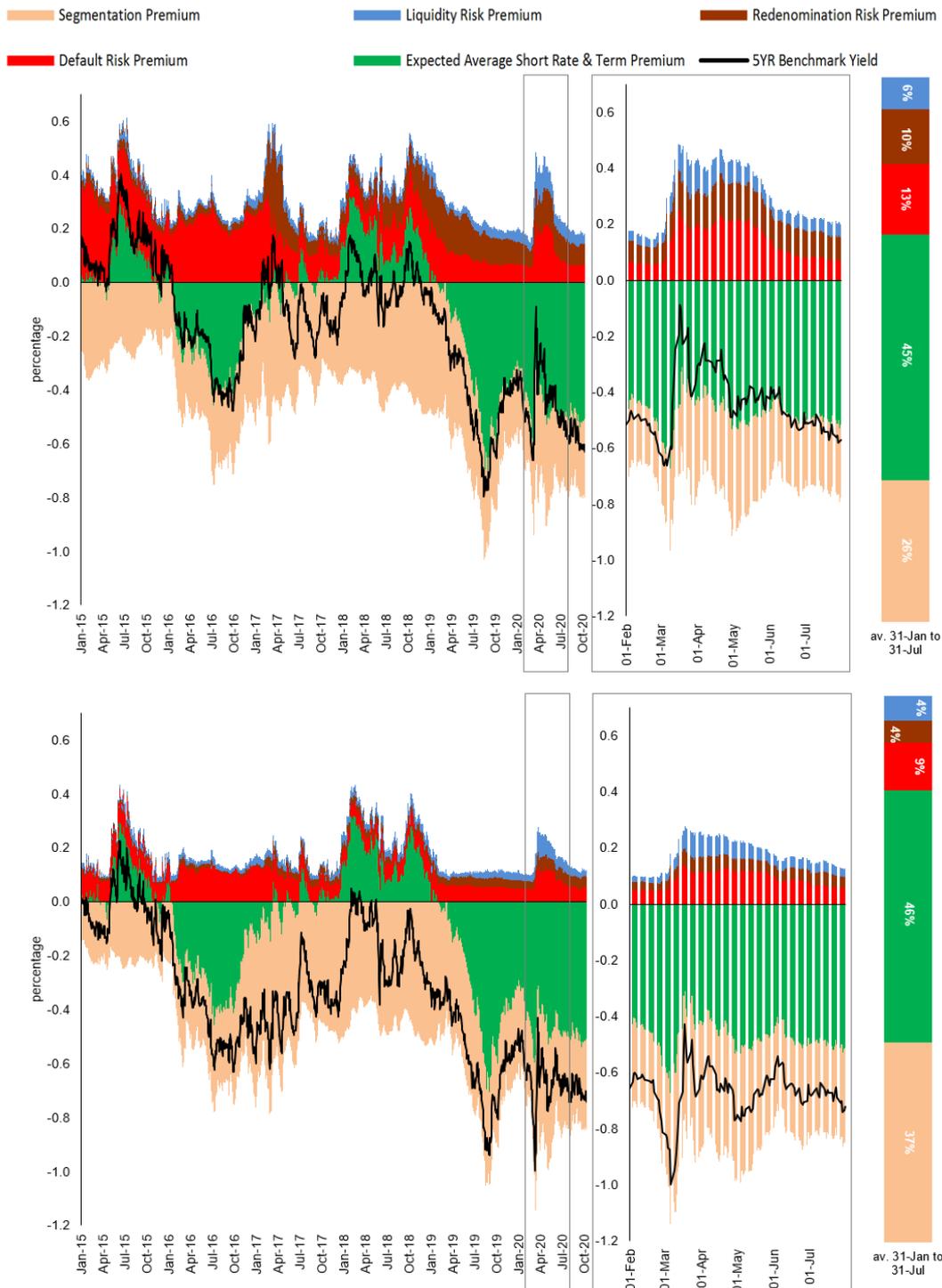


Table 1: Bond premia descriptive statistics

Sample means (first row) and standard deviations (second row, in brackets) associated with risk premium estimates as reported in Figures 2 and 3. Entries are in percentage points. The pre-Covid-19 sample ranges from 1 January 2015 to 30 January 2020. The Covid-19 sample refers to the zoomed-in period between 31 January 2020 and 31 July 2020. The final column refers to the complete sample from 1 January 2015 to 9 October 2020. The first component (expected future short-term risk-free rates and term premium) is identical across countries, and therefore only reported once.

	Pre-Covid-19	Covid-19	Full Sample
Italy			
$\mathbb{E}[\text{short rate}]$ & term premium	-0.065 (0.231)	-0.472 (0.056)	-0.115 (0.256)
Default risk premium	0.920 (0.219)	1.030 (0.299)	0.923 (0.229)
Redenomination risk premium	0.396 (0.289)	0.452 (0.088)	0.401 (0.273)
Liquidity risk premium	0.029 (0.019)	0.077 (0.042)	0.033 (0.026)
Segmentation premium	-0.357 (0.202)	-0.261 (0.082)	-0.348 (0.193)
Spain			
Default risk premium	0.470 (0.215)	0.421 (0.176)	0.460 (0.211)
Redenomination risk premium	0.150 (0.063)	0.243 (0.077)	0.159 (0.068)
Liquidity risk premium	0.030 (0.013)	0.075 (0.040)	0.034 (0.021)
Segmentation premium	-0.239 (0.124)	-0.280 (0.121)	-0.243 (0.122)
France			
Default risk premium	0.164 (0.075)	0.135 (0.063)	0.158 (0.076)
Redenomination risk premium	0.074 (0.055)	0.105 (0.024)	0.077 (0.053)
Liquidity risk premium	0.022 (0.009)	0.061 (0.025)	0.026 (0.016)
Segmentation premium	-0.315 (0.086)	-0.272 (0.045)	-0.309 (0.083)
Germany			
Default risk premium	0.077 (0.026)	0.089 (0.029)	0.077 (0.027)
Redenomination risk premium	0.021 (0.010)	0.042 (0.009)	0.024 (0.012)
Liquidity risk premium	0.017 (0.006)	0.046 (0.020)	0.020 (0.012)
Segmentation premium	-0.360 (0.119)	-0.374 (0.064)	-0.360 (0.113)

Variation in the redenomination risk premium is not only relevant for Italian yields. The French redenomination risk premium became economically significant in early 2017 when the candidate of Front National, Marine Le Pen, featured highly in the polls for the French presidential election (see the top panel of Figure 3, and also [Kremens \(2021\)](#) for a discussion). The French redenomination risk premium increased to approximately 30 bps in the run-up to the May 2017 election, accounting for approximately one third of French yields at the time. By contrast, redenomination risk premia are minor for German yields during our sample. German yields are almost completely explained by variation in the OIS EUR rate and the segmentation premium.

