Web Appendix to

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

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A A regression-based decomposition approach

This section develops a regression-based decomposition approach which does not rely on state space methods but leads to approximately comparable sovereign yield decomposition results.

In the regression-based approach, we first estimate the loading parameters β by a (restricted) least squares regression of sovereign yields on the other financial instruments' rates. We run this regression in first differences to prevent problems associated with persistent regressors (e.g., Granger and Newbold (1974)). All data are stacked vertically to obtain common parameter estimates across countries. The remaining estimates in ψ can subsequently be obtained conditional on β, if desired, as follows. First, the scaled regressors are subtracted from the (average of the two observed) five-year benchmark bond yields to obtain a regression-based segmentation premium. Any measurement error/noise in bond yields is attributed to the segmentation premium. Second, all scaled yield components can be stacked into α_t^*. The volatility and correlation coefficients δ and ρ can now be obtained from the covariance matrix of $\eta_t = \Delta\alpha_t^*$. Measurement error variances γ are set to zero.

Figures A.1 and A.2 compare the two estimation approaches for Italy, Spain, France, and Germany. The decomposition results are visibly similar for all four countries. The restrictions $\beta_1 = \beta_2 = 1$ were imposed in either case. The estimate of $\beta_3^{\text{OLS}} = 0.22$ is similar to $\beta_3^{\text{ML}} = 0.25$; see Section 4.1.

Figure A.1: Comparison of filtering- and OLS-based decompositions: IT and ES

Filtering- and OLS-based risk premium estimates for IT (top) and ES (bottom). Six panels each refer to i) the five-year bond yield that is decomposed into ii) expected future risk-free short-term rates and term premium, iii) default risk premium, iv) redenomination risk premium, v) liquidity risk premium, and vi) segmentation premium.

