Drivers of Convenience Yields

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Abstract

Credit spreads cannot be explained by default risk alone. A significant non-default component in credit spreads reflects the "convenience" of safe sovereign bonds. Using comprehensive eurozone bond and portfolio data, we estimate convenience premia for three key services—liquidity, collateral value, and regulatory capital relief—and decompose AAA sovereign bond yields accordingly. Regulatory capital requirements have been the dominant driver of convenience yields over the past decade, reducing governments' cost of capital by 18 bps—one-fifth of average sovereign yields. Exploiting policy-induced shocks, we show that these services shape asset prices and that monetary and regulatory policies significantly affect bond markets through a "convenience yield channel."

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1 Introduction

The modern asset pricing literature recognizes that investors value financial assets not only for their promised cash flows, but also for the additional services they provide, such as liquidity, collateral pledgeability, and the ability to satisfy regulatory requirements.[1] A common approach to estimating the value of these services is to calculate "convenience yields"—the yield differential between assets that generate comparable cash flows, but different service flows. Although convenience yields explain a significant share of the time series and cross-sectional variation in corporate and sovereign bond valuations, they are typically measured as a residual term.[2] Consequently, convenience yield, albeit key to understanding the cost of capital for government and firm financing, remains an umbrella term that is silent about the precise forces driving the price gap.[3]

We exploit comprehensive bond characteristics and granular sectoral portfolio holdings data in the euro area to decompose convenience yield into three key services: liquidity, collateral value, and regulatory capital value. Our identification strategy relies on constructing a panel of synthetic assets with similar cash flows but heterogeneous service content. Fixed income markets provide an ideal setting for this approach.

We match risky corporate and sovereign bonds with their corresponding credit default swaps (CDS), creating synthetic bonds with nearly identical cash flows but markedly different prices. We then define the CDS-bond basis as the spread between the hedged bond yield and the yield on a duration-matched AAA sovereign bond. The advantage of this approach is that the CDS-bond basis provides a model-free measure of the spread between instruments with nearly identical cash flows but different abilities to provide liquidity, collateral, and regulatory capital relief services. We exploit the large cross-sectional variation in the CDS-bond basis

[1] See, e.g., Brunnermeier et al. [2024], Gorton [2017].

[2] See, e.g., Krishnamurthy and Vissing-Jorgensen [2012], Sunderam [2015], Mota [2023], and Jiang et al. [2025].

[3] A substantial body of literature documents the influence of liquidity premia on corporate bond valuation (e.g., Longstaff et al. [2005], Bao et al. [2011]), while others examine the impact of collateral eligibility (Chen et al. [2023]). The term "convenience yield" in this paper denotes the value of *all* services that contribute to bond valuation beyond cash flows, including liquidity and pledgeability.

to estimate sector-specific premia for each service. We then use ISIN-level portfolio holdings to document that different investor types systematically hold bonds offering distinct service bundles and accept correspondingly lower yields. This cross-sectional variation in ownership patterns allows us to identify sector-specific demand for each service component.

To validate the causal impact of these services on bond prices, we conduct event studies around policy-driven shocks affecting each service: the Solvency II Directive that increased insurance companies' demand for bonds with low implied regulatory capital requirements; changes to the ECB collateral framework that altered the collateral value of certain bonds; and the introduction of corporate QE, which enhanced the liquidity of bonds eligible for ECB purchases. We interpret these interventions as exogenous shifts in either the supply of service characteristics embedded in bonds or investor demand for these services. We find that all three policy changes have large and significant effects on convenience yields and portfolio holdings. These analyses not only validate our choice of service components for the decomposition, but also reveal that regulation and monetary policy have substantial implications for asset prices through the convenience yield channel.

Our central finding is that AAA-rated sovereign convenience yields in the euro area have been primarily driven by regulatory capital requirements for insurance companies and pension funds (ICPF) over the past decade. These regulations compel ICPF to hold safe, high-duration assets, generating substantial demand for sovereign bonds beyond their cash flow characteristics. Consistent with this regulatory channel, portfolios mimicking ICPF holdings have systematically underperformed the market portfolio, indicating that these investors willingly accept lower yields in exchange for regulatory benefits.

Our paper is organized into three parts. First, we build on Fama and French [2007] and Pástor et al. [2021] and present a model in which investors value not only cash flows, but also service flows in financial assets. The preferences for service flows are heterogeneous among investors. The model generates a multifactor representation of bond returns, where factors account not only for traditional risk sources, but also for service flows. As a result, the finance textbook version of the law of one price, which focuses solely on cash flows, does not apply—two assets generating identical cash flows can trade at different prices when they provide distinct service flows. We define convenience yields as the equilibrium expected

return differential between two scenarios: a benchmark case where investors value only cash flows, and an environment where investors also value service flows. A key insight from the model is that investors tilt their portfolios towards assets that provide the services they value most. Thus, variation in portfolio convenience yields across investors stems solely from differences in the value they assign to each service. In equilibrium, convenience yields represent the equilibrium premium investors are willing to forgo to hold assets that provide services they value.