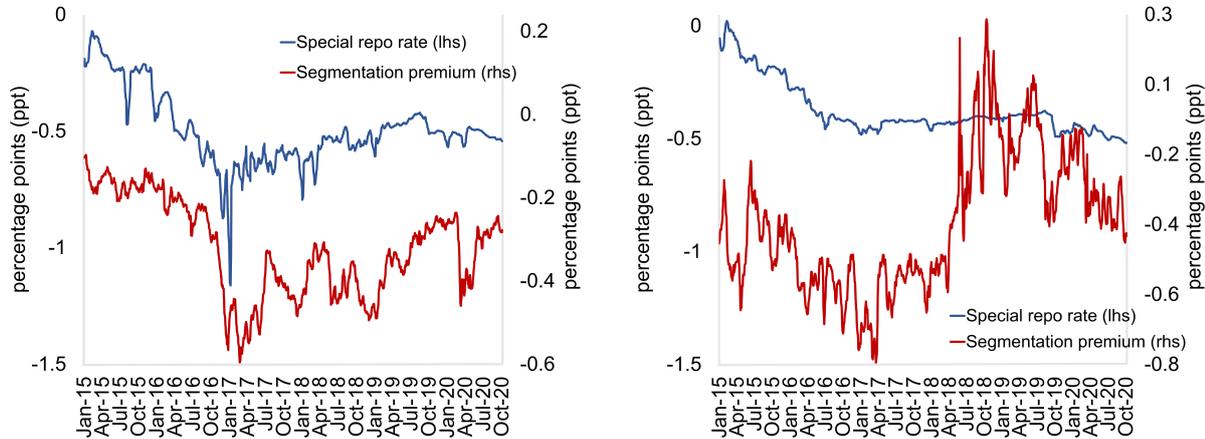
Figures 2 - 3 and Table 1 suggest that euro area sovereign bond yields contain a substantial and negative segmentation (convenience) premium. The German segmentation premium is the most negative, at approximately -36 bps on average over the full sample. This suggests that the German sovereign bond is the most highly sought-after bond in our sample. Interestingly, German, French, and Italian convenience yields were similar between 2015 and 2019 before the onset of the Covid-19 pandemic (after accounting for term, default, redenomination, and liquidity risk premia), before diverging to some extent during the pandemic recession. This is in line with the ECB's PSPP, as announced on 22 January 2015, acquiring these bonds in approximately similar amounts (in accordance with the ECB's capital key, see our discussion in Section 4.4 below), and with their symmetric treatment in the ECB's collateral framework and banking sector liquidity regulation.

In our framework, a consistently negative segmentation premium means that investors are willing to accept a lower return from sovereign bonds compared to holding an alternative position that has the same payoff. Specifically, investors then prefer sovereign bonds over a long position in the five-year OIS contract and a short position in a CT2014 CDS contract that protects against default and redenomination risk.

A bond's convenience yield is probably related to its value as collateral. Figure 4 compares our estimates of the German (left) and Italian (right) segmentation premium with an observable measure of convenience, the special repo rate ([Duffie \(1996\)](#), [Krishnamurthy \(2002\)](#); Web Appendix D presents the corresponding plots for France and Spain). The special repo rate is the interest rate a lender in the repo market receives from a borrower, using a specific security (the five-year sovereign benchmark bond) as collateral. The left panel of the Figure 4 shows a strong positive co-movement

Figure 4: DE and IT segmentation premium and special repo rate

Special repo rate (blue solid line) and segmentation premium estimate (red solid line) for German (left) and Italian (right) five-year sovereign benchmark bonds. Data are daily between 2 January 2015 and 9 October 2020. Special repo rates are smoothed using a 20-day moving average.



between the German segmentation premium estimate and the corresponding special repo rate, suggesting that the convenience stems in part from the German bond’s value as collateral. The co-movement is particularly pronounced between March 2015 (when the ECB’s PSPP was first activated) and the end of 2016 (when a change in the Eurosystem’s Securities Lending Facility made German government bonds more widely available).²⁹

Our segmentation premium estimates, however, do not always closely align with special repo rates as an observed measure of convenience. The right panel of Figure 4 compares our estimate of the Italian segmentation premium with the corresponding special repo rate of the Italian five-year sovereign benchmark bond. A strong positive co-movement is visible only initially. The upward movement in the segmentation premium estimate in 2018 coincides with the increase in redenomination risk, owing to domestic political developments as previously discussed. Possibly, some investors dropped out of the market, and Italian bonds had to be held by a smaller subset of investors that demanded an extra premium.

In addition to its value as collateral, also central bank asset purchases can affect a bond’s convenience yield. As argued in Corradin and Maddaloni (2020), the central bank is a buy-and-hold investor that can decrease asset supply over time if the purchased assets become locked away

²⁹See e.g. https://www.ecb.europa.eu/press/pr/date/2016/html/pr161208_2.en.html.

in its portfolio.³⁰ If the central bank does not lend (or marginally lends) the purchased bonds back to the repo market through a security lending facility, then individual bonds can become scarce and thus more valuable to their holders.³¹

4.3 Risk premia during the Covid-19 pandemic

This section discusses our risk premium estimates since the onset of the Covid-19 pandemic in early 2020. To this end we focus on the right panels of Figures 2 and 3. The right panels magnify the six months between 31 January and 31 July 2020. On 30 January 2020, the World Health Organization declared that the Covid-19 outbreak constitutes a “public health emergency of international concern,” sometimes also referred to as a pandemic.