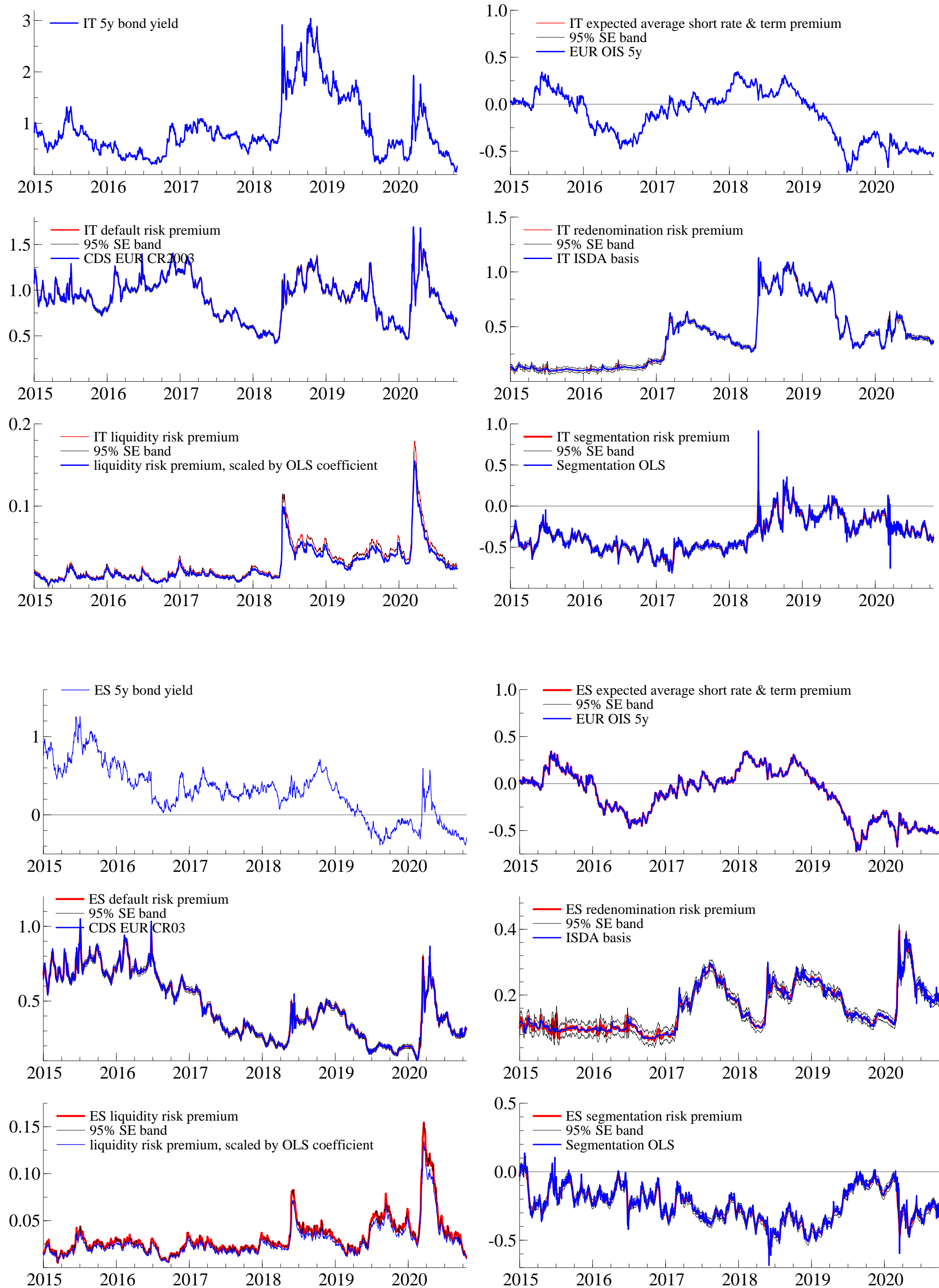
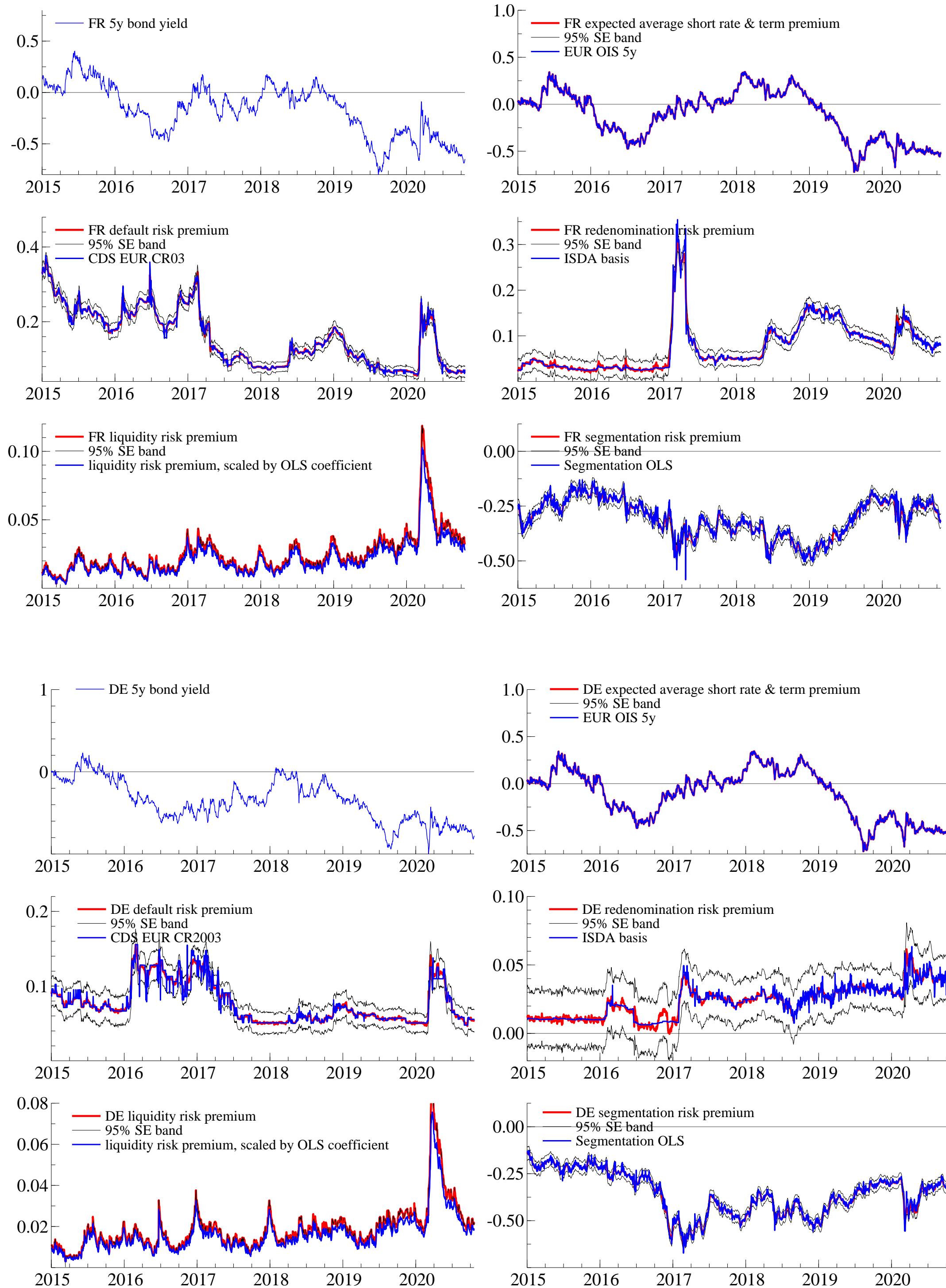