Second, we leverage our model's insights to empirically quantify how various services and investor groups contribute to convenience yields. We collect data measuring three key services: liquidity, collateral value, and ICPF regulatory capital value. We measure liquidity through bid-ask spreads, collateral value through ECB collateral framework haircuts, and regulatory capital value via a combination of Solvency II insurance regulation's "spread risk" parameter and duration. For our empirical analysis, we map convenience yields to the CDS-bond basis.[4] Through the lens of our model, since the synthetic risk-free bond replicates cash flows but not service flows, the CDS-bond basis captures the relative convenience yield between corporate bonds and safe Treasuries. As expected, since risky bonds provide inferior service flows, the CDS-bond basis is on average negative.

There is substantial cross-sectional variation in the CDS-bond basis. We exploit this variation by running cross-sectional regressions at each point in time, following the approach of Fama and MacBeth [1973], to estimate the premium associated with each service. Our main findings indicate that over the past decade, the convenience yield of AAA-rated sovereign bonds in the euro area has been primarily driven by regulatory capital value. More specifically, the premium for assets with high regulatory capital value accounts for 40–60% of the average convenience yield throughout most of our sample period. This translates to AAA sovereigns financing themselves at rates 35 bps lower than other entities on average, with 18 bps attributable to the beneficial regulatory treatment under Solvency II regulation.

[4]We define the CDS-bond basis as the yield spread between the average AAA sovereign bond and the CDS-hedged risky bond. Research about the U.S. market (Bai and Collin-Dufresne [2019], Mota [2023]) has shown that the CDS-bond basis is, on average, negative and increases in credit quality. As we show below, the same pattern emerges for the euro area.

In the third part of the paper, we study policy shocks to the services whose contributions we estimated in the previous part. This serves two purposes: (a) it validates our choice of services for the decomposition of convenience yield, and (b) it illustrates how regulation and monetary policy (conventional or unconventional) are transmitted to asset prices through the convenience yield component.

First, we study how bond-level capital charges for European insurance companies affect convenience yield. We do so by analyzing how the CDS-bond basis and ICPF portfolios behave in response to the EU-wide application of the Solvency II regulatory framework on January 1, 2016. Our approach is inspired by the finding in Jansen [2025] that Solvency II—in particular, the specific regulatory discount curve for insurers' liabilities—incentivized European insurers to hold bonds with maturities around 20 years. We show that after Solvency II became binding, the difference in convenience yields between bonds with low vs. high risk-based capital requirements (in the 20-year duration segment) increases by 20 basis points, and ICPF rebalance towards these high-regulatory value bonds. We interpret these results as evidence that regulatory constraints on the balance sheets of ICPF are key drivers of the convenience yield, particularly by increasing the valuation of bonds with high regulatory value.

Second, we focus on collateral value, which mainly impacts the banking sector. Motivated by the fact that banks are the only entities that can directly borrow from the ECB against high-quality collateral, we study the impact of haircuts (and hence collateral value) on convenience yield. We show that after a change in the ECB's collateral framework that reduced the collateral value of a large class of bank bonds after 2018, the average CDS-bond basis of these bonds fell significantly (by 4–7 basis points, equivalent to 10% for the average bond) compared to that of otherwise similar bank bonds. In response to that shock, banks rebalanced their bond portfolio toward securities with lower haircuts, which emphasizes banks' particular preference for bonds with high collateral value.

Third and finally, we study the impact of the ECB's corporate bond quantitative easing (QE) program, which we interpret as a positive shock to eligible bonds' liquidity properties. In our companion paper [Corell et al., 2025], we show that corporate QE increases the liquid-

ity of eligible vs. ineligible bonds, a result consistent with earlier findings in Todorov [2020].[5] We focus on the ECB's Corporate Sector Purchase Program (CSPP), announced in March 2016, which initiated large-scale acquisitions of investment-grade, non-bank corporate bonds from the euro area. We show that QE announcement caused the spread between the CDS-bond basis of eligible and ineligible bonds to increase by 13.1 basis points, which accounts for 60% of the total decrease in spreads. Consistent with our interpretation of QE enhancing eligible bonds' liquidity, we show that mutual funds—who are subject to redemption risk and thus prefer liquid assets—rebalance their portfolio towards QE-eligible bonds, despite their relative price increase. This finding provides compelling empirical evidence that corporate QE affects not only eligible bonds' default risk, but also their service flows.

Our work offers important insights into corporate bond pricing and how it is shaped by policy decisions. Demand-based asset pricing uses characteristics known to predict returns to estimate investors' heterogeneous demand curves and their impact on asset prices [Koijen and Yogo, 2019; Bretscher et al., 2023]. However, our paper shows that characteristics driving risk and returns alone are not sufficient to fully explain demand for assets. Preferences for specific service flows might be one of the reasons why investors' demand for bonds appears so inelastic to price variation. Furthermore, our empirical tests show that asset-specific service flows vary over time, particularly in response to regulatory and monetary policy changes. Therefore, models that assume time-invariant demand for assets such as Treasuries, due to their non-pecuniary benefits, cannot accurately estimate the impact of supply channels on bond yields. Fundamentally, such models will miscalculate the ability of governments and firms to issue bonds without affecting prices. This demand elasticity is key to understanding governments' fiscal space [Mian et al., 2022].