Italian and Spanish sovereign yields started to increase at the end of February 2020, while German and French yields increased by much less; see also Figure 1. The increase in yields was most notable for Italy, where yield rose from 0.37% to 1.96% just before the ECB’s PEPP announcement on 18 March 2020. The increase is mainly attributed to the default and redenomination risk premium, which both increased during the Covid-19 pandemic. The Italian default risk premium increased by 110 bps. The Italian redenomination risk premium increased by 29 bps, but remained lower than what was observed in 2018. The Italian liquidity risk premium was economically small between 2015 and 2019, but became more important during the early phase of the Covid-19 pandemic at approximately 15 bps before 18 March 2020.³²

The right-hand-side bars in Figures 2 and 3 indicate the relative importance of each risk premium between 31 January and 31 July 2020. The percentages refer to the share of each component in the sum over the absolute values of all components, subsequently averaged over all trading days

³⁰Corradin and Maddaloni (2020) extend the search-based dynamic model by Vayanos and Weill (2008) in which assets with identical cash flows can trade at different prices in spot and repo markets by introducing the central bank as a key player. Our argument is also in line with standard reasoning on the transmission channels of quantitative easing (see e.g. Eser, Lemke, Nyholm, Radde, and Vladu (2019) and Bernanke (2020) and the references therein).

³¹The impact of central bank purchases on bond prices is even larger when bond markets are also segmented (see e.g. Gromb and Vayanos (2002), Duffie (2010)) because central bank asset purchases are then absorbed by only a subset of market participants. Euro area sovereign bond markets were arguably well-integrated prior to the global financial crisis (Pagano and Von Thadden (2004)), but saw a substantial re-fragmentation during the euro area sovereign debt crisis, leading to a persistent increase in investor home bias (Ehrmann and Fratzscher (2017) and Kojien, Koulischer, Nguyen, and Yogo (2021)).

³²Given the size of the Covid-19 shock, other debt markets, including corporate and covered bond markets, also witnessed a decline in market liquidity. For the euro area, see e.g. Breckenfelder and Ivashina (2021). For a discussion of U.S. markets, see e.g. O’Hara and Zhou (2021), Kargar, Lester, Lindsay, Liu, Weill, and Zúñiga (2021), and Boyarchenko, Kovner, and Shachar (2022).

between 31 January and 31 July 2020 (for each component’s magnitudes in basis points, see Table 1). Between 31 January and 31 July 2020 the default risk premium accounts for 45% of the Italian “yield” (total), and for 28% of the Spanish “yield.” The redenomination risk premium accounts for 20% of the Italian “yield” (total), and for 16% of the Spanish “yield.” Both default and redenomination risk were thus dominant risk premia for these countries following the outbreak of the Covid-19 pandemic.

The right-hand-side bars in Figure 3 suggest that default, redenomination, and liquidity risk premia continued to play a minor role for French and German yields between 31 January and 31 July 2020. Instead, French and German yields are mostly explained by expected future short-term risk-free rates and a term premium (45% and 46% of total), and a segmentation premium (26% and 37% of total).

4.4 Event study

The extracted yield premia can be studied further based on event study regressions. Such regressions allow us to disentangle the channels through which ECB monetary policy and EU fiscal policy announcements affected sovereign yields. We first discuss the key events and regression setup before turning to the impact estimates.

4.4.1 Discussion of events

The right panel of Figure 1 contains vertical lines that indicate several key monetary and fiscal policy announcements in the euro area. This section discusses these announcements in detail. We do not consider announcements by other central banks, or by other fiscal policy makers, as these were probably less important for euro area sovereign yields at the time.³³

Figure 1 suggests that the outbreak of Covid-19 caused asymmetric responses across sovereign yields. Sovereign yields started to diverge in February 2020, mainly driven by Italian and Spanish yields. To stabilise markets, and to improve the economic and inflation outlook, the ECB announced

³³Hartley and Rebucci (2020) provide international evidence of QE announcements made by 21 central banks on local sovereign bond yields and bilateral USD exchange rates in March and April 2020. Using an event study approach, they find that the Fed’s policies may have affected international (mostly emerging markets’) yields and played an important role in addressing the global dollar shortage triggered by the outbreak of Covid-19. Individual countries’ QE announcements contributed significantly to stabilizing local yields even after controlling for the Fed’s and other central banks’ announcements.

its PEPP on 18 March 2020 (first vertical line). On the 7 and 22 April 2020 the ECB temporarily relaxed its collateral requirements (no lines, for visibility). On 5 May 2020 (third line), the German Federal Constitutional Court ruled on the compatibility of the ECB's earlier PSPP (not PEPP) with German constitutional law. The ruling was interpreted at the time to possibly constrain the ECB's latitude regarding future sovereign bond purchases, and could be interpreted as a contractionary unconventional monetary policy shock. On 4 June 2020 (fifth line), the ECB decided to increase the PEPP envelope by €600 bn to a total of €1,350 bn.

All monetary policy-related announcements mentioned above are expansionary (with the exception of the 5 May 2020), pointing to a later increase in the size of the Eurosystem's consolidated balance sheet. Such expansionary announcements could be expected to decrease term premia ([Eser, Lemke, Nyholm, Radde, and Vladu \(2019\)](#)), possibly decrease credit-related premia ([Calvo \(1988\)](#), [Eser and Schwaab \(2016\)](#)), decrease liquidity risk premia ([De Pooter, Martin, and Pruitt \(2018\)](#)), and possibly decrease segmentation premia as well ([Corradin and Maddaloni \(2020\)](#)).

In April 2020, a common fiscal policy response to the Covid-19 pandemic recession was initiated by EU heads of state to complement the ECB's strongly accommodative monetary policy. On 23 April 2020 (second line), EU leaders agreed to assemble a €540 bn recovery package, comprising three support measures. This package would later evolve into the EU's temporary program to mitigate unemployment risks (SURE), a loan guarantee scheme by the European Investment Bank, and a credit line to governments from the European Stability Mechanism. The announcement also called for an EU recovery fund of "sufficient magnitude" that was "needed and urgent." On 18 May 2020 (fourth line), the German chancellor Angela Merkel and French president Emmanuel Macron announced their joint proposal for a €500 bn EU recovery fund, in line with the 23 April announcement. On 21 July 2020 (sixth line), EU heads of state reached an agreement on the technical details of their new NGEU initiative, embedding the EU recovery fund into an even larger, €750 bn "resilience and recovery" plan.