Figure A.2: Comparison of filtering- and OLS-based decompositions: FR and DE
Filtering- and OLS-based risk premium estimates for FR (top) and DE (bottom). Six panels each refer to i) the five-year bond yield that is decomposed into ii) expected future risk-free short-term rates and term premium, iii) default risk premium, iv) redenomination risk premium, v) liquidity risk premium, and vi) segmentation premium.



B Identification summary tables

This section discusses two summary tables that compare KNV's identification approach to our approach. Table B.1 reproduces KNV's baseline approach for Italian data (their Table 2B, page 15). The table relates four observed time series (presented in rows) to four sovereign bond risk premia to be identified (in columns). To explain Table B.1's third and fourth row, ENI is an Italian multinational oil and gas company whose bond yield was assumed to be independent of Italian sovereign default risk. CDS contracts referencing single-name euro area corporates, such as ENI, are rare and illiquid.

Table B.1: KNV's baseline implementation for Italy

	default risk premium	corporate default risk premium	redenomination risk premium	segmentation risk premium
≈5y IT EUR bond yield - EUR 5y OIS rate	1	0	1	1
≈5y IT USD bond yield - USD 5y OIS rate	1	0	0	0
≈5y ENI EUR bond yield - USD 5y OIS rate	0	1	1	0
5y ENI USD CDS CT2003 spread	0	1	0	0

By contrast, Table B.2 corresponds to our approach as explained in Sections 2.2 and 2.4. It relates seven observed time series (presented in rows) to five sovereign bond risk premia to be identified (in columns). The "aid component" (fifth column of Table B.2) corresponds to the five-year CDS USD CT2003 time series, adjusted for measurement error. (Note that the sixth row of Table B.2 is a selection vector, corresponding to the fourth row of an I_6 identity matrix.) This specification identifies redenomination risk as the difference between the 5y CDS USD CT2014 and the 5y CDS USD CT2003 time series when both CDS spreads are subject to measurement error (see fifth row of Table B.2).

Table B.2: Our implementation for Germany, France, Italy, and Spain

	expected short-rate & term premium	default risk premium	redenomination risk premium	"aid" component	liquidity risk premium	segmentation risk premium
5y bond yield, BBG	1	β_1	β_2	0	β_3	1
5y bond yield, Reuters	1	β_1	β_2	0	β_3	1
5y OIS EUR rate	1	0	0	0	0	0
5y CDS EUR CT2003	0	1	0	0	0	0
5y CDS USD CT2014	0	0	1	1	0	0
5y CDS USD CT2003	0	0	0	1	0	0
5y liquidity risk factor	0	0	0	0	1	0

C Measuring default risk: USD bond spread vs. ISDA 2003 CDS spread

This section compares two alternative measures of the default risk premium: a risk spread taken from U.S. dollar (USD)-denominated bonds issued by a euro area sovereign on the one hand, and the euro (EUR)-denominated ISDA 2003 CDS spread on the other hand. KNV infer the default risk premium from the spread between the yield of a USD-denominated foreign-law sovereign bond and the corresponding USD OIS rate. By contrast, we rely on the EUR CT2003 CDS spread.