[5]Our notion of liquidity goes beyond what traditional measures of transaction costs (such as turnover or bid-ask spreads) capture. Similar to Haddad et al. [2023, 2024], we argue that QE conveys the implicit state-contingent promise by the ECB to support the bond market, especially in times of stress. In a companion paper [Corell et al., 2025] we elaborate on this interpretation in more detail. Among other things, we show that mutual funds with more volatile flows—and thus more exposure to redemption and fire sale risk—are precisely the ones who purchase most eligible bonds and partially substitute them for their most liquid assets (such as cash and Treasury bonds).

In addition, the direct impact of regulation and monetary policy on asset characteristics, such as liquidity or collateral value, highlights an important consideration for policymakers regarding the effects of policies on asset prices and capital allocation. In a world with high public debt, particularly among governments of developed countries, actions that force regulated institutions to hold certain assets have a large impact on asset prices and wealth allocation. A large literature on "financial repression" has studied the important role of banks holding sovereign debt (some recent references are Becker and Ivashina [2018], Chari et al. [2020], Jeanne [2025], Payne and Szoke [2025]). Our work shows that the focus should not only be on banks, but also on long-term investors like insurance companies and pension funds that are incentivized to hold certain assets due to the regulatory framework and duration exposure. Furthermore, even if indirectly, policies such as the collateral framework imposed by the ECB affect investors who value collateral, and therefore prices and portfolio allocation. In summary, our paper highlights that policy decisions have a large and heterogeneous impact on the prices of corporate and sovereign bonds.

2 Related Literature

This paper connects several important strands of literature. First, we build on the growing research on safe assets and convenience yields, which highlights the large impact of convenience yields on bond valuation and therefore the cost of capital of countries and firms. Following the work of Krishnamurthy and Vissing-Jorgensen [2012] and Mota [2023], we explore the fact that corporate bonds are imperfect substitutes for traditional safe assets like Treasuries, commanding their own convenience yields. Key to our analyses is that both asset classes carry service flows on their own, suggesting common factors linking convenience yields across different fixed income assets.

Several papers explore the nature of convenience yields. For example, Acharya and Laarits [2023] explore the dynamics of Treasury convenience yields by exploring their relationship with hedging demand. They document the time-varying nature of convenience yields and their connection to broader market conditions. Our work extends this research by exploiting the substantial cross-sectional variation in the CDS-bond basis to identify the specific drivers of convenience yields. We provide novel evidence that convenience yields cannot be explained

by a single factor but rather require a multi-factor framework incorporating services such as liquidity, duration, regulatory capital requirements, and collateral value.

Second, our paper advances the literature on clientele or preferred habitat effects on asset prices (Amihud and Mendelson [1986], Vayanos and Vila [2021]). For example, Amihud and Mendelson [1986] propose a model in which investors differ in their trading horizons, leading to an equilibrium where liquid assets are held by frequent traders and illiquid assets by investors with longer holding periods. Chen et al. [2020] empirically test this theory in the corporate bond market, showing that the non-default component correlates with insurance companies' illiquidity preferences. We extend this framework by recognizing that investors value not only liquidity, but also other services such as pledgeability (Chen et al. [2023]) and regulatory capital advantages (Becker and Ivashina [2015], Koijen and Yogo [2022a], Sen [2023]). Our model incorporates demand for these various services in reduced form, acknowledging their endogenous and time-varying nature. This approach contributes to the emerging literature on investor-specific demand shocks and their impact on asset price fluctuations (Koijen and Yogo [2019] and Gabaix and Koijen [2020]). Our key innovation is to leverage pricing and holdings data to demonstrate how preferences for these services drive portfolio decisions and bond valuation.

Third, we contribute to the extensive literature on corporate bond pricing. Numerous studies establish that default risk alone cannot explain corporate bond valuations (Elton et al. [2001] and Huang and Huang [2012]) and that liquidity significantly affects prices (see Amihud et al. [2006] and Vayanos and Wang [2013] for surveys). Bai and Collin-Dufresne [2019] explore determinants of cross-sectional variation in the US corporate CDS-bond basis and find that multiple measures of arbitrage limits, including collateral value and trading liquidity, affect the basis. Furthermore, Pelizzon et al. [2024] document an "eligibility premium" in European corporate bonds when they become eligible as collateral in ECB repo operations. Similarly, Chen et al. [2023] show that Chinese investment-grade corporate bonds experience significant yield increases when they become ineligible for repo collateral. We build on the idea that corporate bond valuation is influenced by various factors simultaneously beyond cash flows and apply traditional asset pricing techniques to the cross-section of corporate and sovereign bonds to attribute premiums to different services

driving yield spreads.