All these fiscal announcements are expansionary, adding debt to the EU's balance sheet. Such announcements could be expected to decrease expected future short-term risk-free interest rates, for example if market participants perceived the central bank to be subject to fiscal dominance (see e.g. [Reinhart and Sbrancia \(2015\)](#); [Schnabel \(2020\)](#)). Alternatively, such announcements could also

increase expected future short-term risk-free interest rates, for example if additional fiscal stimulus was perceived as inflationary (Blanchard (2016)). Expansionary fiscal announcements could be expected to increase the default risk premia of the sovereigns that guarantee the EU’s new debt (Calvo (1988)), or to decrease them if the new funds were perceived as supporting sovereigns’ economic outlook and thus help increase debt sustainability. The impact of these fiscal announcements is thus an empirical question, and could go either way. The fiscal announcements could also be expected, possibly, to increase the German segmentation premium if market participants perceived the new EU-issued debt to be a competing euro-denominated safe asset (Brunnermeier, Merkel, and Sannikov (2021)).

4.4.2 Methodology

To study the impact of each of these announcements we consider the regression specification

$$\Delta r_t^c = \kappa_0^c + \kappa_1^c D_t + u_t^c, \quad (4)$$

where Δr_t^c is the daily change in the five-year yield (or, alternatively, the daily change in a certain yield component) associated with country c at time t , D_t is a vector of dummy variables associated with certain ECB monetary policy and EU fiscal policy announcements, κ_0^c and κ_1^c are a constant and slope parameters to be estimated, and u_t^c is the usual regression error term. The impact coefficient κ_1^c measures the surprise component in each announcement.³⁴ We estimate the parameters in Equation (4) by simple least squares, and report Newey and West (1987) standard errors.³⁵

Our event study regression results are reported in Tables 2 and 3 below. The total effect summed across all components is not exactly equal to the bond yield effects shown in Tables 2 and 3 because the Kalman filter allows for measurement error. Such measurement error is typically small; see Section 4.1. Trading around major policy announcements, however, can lead to transitory market pressures and thus deviations from the sum over all persistent components.

³⁴The dummy variables in D_t are set to 0.5 on the event day and the following day, in line with the two-day event window approach of KNV. As a result, the least squares estimate of κ is approximately equal (not exactly equal, owing to the constant) to the sum of the two observations following the respective event day.

³⁵Estimating the parameters by seemingly unrelated regression instead would not lead to more efficient estimates because the right-hand-side variables would then be common across countries; see e.g. Greene (2003, Chapter 14) for a discussion.

Table 2: Event study estimates - monetary policy announcements

Impact estimates from the event study regression (4). The event dates are given in Section 4.4.1 (see also Figure 1). We consider two-day event windows. P-values are based on [Newey and West \(1987\)](#) HAC standard errors with a one lag bandwidth.

	(1)	(2)	(3)	(4)	(5)	(6)
	5Y bond yield	Short rate & term premium	Default risk premium	Redenomination risk premium	Liquidity risk premium	Segmentation premium
Italy						
22-Jan-15	-8.45*	-5.53***	-8.63***	-0.98**	0.18***	3.56***
<i>PSPP</i>	(4.85)	(0.91)	(0.83)	(0.43)	(0.05)	(0.68)
18-Mar-20	-77.59**	13.29***	-34.64***	-14.21***	2.51***	-16.47***
<i>PEPP</i>	(36.60)	(5.10)	(12.92)	(5.07)	(0.11)	(4.16)
5-May-20	22.39***	2.68	9.62***	2.91***	-0.61*	2.88***
<i>German court</i>	(0.42)	(1.90)	(1.99)	(0.90)	(0.34)	(0.26)
4-Jun-20	-17.36***	3.38***	-18.31***	-6.25***	-0.27**	2.55***
<i>PEPP exp.</i>	(5.85)	(0.37)	(0.69)	(0.20)	(0.11)	(0.86)
Spain						
22-Jan-15	-10.35***	-5.53***	-5.02***	-1.32***	-0.01	1.20
<i>PSPP</i>	(3.66)	(0.91)	(0.10)	(0.06)	(0.19)	(1.10)
18-Mar-20	-10.60	13.29***	-3.60	-5.35	0.49**	-9.51***
<i>PEPP</i>	(19.27)	(5.10)	(10.01)	(3.52)	(0.24)	(1.46)
5-May-20	8.47***	2.68	2.11	0.64	-0.69	1.02
<i>German court</i>	(0.54)	(1.90)	(1.46)	(0.80)	(0.50)	(0.64)
4-Jun-20	-5.45***	3.38***	-5.19***	-3.27***	-0.62***	1.24***
<i>PEPP exp.</i>	(1.67)	(0.37)	(0.12)	(0.05)	(0.01)	(0.28)
France						
22-Jan-15	-6.40***	-5.53***	0.05	0.30***	0.04	-1.37***
<i>PSPP</i>	(0.57)	(0.91)	(0.26)	(0.09)	(0.17)	(0.40)
18-Mar-20	9.52	13.29***	-2.90**	-1.32***	1.18***	-2.36***
<i>PEPP</i>	(5.89)	(5.10)	(1.44)	(0.23)	(0.31)	(0.68)
5-May-20	5.41	2.68	-0.16	-0.01	-0.53	1.85**
<i>German court</i>	(4.66)	(1.90)	(0.10)	(0.20)	(0.36)	(0.84)
4-Jun-20	-0.99	3.38***	-2.32***	-0.89**	0.08	-0.17
<i>PEPP exp.</i>	(1.91)	(0.37)	(0.38)	(0.38)	(0.40)	(0.40)
Germany						
22-Jan-15	-6.01***	-5.53***	0.15	0.19*	-0.00	-0.28
<i>PSPP</i>	(0.57)	(0.91)	(0.18)	(0.10)	(0.17)	(0.26)
18-Mar-20	24.18***	13.29***	0.29	0.94***	2.01***	2.49***
<i>PEPP</i>	(3.02)	(5.10)	(0.56)	(0.10)	(0.36)	(0.38)
5-May-20	3.25	2.68	-0.07	-0.22	-0.54**	0.63
<i>German court</i>	(3.83)	(1.90)	(0.08)	(0.16)	(0.23)	(0.53)
4-Jun-20	3.90***	3.38***	-1.48***	-0.12	-0.18*	1.29***
<i>PEPP exp.</i>	(0.77)	(0.37)	(0.33)	(0.15)	(0.09)	(0.11)