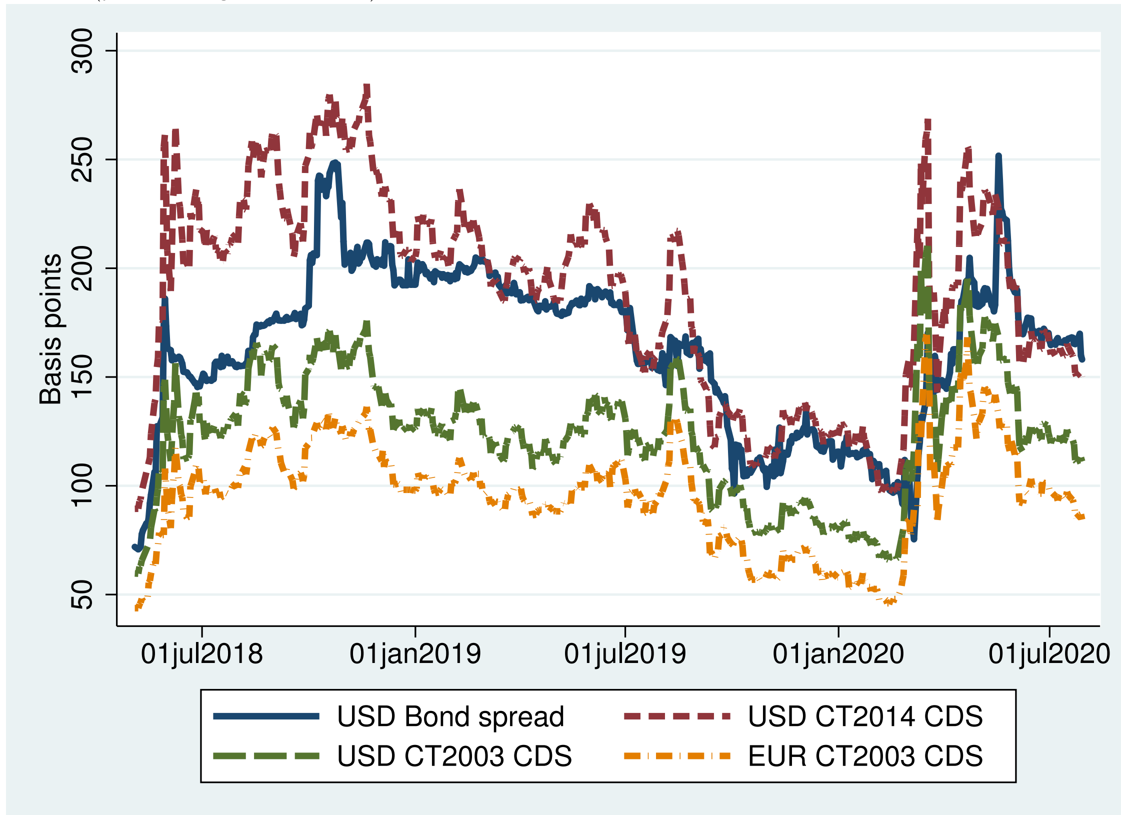
For this comparison we need to rely exclusively on Italian data, for the simple reason that, to our knowledge, France, Germany, and Spain do not have outstanding USD-denominated sovereign bonds, rendering the KNV approach infeasible for these three countries. And even for Italy, we need to make do with only two USD-denominated sovereign bonds. We obtain bid, ask, and mid prices, as well as implied yields for these two bonds. The data are at a daily frequency, ranging from 1 May 2018 until 9 October 2020. CDS spreads are obtained from Credit Market Analysis (CMA) DataVision, also ranging from 1 May 2018 until 9 October 2020. CMA reports bid, ask, and mid quotes, allowing us to compare bid-ask spreads below.

The first Italian bond matures in 2023 (Republic of ITALY 4.75 8/1/2023 Govt), implying a residual maturity of about five years in mid-2018. The residual maturity of this bond thus approximately matches the maturity of a five-year CDS contract. The second bond matures in 2033 (Republic of ITALY 6 5/1/2033 Govt). We obtain KNV's USD bond-based yield spread as follows. First, we linearly interpolate the two Italian bond yields to obtain the yield of a hypothetical five-year constant-maturity bond. We then subtract the five-year USD OIS rate.

Figure C.1 plots the USD-denominated bond spread. The bond spread (blue continuous line) can now be compared to the five-year USD CT2003 CDS spread (green long-dashed line), the USD CT2014 CDS spread (red dashed line), and the EUR CT2003 CDS spread (yellow long-dashed line). The USD CT2003 CDS spread and the USD bond spread co-move most closely, with a correlation coefficient of approximately 83%. The USD-denominated bond spread is larger on average than the USD CT2003 CDS spread. This is intuitive. As discussed in KNV, the USD-denominated bond spread can embed other premia. For example, *i*) USD-denominated bonds are potentially much less liquid than euro-denominated bonds, *ii*) they might be taxed differently than euro-denominated bonds, and *iii*) may be held by a different investor type. All of these frictions can affect their

Figure C.1: Alternative default risk premium measures for Italy

KNV's USD bond-based risk spread (blue continuous line), the five-year USD CT2003 CDS spread (green long-dashed line), the five-year USD CT2014 CDS spread (red dashed line), and the five-year EUR CT2003 CDS spread (yellow long-dashed line).



yields. To account for these frictions, KNV at times extend their statistical framework to try and estimate a foreign segmentation component.