Fourth, our research expands the growing literature on unconventional monetary policy's impact on asset prices (Andrade et al. [2016], Koijen et al. [2016], Krishnamurthy and Vissing-Jorgensen [2012], Krishnamurthy et al. [2018]). Our analysis of the ECB's corporate QE program relates closely to Todorov [2020] and Breckenfelder and Hoerova [2023], who show that CSPP reduced bond yields and that funds holding eligible bonds experienced better performance during Covid-19 distress. We connect these findings by showing that corporate QE persistently affected convenience yields through enhanced liquidity, with eligibility serving as insurance against fire sale discounts. By demonstrating that interest rates and corporate QE cause significant variation in convenience yields, we present new perspectives on monetary policy transmission through service flows—a channel we explore in detail in our companion paper Corell et al. [2025].[6]

Arguably, collateral policy can also be seen as a form of (unconventional) monetary policy. We are not the first to study the effect of ECB collateral eligibility on the corporate bond market. In particular, Pelizzon et al. [2024] show that when bonds become eligible to be pledged in the "primary" collateral market (i.e., in open market operations with the ECB), their use in the "secondary" money market (so-called securities lending) also increases. In addition, yields decline relative to the control group of ineligible bonds. These findings relate to our paper in two important ways: First, the documented "eligibility premium" in bond prices is consistent with our interpretation of collateral value as a service that gives rise to convenience yield. We go beyond Pelizzon et al. [2024] in showing that ECB collateral eligibility significantly affects not just yields, but the CDS-bond basis. Second, the fact that ECB-induced changes to collateral eligibility spill over to secondary markets suggests that ECB collateral haircuts are a useful proxy for overall collateral value, even though central bank open market operations are exclusively available to banks.[7]

[6]Notice that what we call liquidity services has long been studied in the literature as liquidity premium or risk, see for example Acharya and Pedersen [2005]. The advantage of our framework is the ability to combine other possible services under the same framework.

[7]Pelizzon et al. [2024] use bond-level data from IHS Markit on the fees banks pay in the securities lending market to borrow specific ECB-eligible bonds. Unfortunately, we do not have access to these data, but it

Our work also shares insights with the recent literature on how regulatory and business-model-related constraints affect portfolio decisions for insurance companies and pension funds (ICPF) (see, e.g., Koijen and Yogo [2015], Koijen and Yogo [2022b]), and how these in turn affect asset prices [Kubitza, 2025; Li, 2025]. Specifically, due to their negative duration gap, ICPF have an incentive to hedge against falling interest rates to maintain solvency and—in the case of insurers—comply with Solvency II regulation [Jansen, 2025].[8] Our paper contributes to this literature by showing how these constraints have a large and direct impact on governments' cost of funding, as regulatory capital alone accounts for up to 60% of the AAA-sovereign convenience yield. Moreover, we confirm (and extend) the finding in Jansen [2025] that in response to a reform in the context of Solvency II (which specified the applicable regulatory discount curve), European ICPF shifted their portfolios towards bonds with maturities around 20 years, and away from shorter and longer maturities. As a result, the yield curve steepened at the long end.

3 Model

In this section, we develop an asset pricing model in which investors value financial assets not only for their cash flows but also for the service attributes they provide. Our model builds on Pástor et al. [2021], generalizing their framework from a single non-pecuniary benefit (greenness) to accommodate multiple service dimensions simultaneously. The model characterizes how convenience yields arise from heterogeneous investor preferences over these services and how they relate to equilibrium portfolio allocations. While deliberately stylized, the model delivers a set of clear insights that guide our empirical analysis.

There are N assets indexed by $n \in \{1, 2, \ldots, N\}$ and a continuum of heterogeneous investors indexed by i, each with distinct preferences over the various service attributes. There exists a risk-free asset with return r_t^f in zero net supply. Let $\boldsymbol{r}_{t+1}$ be the $(N \times 1)$ vector of returns in excess of the risk-free rate $\boldsymbol{r}_{t+1} = \boldsymbol{\mu}_t + \boldsymbol{\epsilon}_{t+1}$, where $\boldsymbol{\mu}_t$ contains the

would be an interesting exercise to use them as market-based proxies for bonds' collateral value.

[8] As Alfaro et al. [2024] and Jansen et al. [2023] show, hedging strategies, e.g., based on interest rate swaps, in turn expose these institutions to significant risk of margin calls in the event of rising rates.

expected equilibrium excess returns and $\boldsymbol{\epsilon}_{t+1} \sim \mathcal{N}(\mathbf{0}, \Sigma_t)$.

In addition to returns, assets provide a set of service flows. The services are collected in $\boldsymbol{Z}_t$, a $(N \times K)$ matrix of asset characteristics that determines the quantity of service k provided by asset n. Agents have heterogeneous valuations of services, collected in the loading vector $\tilde{\boldsymbol{\lambda}}_{it}$, a $(K \times 1)$ vector that represents how much investor i values each characteristic k. The service flows therefore have an asset-specific and an agent-specific component:

$$\tilde{\boldsymbol{s}}_{it} = \boldsymbol{Z}_t \tilde{\boldsymbol{\lambda}}_{it}. \tag{1}$$

Investor i's wealth at time $t+1$ is given by $w_{i,t+1} = w_{i0}\left(1 + r_t^f + \boldsymbol{x}_{it}' \boldsymbol{r}_{t+1}\right)$ where w_{i0} denotes initial wealth. Each investor has exponential utility over next period wealth and services:

$$U_i(w_{i,t+1}, \boldsymbol{x}_{it}) = -\exp(-A_i w_{i,t+1} - \boldsymbol{x}_{it}' \tilde{\boldsymbol{s}}_{it}),$$

where A_i is the agent's absolute risk aversion and $\boldsymbol{x}_{it}' \tilde{\boldsymbol{s}}_{it}$ is the total value of service flows the investor derives from her portfolio.