4.4.3 Impact of monetary policy announcements

Table 2 suggests that the ECB's PEPP announcements on 18 March 2020 led to a large reduction in Italian yields, to a moderate reduction in Spanish yields, and to an increase in French and German yields. On 18 March 2020, Italian yields first reached 196 bps and then decreased by 78 bps over the next two days. Our statistical model attributes this decrease to a lower default risk premium (by 35 bps), redenomination risk premium (by 14 bps), and segmentation premium (by 16 bps). Spanish yields decreased by 11 bps, brought about by a lower segmentation premium (by 10 bps). French and German yields increased by 10 bps and 24 bps, respectively. Our model assigns the increase in

French and German yields to higher than expected future short-term risk-free (monetary policy) rates and term premium. Most probably, market participants had expected a cut in the ECB's deposit facility rate to counteract the effects of the Covid-19 pandemic, which did not happen. Instead, additional bond purchases became the instrument of choice.³⁶

The asymmetric impact on yields (ES and IT down, DE and FR up), including its differential impact on countries' segmentation/convenience premia, may be attributable to the unprecedented flexibility of the PEPP. The press release from the ECB stated that *"For the purchases of public sector securities, the benchmark allocation across jurisdictions will continue to be the capital key of the national central banks. At the same time, purchases under the new PEPP will be conducted in a flexible manner. This allows for fluctuations in the distribution of purchase flows over time, across asset classes and among jurisdictions."*³⁷ As a result, within the PEPP, the ECB can deviate from the country-limits set by the ECB's capital key that had guided the cross-country allocation of purchases under the PSPP. This means that the ECB is allowed to overweight, at least temporarily, certain sovereign bonds relative to others in its purchases. In addition, the PEPP framework grants the ECB additional latitude regarding the pace of the purchases over time, as well as regarding which asset classes are acquired (e.g., sovereign bonds vs. corporate bonds). Finally, there are no a-priori purchase limits within the PEPP framework. Such purchase limits apply to the PSPP, where they are aimed at avoiding that the ECB becomes a predominant creditor of euro area countries.³⁸

Previous ECB asset purchase programs, including the PSPP, did not have the PEPP's flexibility. The ECB's PSPP announcement, on 22 January 2015, led to a symmetric reduction in all four countries' yields. The reductions were primarily brought about by lower expected future short-term risk-free rates and term premium, as well as lower default risk premia for Italy and Spain. The symmetry of the yield responses on 22 January 2015 is thus in contrast to the asymmetry of yield responses observed on 18 March 2020 (and 4 June 2020).³⁹

³⁶Around 18 March, the U.S. Federal Reserve bought a substantial amount of U.S. Treasury bonds to support Treasury bond market functioning; see e.g. He, Nagel, and Song (2022). In principle, these purchases could have affected euro area sovereign yields as well. We would not expect these spillovers to be large, however, as, to our knowledge, the Federal Reserve did not buy any euro-denominated bonds at the time.

³⁷See https://www.ecb.europa.eu/press/pr/date/2020/html/ecb.pr200318_1~3949d6f266.en.html.

³⁸So-called issuer limits refer to the maximum share of an issuer's outstanding debt securities that the Eurosystem may buy. Issue limits refer to the maximum share of a single PSPP-eligible security that the Eurosystem may hold. Within the PSPP, the Eurosystem can buy only up to 33% of a country's outstanding securities (issuer limit) and up to 33% of any particular bond series as identified by its ISIN code (issue limit).

³⁹Web Appendix G reports further event study estimates for ECB announcements relating to changes in the pace

On 4 June 2020, the PEPP's total envelope was extended by €600 bn to €1,350 bn. Table 2 suggests that the PEPP extension led to a further reduction in Italian and Spanish yields, to no significant change in French yields, and to an increase in German yields. Italian yields decreased by an additional 17 bps. Our statistical model attributes this decrease mainly to a lower default risk premium (by 18 bps) and redenomination risk premium (by 6 bps). Spanish yields decreased by 5 bps, mainly owing to a lower default risk premium (by 5 bps) and redenomination risk premium (by 3 bps).

On 5 May 2020, the German Federal Constitutional Court (GFCC) ruled on the compatibility of the ECB's PSPP with German constitutional law. The ruling was interpreted at the time to potentially constrain the ECB's latitude regarding future sovereign bond purchases, and is thus similar to a contractionary unconventional monetary policy shock. The GFCC's ruling led to a substantial increase in Italian and Spanish yields, by 22 and 8 bps, respectively. The increase in French and German yields (by 5 and 3 bps) is less pronounced and not statistically significant. Our statistical model attributes the increase in Italian yield to an increased default risk premium (by 10 bps), redenomination risk premium (by 3 bps), and segmentation premium (by 3 bps). The increase in Spanish yield is assigned to the same channels, which, however, are not statistically significant in this instance.

4.4.4 Impact of fiscal policy announcements

We now turn to our EU fiscal policy announcements as discussed in Section 4.4.1.⁴⁰ Table 3 presents the associated findings.

On 23 April 2020, EU heads of state announced a novel and large recovery package. As a result, Italian, Spanish, French, and German yields decreased by 23, 14, 11, and 5 bps, respectively. The symmetric impact of the fiscal policy announcement on sovereign yields is in stark contrast to the asymmetric impact of the ECB's PEPP announcements on 18 March and 4 June 2020 as studied

of PSPP purchases, modifications in PSPP eligibility criteria, and PSPP securities lending. The impact estimates are generally in the single digit basis points, and not always statistically significant. In particular, the impact estimates tend to be smaller than those relating to the ECB's PEPP announcements on 18 March and 4 June 2020.

⁴⁰Previous literature evaluates the impact of relevant EU fiscal policy events on euro area long term sovereign yields. Afonso, Jalles, and Kazemi (2020) find that the announcement of a negative fiscal forecast by European Commission (e.g. upward revision in the public-to-GDP ratio) contributed to the increase in bond spreads while a positive fiscal announcement (e.g. downward revision in the public-to-GDP ratio) contributed to the decrease in spreads for the period 1999 – 2016.