The five-year EUR CT2003 CDS spread strongly co-moves with its USD CT2003 CDS spread counterpart. The correlation coefficient is approximately 98%. The EUR CT2003 CDS spread is lower than the USD CT2003 CDS spread throughout the sample. This is intuitive, as only the latter provides additional protection against a depreciation of the euro against the U.S. dollar should a sovereign credit event occur; see e.g. Monfort et al. (2020).

The five-year USD CT2014 CDS spread and the USD bond spread also co-move, but do so less closely. The correlation coefficient is approximately 75%. The USD CT2014 CDS spread provides protection against both default and redenomination risk (as well as against a depreciation of the euro against the U.S. dollar should a sovereign credit event occur). As a result, it should provide an upper bound to any proxy for the default risk premium.

Finally, we compare the market liquidity of the five-year EUR CT2003 CDS contract with that of the two U.S. dollar-denominated Italian sovereign bonds. We focus on the bid-ask spread for this purpose. The EUR CT2003 CDS contract is more liquid on average (bid-ask spread of approximately 7.6 bps) than the two U.S. dollar-denominated sovereign bonds (bid-ask spreads of 10.9 bps and 11.6 bps, respectively). We conclude that, for our sample, CDS spreads are the most available, direct, and liquid measure of a sovereign's default risk.

D ISDA 2014 and 2003 CDS terms

D.1 Credit event definitions: redenomination risk

The International Swaps and Derivatives Association (ISDA) is a trade organization of participants in the market for over-the-counter derivatives. As one of its main functions, it sets rules and definitions for the CDS market. The ISDA's standardized definitions have changed occasionally in response to new developments. The most recent update was implemented in September 2014. Before that, the most recent update was released in 2003.

Under the 2003 definition, a sovereign could redenominate an obligation into a number of "permitted currencies" without triggering a default. Specifically,

> "Permitted Currency" means (1) the legal tender of any Group of 7 country (or any country that becomes a member of the Group of 7 if such Group of 7 expands its membership) or (2) the legal tender of any country which, as of the date of such change, is a member of the Organisation for Economic Cooperation and Development and has a local currency long-term debt rating of either AAA or higher assigned to it by Standard & Poor's, a division of The McGraw-Hill Companies, Inc. or any successor to the rating business thereof, Aaa or higher assigned to it by Moody's Investors Service, Inc. or any successor to the rating business thereof or AAA or higher assigned to it by Fitch Ratings or any successor to the rating business thereof."

France, Germany, and Italy are part of the G7 countries. (In addition, Germany is an OECD member country with a sufficiently high rating. Spain is an OECD country and was rated AAA by S&P between December 2004 and January 2009.) As a result, under the ISDA 2003 rules, France, Germany, and Italy could each issue a new currency, and then redenominate the existing debt into a new currency, without triggering the existent CT2003 CDS contracts. For these countries, CT2003 CDS contracts do not provide adequate protection against a redenomination event. This was widely understood and discussed in the financial press at the time; see e.g. Kaminska (2010).

In our sample, Spain is not a G7 member country. It is an OECD country, but has not been AAA-rated since 2009. As a result, the above "G7 loophole" does not apply. Still, two additional issues arise in the case of Spain. First, since the euro area sovereign debt crisis there has been a discussion of the case of a country exiting the euro and redenominating its debt into a new

shared currency (e.g., a "southern states euro"), while another country participating in the new shared currency is a G7 country (e.g., Italy). It is then unclear whether this new shared currency is a "permitted currency," and whether the Spanish CDS would trigger as a result.[1] Second, the ISDA Credit Derivatives Determinations Committee would have been ultimately responsible for assessing whether the "redenomination" event directly or indirectly arises from a deterioration in the creditworthiness or financial condition of the sovereign at the time. Such a deterioration could be difficult, and time-consuming, to prove following a "redenomination". With these two justifications in mind we also use the ISDA basis to inform the redenomination risk premium estimate for Spain. Alternatively, the reader is free to refer to the sum of the Spanish redenomination risk premium and default risk premium collectively as Spanish "credit-related premia."

In response to the euro area sovereign debt crisis, and growing concerns about the possibility of a redenomination of some euro area government debt, the ISDA amended Section 4.7 in its 2014 terms. Now, the only permitted currencies are enumerated explicitly as

> ... the lawful currency of Canada, Japan, Switzerland, the United Kingdom, the U.S., and the euro and any successor currency to any of the aforementioned currencies (which in the case of the euro, shall mean the currency which succeeds to and replaces the euro in whole.)"