The investor's problem admits a closed-form solution. As shown in Appendix A, the investor's optimal allocation is given by

$$\boldsymbol{x}_{it} = \frac{1}{a_i} \Sigma_t^{-1} \left(\boldsymbol{\mu}_t + \boldsymbol{Z}_t \tilde{\boldsymbol{\lambda}}_{it}\right), \tag{2}$$

where $a_i = A_i w_{i0}$ is agent i's relative risk aversion.[9] For tractability, we assume that $a_i = a$ for all agents and define $\boldsymbol{\lambda}_{it} = \tilde{\boldsymbol{\lambda}}_{it}/a$ the scaled valuation vector of service flows.

Expected Excess Returns We can use market clearing to compute expected returns. Let $\tilde{w}_{i0} := w_{i0}/w_0$, where w_0 denotes total wealth in the economy. Because the risk-free asset is in zero net supply, market clearing implies that the weights of the market portfolio

[9] We model the demand for services in a reduced-form framework which, in many applications, is isomorphic to modeling mean–variance agents subject to regulatory, liquidity, or collateral constraints (e.g. Frazzini and Pedersen [2014]). The key advantage of our approach is its ability to incorporate multiple frictions within a unified framework.

$\boldsymbol{x}_{mt}$ satisfy

$$\begin{aligned}\boldsymbol{x}_{mt} &= \int_i \tilde{w}_{i0}\boldsymbol{x}_{it}\, di \\ &= \frac{1}{a}\Sigma_t^{-1}\left(\boldsymbol{\mu}_t + \boldsymbol{Z}_t\bar{\boldsymbol{\lambda}}_t\right),\end{aligned} \tag{3}$$

where $\bar{\boldsymbol{\lambda}}_t = \int_i \tilde{w}_{i0}\boldsymbol{\lambda}_{it}\, di$ denotes the wealth-weighted valuation of service flows across investors.

For simplicity, we further assume that the market portfolio has zero market-weighted service vector, i.e., $\boldsymbol{x}_{mt}'\boldsymbol{Z}_t = \boldsymbol{0}$. This normalization implies that the market risk premium is independent of agents' preferences for services. Equivalently, we can view $\boldsymbol{Z}_t$ as being defined so that agents derive utility (disutility) from holdings that provide more (or less) services than the market. As we show in Appendix A, expected excess returns are given by

$$\boldsymbol{\mu}_t = \boldsymbol{\beta}_t\mu_{mt} - \boldsymbol{Z}_t\bar{\boldsymbol{\lambda}}_t, \tag{4}$$

where $\boldsymbol{\beta}_t = \frac{\Sigma_t\boldsymbol{x}_{mt}}{\sigma_{mt}^2}$ denotes the vector of market betas and μ_{mt} is the expected excess return on the market portfolio. Equation 4 shows that the CAPM does not hold. In equilibrium, two assets with the same exposure to market risk, $\beta_t(n)$, can have different expected returns because they provide different service flows $\boldsymbol{Z}_t$. We capture this wedge by defining the convenience value of asset n as

$$cy_t(n) = \boldsymbol{Z}_t(n)\,\bar{\boldsymbol{\lambda}}_t, \tag{5}$$

which represents the returns that investors are willing to forgo because of the additional benefits the asset provides.

Investors' Heterogeneous Allocation Using equation (2) together with market clearing, investor i's allocation can be written as

$$\boldsymbol{x}_{it} = \boldsymbol{x}_{mt} + \frac{1}{a}\Sigma_t^{-1}\boldsymbol{Z}_t\left(\boldsymbol{\lambda}_{it} - \bar{\boldsymbol{\lambda}}_t\right). \tag{6}$$

This equation clearly shows that, compared to a benchmark model without service flows, investors deviate from the standard tangency portfolio x_m and tilt their portfolios toward assets that provide services $\boldsymbol{Z}_t$. This represents a deviation from the two-fund separation theorem. Private valuations for services cause investors to tilt their portfolios away from

the market portfolio, and the magnitude of this tilt increases with investors' preferences for services, $\boldsymbol{\lambda}_{it}$, relative to the wealth-weighted average $\bar{\boldsymbol{\lambda}}_t$.

3.1 Model Predictions

We derive three empirical predictions, which we test in the remainder of the paper. The proofs are in Appendix A.

Prediction 1. *The cross-sectional variation in convenience yields is driven by cross-sectional variation in bond-specific service flows,* $\boldsymbol{Z}_t$.

As shown in equation (5), the convenience yield of asset n is given by $cy_t(n) = \boldsymbol{Z}_t(n)\,\bar{\boldsymbol{\lambda}}_t$. Thus, differences in expected returns across bonds with identical exposure to systematic risk arise solely from differences in the services they provide and from the equilibrium price of these services, $\bar{\boldsymbol{\lambda}}_t$.

There is a large literature exploring the characteristics that drive expected returns and their relationship to exposure to systematic risk factors [Fama and French, 1993; Daniel and Titman, 1997; Daniel et al., 2020]. In our setting, not only characteristics related to cash flows, but also characteristics related to service flows explain returns. Thus, omitting characteristics related to service flows would lead to misspecified asset pricing models. The private valuation of these specific services causes bonds to have different prices, even when bonds have identical expected cash flows.