Table 3: Event study estimates - EU fiscal policy announcements

Impact estimates from the event study regression (4). The event dates are given in Section 4.4.1 (see also Figure 1). We consider two-day event windows. P-values are based on [Newey and West \(1987\)](#) HAC standard errors with a one lag bandwidth.

	(1)	(2)	(3)	(4)	(5)	(6)
	5Y bond yield	Short rate & term premium	Default risk premium	Redenomination risk premium	Liquidity risk premium	Segmentation premium
Italy						
23-Apr-20	-22.62***	-5.23***	-13.55***	-3.43***	-0.59**	-1.65***
<i>Recovery package</i>	(1.80)	(1.55)	(1.23)	(0.31)	(0.28)	(0.36)
18-May-20	-23.42***	2.38***	-11.70***	-4.76***	-0.17	-4.91***
<i>German-French proposal</i>	(6.07)	(0.86)	(0.46)	(0.09)	(0.13)	(0.79)
21-Jul-20	-7.80***	-2.03***	-2.50***	-0.27**	0.16***	-2.91***
<i>EU recovery fund</i>	(1.27)	(0.12)	(0.41)	(0.11)	(0.03)	(0.12)
Spain						
23-Apr-20	-14.11***	-5.23***	-7.41***	-1.22***	-0.19***	-0.66
<i>Recovery package</i>	(1.48)	(1.55)	(0.54)	(0.10)	(0.02)	(0.49)
18-May-20	-9.40***	2.38***	-8.42***	-2.91***	-0.60***	0.77***
<i>German-French proposal</i>	(1.09)	(0.86)	(0.52)	(0.25)	(0.05)	(0.14)
21-Jul-20	-1.64***	-2.03***	-2.70***	-0.77***	-0.17	2.59***
<i>EU recovery fund</i>	(0.28)	(0.12)	(0.15)	(0.19)	(0.23)	(0.18)
France						
23-Apr-20	-10.81***	-5.23***	-1.66***	-1.03***	-0.83***	-0.85
<i>Recovery package</i>	(0.67)	(1.55)	(0.63)	(0.14)	(0.22)	(0.61)
18-May-20	2.11	2.38***	-1.65**	-0.54***	-0.54***	1.25***
<i>German-French proposal</i>	(1.90)	(0.86)	(0.68)	(0.16)	(0.11)	(0.34)
21-Jul-20	-2.90*	-2.03***	-0.51**	-0.38**	-0.18	0.32
<i>EU recovery fund</i>	(1.51)	(0.12)	(0.24)	(0.17)	(0.26)	(0.54)
Germany						
23-Apr-20	-5.31***	-5.23***	0.09***	-0.10***	-0.52***	1.27***
<i>Recovery package</i>	(1.76)	(1.55)	(0.03)	(0.02)	(0.09)	(0.18)
18-May-20	6.96***	2.38***	-0.10	-0.03**	-0.34***	2.54***
<i>German-French proposal</i>	(1.33)	(0.86)	(0.14)	(0.01)	(0.09)	(0.25)
21-Jul-20	-2.90**	-2.03***	-0.27***	-0.29***	-0.28***	0.34
<i>EU recovery fund</i>	(1.36)	(0.12)	(0.01)	(0.02)	(0.04)	(0.25)

above. While the monetary policy announcements benefited some vulnerable countries more than others, the fiscal announcement lowered euro area bond yields more uniformly. We attribute the observed 23 bps decrease in Italian yields on 23 April 2020 to lower risk premia across the board: The default risk premium (by 14 bps), future short rates and the term premium (by 5 bps), the redenomination risk premium (by 3 bps), the segmentation premium (by 2 bps), and the liquidity risk premium (by 1 bps) all decreased. The same pattern is observed for Spanish yields: all yield components decreased simultaneously. French and German yields decreased amid lowered expectations of future short-term risk-free rates and term premium.⁴¹

⁴¹On 22 April 2020, one day before the EU's announcement of its recovery package, the ECB announced that it decided to accept recently downgraded bonds in its eligible collateral pool, effectively lowering the credit rating threshold for asset eligibility in Eurosystem credit operations by two notches, from BBB- to B-. The yield response on 22 April affected Italian yields, and left the other yields approximately unchanged. If we estimate an event study regression with a dummy for the 21 and 22 April 2020, then we do not find a stabilising effect on Italian yields; see Web Appendix G. This might suggest that the easing of ECB collateral rules on 22 April might have been long anticipated, and that the impact of the EU's fiscal policy announcement on 23 April 2020 is not driven by the ECB's announcement one day before.

On 21 July 2020, EU heads of state reached an agreement fleshing out the technical details of its NGEU program. Also this announcement led to a uniform reduction in all yields. Italian, Spanish, French, and German yields decreased by 8, 2, 3, and 3 bps, respectively. The decrease in Italian yields is mainly attributed to a decrease in the default risk premium (3 bps) and segmentation premium (3 bps).

We interpret these findings as reflecting market participants' assessment that expansive fiscal policy can play an important role in supporting the central bank's monetary policy to improve the economic outlook in a coordinated fashion, as e.g. argued by [Bartsch, Benassy-Quere, Corsetti, and Debrun \(2021\)](#). In addition, the common EU fiscal policy supported vulnerable countries by removing risk from weakened sovereign budgets, facilitating lower default risk premia and higher convenience yield premia. In line with this interpretation, [Augustin, Sokolovski, Subrahmanyam, and Tomio \(2022\)](#) find a positive and significant sensitivity of sovereign CDS spreads to the intensity of the Covid-19 spread for fiscally constrained governments, suggesting that sovereign resilience to external shocks was impaired. Finally, the strong policy response at the European level may have lowered political risks in vulnerable countries, facilitating lower redenomination risk premia.