As a result, the new ISDA 2014 wording effectively addresses and removes the "G7-loophole" in its 2003 terms. Under the ISDA 2014 definitions, a redenomination of debt into a new French, German, Italian, or Spanish currency would trigger a sovereign CT2014 CDS contract (provided the redenomination is detrimental to bondholders, see the next paragraph).

Finally, the ISDA 2014 terms also replaced the requirement that a restructuring credit event would be triggered only in the case of a deterioration in the creditworthiness or financial condition of the sovereign that exits the euro. Because it would be difficult to judge whether or not such a deterioration has taken place, the 2014 ISDA definitions switched off this requirement. Instead, it introduced a more "rule-based" requirement, stating that the restructuring credit event is triggered by *any* redenomination into a new currency, as long as an implied haircut or market loss occurs to existing bondholders.

[1] See `https://www.isda.org/a/sFiDE/icm-21318534-v8-memo-to-kirsty-taylor.pdf`.

D.2 Asset package delivery

The changes discussed is Section D.1 are not the only ones distinguishing the ISDA 2003 and 2014 terms. This could matter for our use of the ISDA basis as a measure of redenomination risk. This section discusses another change in terms, commonly referred to as the "asset package delivery" (APD) clause. The new clause clarifies which assets are taken into account when calculating a bond's recovery value at default, and was a direct response to the Greek debt restructuring of 2012. In principle, pricing differences between the ISDA 2003 and 2014 sovereign CDS contracts could also depend on this additional clause. We argue, however, that the addition of the APD clause is unlikely to lead to an economically significant pricing differential between CT2003 and CT2014 contracts in our sample because the magnitude of the recovery value matters most when countries are close to default. This is not the case in our sample.[2] We acknowledge that, if the APD clause led to a constant level shift in the spread between 2003 and 2014 contracts, our redenomination risk premium estimates would be too high, and our segmentation premium estimates would be too low/negative. Our event study results in Section 4.4 would remain unaffected.

In 2012, the Greek government enforced a mandatory exchange of its domestic law bonds for *i*) new Greek domestic law bonds with 30 years to maturity and a new coupon rate of 2%, whose par value of 46.5 cents, to be exchanged for one euro of par value of the old bonds, implied a significant haircut, *ii*) warrants on Greek Gross Domestic Product (GDP),[3] and *iii*) short-term notes to be repaid by the European Financial Stability Facility (EFSF) worth 15 cents of par value. The binding nature of the exchange triggered a restructuring credit event. The hotchpotch of new assets posed a problem for determining the bond's recovery value at default, and thus the CDS's ultimate payoff. Under ISDA 2003 terms, only the new 30-year bonds were eligible for the credit event auction, and the GDP warrants and new EFSF notes were not.

In the Greek case, the outcome of the credit event auction, arguably, did not reflect the real loss suffered by the existing bond holders. The larger the exchange ratio of new bonds per old bond, the lower is the sovereign's remaining debt burden (Duffie and Thukral (2012)). As a result, the price of the new bonds should be higher, all else equal, given the new lower debt burden. Under the

[2]For example, Pan and Singleton (2008) argue that they cannot reliably identify CDS recovery values from a term structure of CDS spreads at low default risk premia, and apply their method to emerging markets (Mexico, Turkey, and Korea) for this reason. In our euro area sample, the maximally observed CDS spread is approximately 180 bps (for Italy, in Spring 2020).

[3]A GDP warrant is a derivative security in which the authorized issuer (a country) promises to pay a return that varies with Gross Domestic Product.

old 2003 terms, as the sovereign increases the aggressiveness of its restructuring, it is, in principle, possible that existing bond holders lose more, and the ISDA 2003 CDS contract pays less.

Under the ISDA 2014 conditions, the APD clause addresses this design flaw in eligibility rules. Specifically, APD now allows market participants to deliver all assets that have been converted in a restructuring event. All these assets are then used to compute the bond's recovery value. In scenarios where bonds are fully expropriated, and no assets are delivered in exchange, the value of the asset package will be deemed to be zero, implying a larger CDS payoff.

E Selected input data plots

This section presents time series plots of selected input data. Figure E.1 plots default risk premia as inferred from five-year EUR CT2003 CDS swap spreads. The top panel of Figure E.2 plots TradeWeb's liquidity measure, which we use as one input into our country-specific liquidity factor. The liquidity measure is computed by TradeWeb from transaction prices vs. price quotes for sovereign bonds within a 2-year to 5.5-year maturity bracket. The bottom panel of Figure E.2 plots the ISDA bases of France, Germany, Italy, and Spain.

Figure E.1: CT2003 CDS spreads

CT2003 EUR CDS spreads in basis points for Germany, France, Italy, and Spain.