Prediction 2. *Holding all else constant, when investor i's preference for service k increases, the convenience yield rises more for assets with higher Z_t^k. Conditional on risk exposure, the investor increases her allocation toward assets with higher Z_t^k relative to assets with lower Z_t^k.*[10]

An increase in $\lambda_{it}(k)$ raises the wealth-weighted valuation of service k, $\bar{\lambda}_t(k)$. Through equation (5), this increases the convenience yield of assets with higher Z_t^k and, by equation (4), lowers their expected excess returns.

[10]By *risk exposure*, we mean that assets share the same covariance structure of returns (equivalently, the relevant risk adjustment through Σ_t^{-1} is the same within the comparison set).

Moreover, equation (6) implies that investors hold heterogeneous portfolios depending on their valuations of services, $\boldsymbol{\lambda}_{it}$. An increase in investor i's preference for service k induces a portfolio tilt toward assets that provide more of that service, conditional on risk exposure, creating a direct link between preference heterogeneity and portfolio heterogeneity across investors.

Prediction 3. *Holding all else constant, an increase in the service flow k of asset n, $Z_t^k(n)$, induces investors with a higher valuation for service k, to rebalance more strongly toward asset n than investors with lower valuations. As a result, the convenience yield of asset n increases.*

This proposition characterizes the effects of a change in asset characteristics, rather than a change in investor preferences. Equation (6) implies that, for a given distribution of preferences, investors with a higher valuation for service k respond more strongly to an increase in $Z_t^k(n)$ by increasing their holdings of asset n. The resulting increase in demand raises the convenience yield of asset n.

Together, Prediction 2 and 3 highlight two distinct but complementary channels through which service flows affect asset prices: changes in investor demand driven by preference heterogeneity, and changes in asset characteristics that alter the service flow. Both channels generate portfolio rebalancing across investors and lead to systematic differences in expected returns across assets.

4 Data

Our objective is to use variation in convenience yields across assets and investors' portfolios to infer the nature of service flows in financial assets that investors value over and above cash flows. Our exercise requires a rich cross-section of assets with equal cash flows but different expected returns, combined with rich variation in holdings. Due to the richness of the data maintained by the ECB, the euro area is an ideal laboratory for our study. We construct a panel of euro area corporate and sovereign bonds that includes information on yields, CDS spreads, ratings, and detailed investor holdings. The main data come from harmonized datasets maintained by the European Central Bank and the Eurosystem.

4.1 Bond Price Data

The first dataset comes from the Centralised Securities Database (CSDB), which is maintained by the Eurosystem and consists of monthly security-by-security information on instruments, issuers, and prices for debt securities traded in the euro area. For the purpose of our analysis, we restrict our sample to senior unsecured bonds with fixed or zero coupon that are issued by euro area entities (corporate or sovereign), euro-denominated, and that have a residual maturity of at least one year. Moreover, we exclude bonds with an outstanding amount of less than €10 million.

For each outstanding bond, we observe its issuer, issuance size, maturity date, price and yield information, and other bond characteristics. Secondary market prices are recorded in a monthly panel. We add information on long-term credit ratings from the four main rating agencies (Standard and Poor's, Fitch, Moody's, DBRS). If applicable, we use the best available rating of the instrument; otherwise, we use the best issuer rating across agencies. Moreover, we add bond-level information on monthly turnover and average bid-ask spreads from the TraX dataset, provided by MarketAxess. CSDB does not reliably provide some important metrics, like duration. We collect the coupon schedule of each bond and calculate the modified duration for each bond in our sample.[11]

For risk-free rates, we use the ECB benchmark interest rate provided under the euro area yield curves estimation.[12] These are estimated daily using AAA-rated euro area central government bonds. Figure B.11 in the appendix presents the time series of the implied benchmark interest rate for different maturities. We merge the benchmark interest rate with the CSDB data based on the month-year and on the bond's duration to compute the credit spread for each bond. We thus obtain credit spreads for a sample of 29,869 bonds (27,726 of which are corporate) by 2,335 distinct issuers across the sample.

To create bonds with virtually the same cash flows, we need to hedge the default risk. We use credit default swaps (CDS) to do so. We merge the CSDB data with single-name CDS

[11] For a subset of bonds, we obtain duration estimates from the iBoxx index provider. We validate our calculations by achieving a 99% correlation between our estimated durations and those provided by iBoxx.

[12] These benchmark rates are published by the ECB on this website.

data from Markit Inc. The merge is done using the Markit reference obligation mapping, LEI codes, name string matching, and manual searches. The spreads are quoted in basis points per annum for a notional value of $10 million and are based on the standard ISDA contract for physical settlement. The original dataset provides daily market CDS spreads in various types of restructuring documentation clauses. Following a conventional rule, we choose the CDS spreads under documentation clause type as "modified restructuring" (MR), the standard clause type in Europe. The original data set provides a term structure of CDS spreads incorporating maturities of different years.[13] We use a linear interpolation to find the maturity-matched CDS spread for each bond. We only consider CDS spreads with an average quote rating above BBB. The CDS average rating reflects a Markit measure of how reliable a reported CDS spread is.[14] To match the seniority and guarantee characteristics of the underlying bonds, we only consider senior and unsecured CDS.