As a final caveat, not all EU fiscal policy announcements led to a uniform reduction in sovereign yields. On 18 May 2020, the German chancellor Angela Merkel and French president Emmanuel Macron announced a joint proposal for a €500 bn European recovery fund. [Table 3](#) suggests that their bilateral announcement led to a sizable reduction in Italian and Spanish yields (by 23 and 9 bps), while moderately increasing French and German yields (by 2 and 7 bps). Our statistical model attributes the decrease in Italian and Spanish yields to lower default risk, redenomination risk, and segmentation premia. By contrast, French and German yields increased moderately amid rising expectations of future short-term risk-free rates and term premium (by 2 bps) and less negative segmentation premia (by 1 and 3 bps).

5 Conclusion

We proposed a novel modeling framework to decompose euro area sovereign bond yields into their most dominant risk premia, building upon key ideas in [Krishnamurthy, Nagel, and Vissing-](#)

Jorgensen (2018). The identification of each risk premium is achieved by modeling sovereign yields jointly with other instruments' rates in an unobserved components model. Our framework can be used to study sovereign yields in detail in the context of regularly recurring monetary policy decisions, as well as, potentially, to monitor euro area financial integration over time.

We apply our model to study the impact of ECB unconventional monetary policy and EU fiscal policy announcements on euro area sovereign yields during the Covid-19 pandemic recession. Both ECB monetary and EU fiscal policy announcements had a pronounced impact on sovereign yields, mainly by affecting default, redenomination, and segmentation premia. The ECB's unconventional monetary policy announcements particularly benefited vulnerable countries hard-hit by Covid-19, owing to unprecedented flexibility when implementing bond purchases. The EU's fiscal policy announcements also stabilized sovereign yields, and uniformly so across countries, possibly by moving fiscal risks onto a shared budget, by lowering political (redenomination) risks through unprecedented collective action at the European level, and by complementing the ECB's monetary policy aimed at improving the economic outlook and therefore debt sustainability.

References

- Afonso, A., J. T. Jalles, and M. Kazemi (2020). The effects of macroeconomic, fiscal and monetary policy announcements on sovereign bond spreads. *International Review of Law and Economics* 63, 105924.
- Andrews, D. W. K. and W. Ploberger (1994). Optimal tests when a nuisance parameter is present only under the alternative. *Econometrica* 62(6), 1383–1414.
- Augustin, P., M. Chernov, and D. Song (2020). Sovereign credit risk and exchange rates: Evidence from CDS quanto spreads. *Journal of Financial Economics* 137, 129–151.
- Augustin, P., V. Sokolovski, M. G. Subrahmanyam, and D. Tomio (2022). In sickness and in debt: The covid-19 impact on sovereign credit risk. *Journal of Financial Economics* 143(3), 1251–1274.
- Balduzzi, P., E. Brancati, M. Brianti, and F. Schiantarelli (2020). Populism, political risk and the economy: Lessons from Italy. *IZA Discussion Paper No. 12929*.
- Bartsch, E., A. Benassy-Quere, G. Corsetti, and X. Debrun (2021). It's all in the mix: How monetary and fiscal policies can work or fail together. *Geneva reports on the world economy* (23), 1–161.

- Bernanke, B. S. (2020). The new tools of monetary policy. *American Economic Association Presidential Address, on January 4, 2020*, 1–57.
- Blanchard, O. (2016). The Phillips curve: back to the '60s? *American Economic Review* 106(5), 31–34.
- Bocola, L. and A. Dovis (2019). Self-fulfilling debt crises: A quantitative analysis. *The American Economic Review* 109, 4343–4377.
- Bonaccolto, G., N. Borri, and A. Consiglio (2021). Breakup and default risks in the great lockdown. *Journal of Banking & Finance*, 296–308.
- Boyarchenko, N., A. Kovner, and O. Shachar (2022). It's what you say and what you buy: A holistic evaluation of the corporate credit facilities. *Journal of Financial Economics* 144 (3), 695–731.
- Breckenfelder, J. and V. Ivashina (2021). Bank balance sheet constraints and bond liquidity. *ECB Working Paper No. 2589*.
- Brunnermeier, M. K., S. Merkel, and Y. Sannikov (2021). Debt as safe assets: Mining the bubble. *Princeton University mimeo*.
- Calvo, G. A. (1988). Servicing the public debt: the role of expectations. *The American Economic Review* 78(4), 647–661.
- Chamon, M., J. Schumacher, and C. Trebesch (2018). Foreign-law bonds: Can they reduce sovereign borrowing costs? *Journal of International Economics* 114, 164–179.
- Corradin, S. and A. Maddaloni (2020). The importance of being special: Repo markets during the crisis. *Journal of Financial Economics* 137(2), 392–429.
- Corsetti, G. and L. Dedola (2016). The mystery of the printing press: Monetary policy and self-fulfilling debt crises. *Journal of the European Economic Association* 14(6), 1329–1371.
- Davidson, R. and J. G. MacKinnon (2004). *Econometric theory and methods*. Oxford University press.
- De Pooter, M., R. F. Martin, and S. Pruitt (2018). The liquidity effects of official bond market intervention. *Journal of Financial and Quantitative Analysis* 53(1), 243–268.
- De Renzis, T., C. Guagliano, and G. Loiacono (2018). Liquidity in fixed income markets risk indicators and EU evidence. ESMA Working Paper, European Securities and Markets Authority.

- De Santis, R. (2019). A measure of redenomination risk. *Journal of Money, Credit and Banking* 51(8), 2173–2206.
- Del Negro, M., D. Giannone, M. P. Giannoni, and A. Tambalotti (2017). Safety, liquidity, and the natural rate of interest. *FRB of New York Staff Report No. 812*, 1–80.
- Del Negro, M., D. Giannone, M. P. Giannoni, and A. Tambalotti (2018). Global trends in interest rates. *FRB of New York Staff Report No. 866*, 1–67.
- Duffie, D. (1996). Special repo rates. *The Journal of Finance* 51(2), 493–526.
- Duffie, D. (2010). Presidential address: Asset price dynamics with slow-moving capital. *Journal of Finance* 65, 1237–1267.
- Duffie, D. and K. J. Singleton (1999). Modeling term structures of defaultable bonds. *Review of Financial Studies* 12(4), 687–720.
- Durbin, J. and S. J. Koopman (2001). *Time Series Analysis by State Space Methods, 2nd edition*. Oxford: Oxford University Press.
- ECB (2009). New evidence on credit and liquidity premia in selected euro area sovereign yields (Box 4). ECB Monthly Bulletin, European Central Bank.
- ECB (2014). The determinants of euro area sovereign bond yield spreads during the crisis. ECB Monthly Bulletin article, May 2014.
- Ehrmann, M. and M. Fratzscher (2017). Euro area government bonds—fragmentation and contagion during the sovereign debt crisis. *Journal of International Money and Finance* 70, 26–44.
- Eickmeier, S., W. Lemke, and M. Marcellino (2015). Classical time varying factor-augmented vector autoregressive models: estimation, forecasting and structural analysis. *Journal of the Royal Statistical Society. Series A (Statistics in Society)*, 493–533.
- Eser, F., M. Carmona Amaro, S. Iacobelli, and M. Rubens (2012). The use of the Eurosystem’s monetary policy instruments and operational framework since 2009. ECB Occasional Paper 135.
- Eser, F., W. Lemke, K. Nyholm, S. Radde, and A. Vladu (2019). Tracing the impact of the ECB’s asset purchase programme on the yield curve. *ECB Working Paper No. 2293*, 1–62.