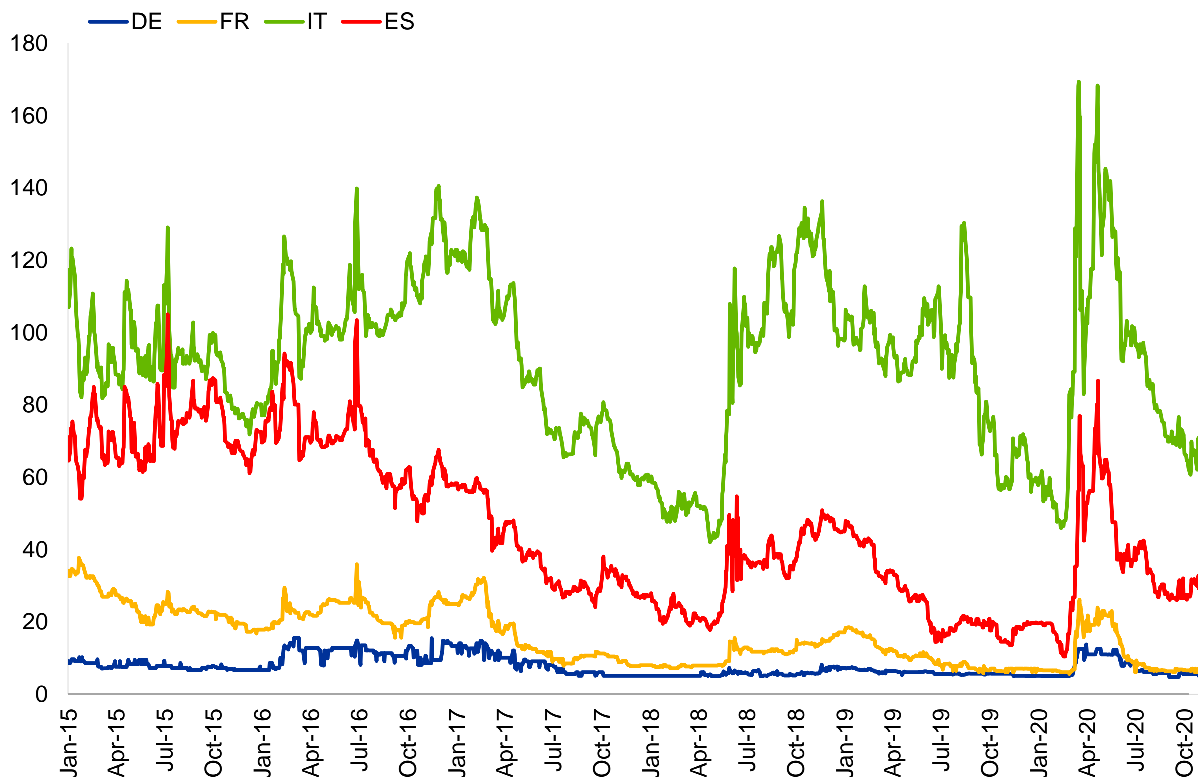
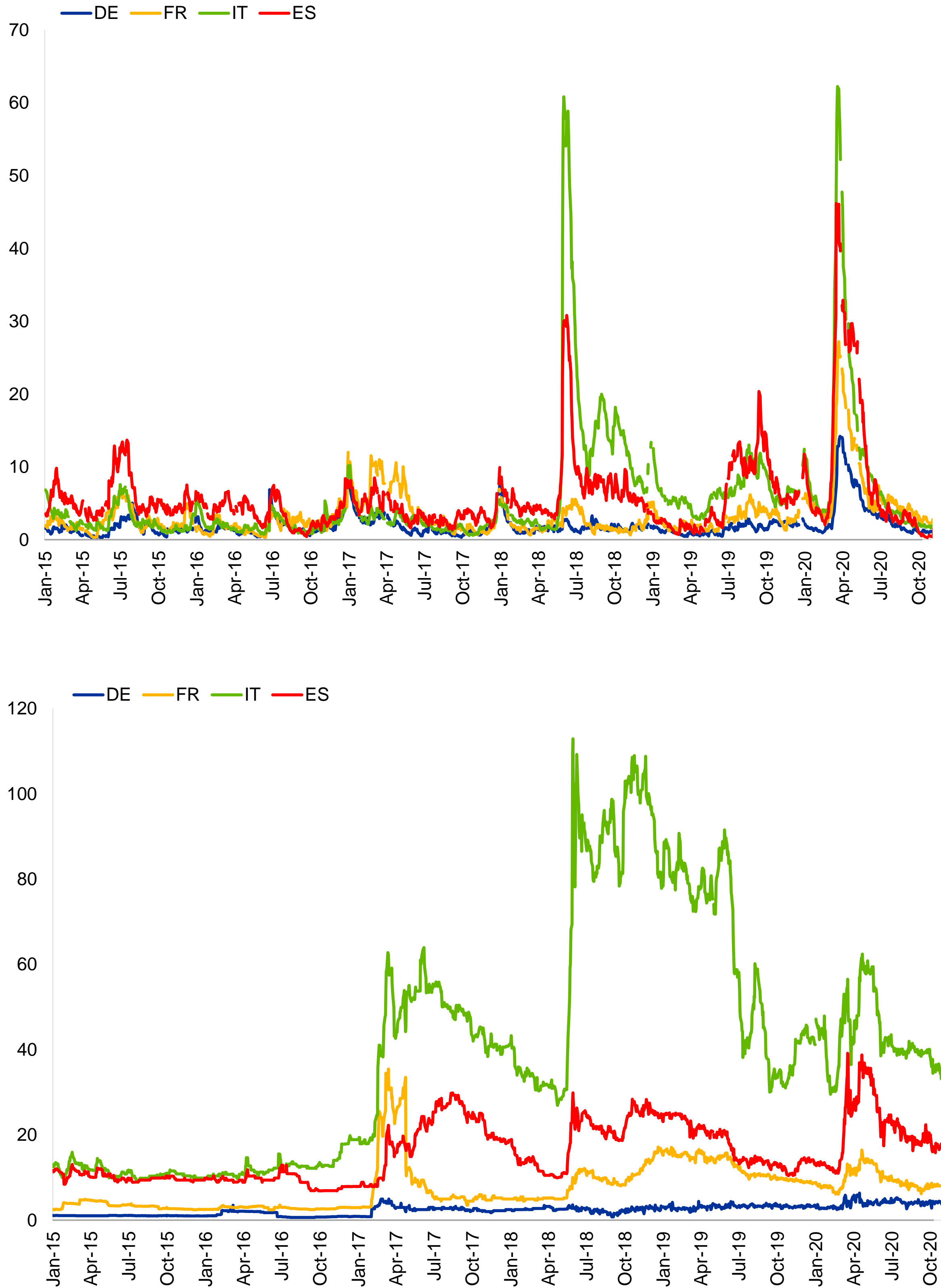