The combined dataset allows us to calculate the *CDS-bond basis* as the difference between a bond's CDS spread and its credit spread. We discard all observations below the 1st and above the 99th monthly percentile in terms of the CDS-bond basis. Our final sample consists of 17,406 distinct bonds (issued by 486 distinct entities) and 574,805 bond-month observations between January 2014 and August 2025. In terms of outstanding amounts, this CDS-matched sample covers approximately 80% of the initial CDSB sample. Summary statistics regarding all variables used in our analysis can be found in Table 1.

Figure 1 shows the average credit spread and the CDS spread of EA corporate and sovereign bonds for different rating categories in the period from January 2014 to August 2025. Note that this is a period of significant fluctuations in credit spreads across all ratings, with a significant spike in March 2020 that was caused by the Covid-19 outbreak. As expected, the credit spread and the CDS spread are higher for lower rated categories with a significant difference between high-yield (HY) and investment-grade (IG) bonds. In a similar manner, Figure 2 presents the average CDS-bond basis of EA corporate and sovereign bonds, calculated as the difference between a bond's CDS spread and its credit spread, across

[13]Specifically, the maturities included in the data set are of 1, 2, 3, 4, 5, 7, 10, 15, 20 and 30 years.

[14]This filter mitigates the concern that the CDS market is most liquid for contracts with 5 years maturity.

different rating categories. Throughout most of our sample period, the average CDS-bond basis remains significantly negative for all rating categories, indicating that investors are willing to forgo yields to hold AAA sovereign bonds rather than other bonds, even after adjusting for credit risk through CDS hedging. Moreover, the CDS-bond basis exhibits a monotonic relationship with ratings, suggesting a consistent preference for higher-rated bonds, even after controlling for credit risk.

In the absence of frictions, the CDS-bond basis should be zero. The prevalence of negative CDS-bond bases in the market is a well-known empirical regularity in the corporate bond literature (e.g., Longstaff et al. [2005], Oehmke and Zawadowski [2017], and Bai and Collin-Dufresne [2019]). The persistent cross-sectional variation across bonds captures the premium attached to services associated with owning high-quality bonds, such as liquidity, collateral value, and regulatory relief. All these interpretations are consistent with the model in Section 3. However, the basis may also reflect frictions in the CDS market, which might not provide a perfect hedge against default risk. We refer the reader to Mota [2023] for a detailed discussion of why CDS market frictions are unlikely to affect the cross-sectional variation of the CDS-bond basis. For the purposes of our paper, as long as CDS market frictions are relatively small and not particularly correlated with the service flows we aim to estimate, these frictions only add noise to our data without meaningfully affecting our results. There is supporting evidence that frictions in the CDS market are likely very small compared to frictions in the cash-bond market, as CDS are derivatives with highly elastic supply and limited counterparty risk due to overcollateralization.

4.2 Holdings Data

Our analyses also focus on investor heterogeneity with respect to preferences for services associated with different bonds. To analyze this investor heterogeneity, we use data from the Securities Holdings Statistics by Sector (SHSS), which are collected by the Eurosystem. The SHSS dataset provides information at the security level on the amount held by euro area investors. The data is aggregated at the selected investor type level. For our analysis, we group the investor types into the following categories: Banks (defined as deposit-taking corporations), insurance companies and pension funds (ICPF), mutual funds (MF), central

banks, and others (which include non-financial corporations, households, general government, and other financial institutions such as hedge funds). We infer the holdings by the rest of the world (RoW) as the residual—i.e., the difference between the total amount outstanding and the amount held by the sectors mentioned above. The frequency of these data is quarterly. As a final step, we match the price dataset at the ISIN-quarter level with the data on investor holdings.

The holdings data shows large heterogeneity in bond portfolio holdings across investors. For example, as illustrated in Figure 3, sovereign bonds account for 75–85% of the foreign sector's bond portfolio, while the corresponding share for EA mutual funds is only between 50–65%.

Figure 4 presents the investor composition for euro area corporate and sovereign bonds during the period 2011Q2–2025Q2. In aggregate, the largest investors in sovereign bonds are the foreign sector and the ECB, whereas in the corporate bond segment, insurance companies and pension funds (ICPF) and mutual funds (MF) play a similarly large role. Direct holdings of the ECB have been growing significantly after the initiation of its asset purchase programs. At the end of June 2024, the ECB held approximately 13.1% of the total outstanding EA corporate bond market, banks 13.9%, mutual funds 21.1%, ICPF 22.0%, other sectors 7.0%, and the rest of the world 22.8%.