- Eser, F. and B. Schwaab (2016). Evaluating the impact of unconventional monetary policy measures: Empirical evidence from the ECB's Securities Markets Programme. *Journal of Financial Economics* 119(1), 147–167.
- Greene, W. H. (2003). *Econometric Analysis, 5th edition*. Prentice Hall.
- Greenwood, R., S. G. Hanson, and J. C. Stein (2015). A comparative-advantage approach to government debt maturity. *The Journal of Finance* 70(4), 1683–1722.
- Greenwood, R. and D. Vayanos (2010). Price pressure in the government bond market. *American Economic Review* 100, 585–590.
- Gromb, D. and D. Vayanos (2002). Equilibrium and welfare in markets with financially constrained arbitrageurs. *Journal of Financial Economics* 66(2-3), 361–407.
- Hamilton, J. D. (1994). *Time Series Analysis*. Princeton University Press.
- Hartley, J. and A. Rebucci (2020). An event study of COVID-19 central bank quantitative easing in advanced and emerging economies. *NBER Working Paper* (27339).
- He, Z., S. Nagel, and Z. Song (2022). Treasury inconvenience yields during the covid-19 crisis. *Journal of Financial Economics* 143(1), 57–79.
- Jiang, Z., H. N. Lustig, S. Van Nieuwerburgh, and M. Z. Xiaolan (2021). Bond convenience yields in the eurozone currency union. *Available at SSRN*.
- Kargar, M., B. Lester, D. Lindsay, S. Liu, P.-O. Weill, and D. Zúñiga (2021). Corporate bond liquidity during the covid-19 crisis. *The Review of Financial Studies* 34(11), 5352–5401.
- Koijen, R. S., F. Koulischer, B. Nguyen, and M. Yogo (2021). Inspecting the mechanism of quantitative easing in the euro area. *Journal of Financial Economics* 140(1), 1–20.
- Koopman, S. J. (1997). Exact initial Kalman filtering and smoothing for nonstationary time series models. *Journal of the American Statistical Association* 92(440), 1630–1638.
- Kremens, L. (2021). Currency redenomination risk. *Foster School of Business, University of Washington, Working Paper*.
- Krishnamurthy, A. (2002). The bond/old-bond spread. *Journal of financial Economics* 66(2-3), 463–506.

- Krishnamurthy, A., S. Nagel, and A. Vissing-Jorgensen (2018). ECB policies involving government bond purchases: Impact and channels. *Review of Finance* 22(1), 1–44.
- Krishnamurthy, A. and A. Vissing-Jorgensen (2012). The aggregate demand for treasury debt. *Journal of Political Economy* 120(2), 233–267.
- Lane, P. R. (2020). The market stabilisation role of the Pandemic Emergency Purchase Programme. ECB Blog post on 22 June 2020.
- Manganelli, S. and G. Wolswijk (2009). What drives spreads in the euro area government bond market? *Economic Policy* 24(58), 191–240.
- Monfort, A., F. Pegoraro, J.-P. Renne, and G. Roussellet (2021). Affine modeling of credit risk, pricing of credit events, and contagion. *Management Science* 67(6), 3674–3693.
- Newey, W. K. and K. D. West (1987). A simple, positive semi-definite, heteroskedasticity and autocorrelation consistent covariance matrix. *Econometrica* 55(3), 703–708.
- O’Hara, M. and X. A. Zhou (2021). Anatomy of a liquidity crisis: Corporate bonds in the covid-19 crisis. *Journal of Financial Economics* 142(1), 46–68.
- Pagano, M. and E.-L. Von Thadden (2004). The European bond markets under EMU. *Oxford Review of Economic Policy* 20(4), 531–554.
- Pelizzon, L., M. G. Subrahmanyam, D. Tomio, and J. Uno (2016). Sovereign credit risk, liquidity, and European Central Bank intervention: Deus ex machina? *Journal of Financial Economics* 122(1), 86–115.
- Primiceri, D. (2005). Time varying structural vector autoregressions and monetary policy. *The Review of Economic Studies* 72, 821–852.
- Reinhart, C. M. and M. Sbrancia (2015). The liquidation of government debt. *Economic Policy* 30(82), 291–333.
- Renne, J.-P. and A. Monfort (2014). Decomposing euro-area sovereign spreads: credit and liquidity risks. *Review of Finance* 18(6), 2103–2151.
- Schnabel, I. (2020). The shadow of fiscal dominance: Misconceptions, perceptions and perspectives. *Speech at the Centre for European Reform and the Eurofi Financial Forum in Berlin, on 11 September 2020*.
- Schwarz, K. (2019). Mind the gap: Disentangling credit and liquidity in risk spreads. *Review of Finance* 23(3), 557–59.

Tholl, J., C. Schwarzbach, S. Pittalis, and H.-J. von Mettenheim (2020). Bank funding and the recent political development in Italy: What about redenomination risk? *International Review of Law and Economics* 64, 905–932.

Vayanos, D. and P.-O. Weill (2008). A search-based theory of the on-the-run phenomenon. *The Journal of Finance* 63(3), 1361–1398.

Visco, I. (2018). Remarks by the Governor of the Bank of Italy. *Giornata Mondiale del Risparmio*, 31 October 2018.