Figure E.2: Tradeweb's liquidity measure (top) and ISDA bases (bottom)

Top: TradeWeb's (il)liquidity measure for sovereign bonds for Germany, France, Italy, and Spain. Bottom: The ISDA bases for the same countries, calculated as the spread between USD CT2014 and USD CT2003 CDS spreads. The vertical axes are in basis points.



F Event study: the ECB's initial announcement of its PSPP on 15 January 2015

This section discusses our event study outcomes associated with the ECB's announcement of its Public Sector Purchase Programme (PSPP) on 15 January 2015. Table F.1 reports the relevant regression results. The ECB's PSPP announcement 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 (column 2), as well as lower default risk premia for Italy and Spain (column 3). The symmetry of the yield responses around the ECB's PSPP announcement on 15 January 2015 is in stark contrast to the ECB's PEPP-related announcements on 18 March 2020 and 4 June 2020, which benefited some vulnerable countries more than others, see Table 2 in the main text.

Table F.1: Event study parameter estimates of PSPP

Impact estimates from the event study regression (4). The event date is 22 January 2015. We consider two-day event windows. P-values are based on Newey and West (1987) HAC standard errors with a one lag bandwidth.

	(1) 5Y Bond Yield	(2) Short Rate & Term Premium	(3) Default Risk Premium	(4) Redenomination Risk Premium	(5) Liquidity Risk Premium	(6) Segmentation Premium
Italy	-8.45*	-5.53***	-8.63***	-0.98**	0.18***	3.56***
	(4.85)	(0.91)	(0.83)	(0.43)	(0.05)	(0.68)
Spain	-10.35***	-5.53***	-5.02***	-1.32***	-0.01	1.20
	(3.66)	(0.91)	(0.10)	(0.06)	(0.19)	(1.10)
France	-6.40***	-5.53***	0.05	0.30***	0.04	-1.37***
	(0.57)	(0.91)	(0.26)	(0.09)	(0.17)	(0.40)
Germany	-6.01***	-5.53***	0.15	0.19*	-0.00	-0.28
	(0.57)	(0.91)	(0.18)	(0.10)	(0.17)	(0.26)

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