The investor composition differs significantly in the cross-section of bonds, as also documented by Darmouni and Papoutsi [2023].[15] To illustrate the heterogeneity, Figure 5 presents the investor composition of EA corporate and sovereign bonds by rating and maturity at the end of 2024. It is evident that the investor base differs significantly based on these two characteristics of the bonds. Insurance companies and pension funds hold a large share of investment grade corporate bonds, and their holding share increases with maturity, reaching almost 40% of the amount outstanding for IG bonds with remaining maturity above 10 years. Mutual funds, on the contrary, hold a significantly larger share of HY bonds across all maturity categories. The ECB holds only investment-grade bonds, and its holding share

[15]Darmouni and Papoutsi [2023] focus on bonds issued by EA non-financial corporations, while we also include bonds issued by financial corporations.

decreases with maturity. In the sovereign bond segment, the rest of the world and the ECB are the two largest investors, with particularly high foreign shares among AAA-rated sovereign bonds. Banks and ICPF hold large amounts of sub-AAA sovereign bonds, with opposite maturity gradients, as expected. The documented segmentation in the euro area bond market demonstrates that investors value specific bond characteristics differently, and for that reason, we expect this heterogeneity in preferences to have implications for bond prices.

4.3 Service flows

Finally, we need proxies for the service flows that drive convenience yields. We identify three measurable services:

1. **Liquidity**: The ability to liquidate bonds at low or no discount—especially in times of funding stress—is valuable, particularly for investors exposed to redemption risk, such as mutual funds. We measure liquidity by $1 - \textit{bid-ask spread}$, where bid-ask spreads are measured as $\frac{ask-bid}{bid}$.[16]

2. **Collateral value**: Banks can use bonds as collateral to obtain funding from the ECB. The central bank publishes daily lists of the ISINs of securities that it considers eligible collateral—the so-called "eligible assets database" (EADB). Among other things, these lists contain the respective haircut applied to the market value of a given bond. For example, if a bond carries a 5% haircut and a bank pledges 10 million euros of that bond, it can only obtain 9.5 million euros of cash in return.[17] We measure the collateral value of bond n at time t as $1 - haircut_t(n) \in [0, 1]$. Our assumption is that ECB haircuts are also good proxies for haircuts in private markets, such as repo facilities.

[16] We also estimated the value of liquidity using turnover. Our analysis of the cross-section of the CDS-bond basis reveals no premium for high-turnover bonds, and the turnover premium remains largely negligible over time. Thus, we conclude that turnover is not a reliable measure of bond liquidity that is valuable to investors in the euro area.

[17] These haircuts are a function of the bond's issuer sector, residual maturity, credit rating, and coupon structure. For more details, see https://www.ecb.europa.eu/mopo/coll/standards/html/index.en.html.

3. **Regulatory value ($RegValue$):** Regulatory frameworks such as Basel III for banks and Solvency II for insurance companies require minimum capital holdings in proportion to asset values. Regulated intermediaries typically face at least two types of capital requirements: credit risk and interest rate risk. For credit risk, we use the regulatory formula for "spread risk" under Solvency II, measuring risk-based capital (RBC) value as $1 - stress_t(n) \in [0, 1]$, where $stress_t(n)$ increases in both the duration and credit risk of bond n.[18] For interest rate risk, the measure is less direct, as the regulatory capital intensity depends on each institution's overall balance sheet exposure to interest rate changes, which is institution-specific and not directly observable. We use modified duration interacted with the credit risk RBC measure to reflect that, on average and conditional on credit risk, duration may play an additional role through the interest rate risk module. We call regulatory value ($RegValue$) the sum of these two components.

For more details on how we measure collateral and regulatory capital value, see sections 7.2 and 7.1 below.

To support our hypothesis that different investor types have different preferences over the services defined above, we first show the average service content of each investor sector's bond portfolio in Figure 6. The main takeaway is that there is considerable variation across investors in the service flows within different institutions' portfolios, likely due to heterogeneous valuation of these services. Among other things, the figure reveals that (a) the ICPF bond portfolio has the longest duration by far, with banks at the other end of the spectrum; (b) banks hold the bond portfolio with the highest collateral value for most of the sample period; (c) mutual funds hold portfolios with relatively low average risk-based capital value (RBC) and liquidity, which reflects their much lower sovereign share (see Figure 3 above). Similarly, the high average liquidity, collateral, and RBC content of non-EA investors' portfolio (RoW) is due to their high sovereign share.

[18]The exact formula for the stress parameter calculation is reported in Appendix F.

5 Decomposing Convenience Yields

Our objective is to use bond characteristics to quantify the market value of each service k and their relative importance in explaining the convenience yield of AAA sovereign bonds. Hence, this section can be seen as a direct empirical test of our model-implied Prediction 1.

We begin by linking the CDS-bond basis to the three specific service flows we defined above: liquidity, collateral, and regulatory capital value. The reader should view this exercise as a projection of the CDS-bond basis onto these three services. If there are services not included in our analysis that also drive convenience yields, our results could be affected in two ways: there would be a large portion of convenience yield unexplained by our chosen services, or if omitted services are correlated with any of our included services, omitted variable bias would arise, with the correlation determining the sign of the bias. One can always extend our framework to include additional services. We believe that this three-service specification strikes the optimal balance between comprehensiveness and tractability: it captures the economically significant drivers of convenience yield for which we have good measures, and this specification delivers strong empirical performance, explaining up to 90% of the level of AAA sovereign bonds convenience yield, measured as the negative of the average CDS-bond basis.

To see how our model-implied measure of convenience yield maps to the empirically measured CDS-bond basis—defined as the difference between the yields of a risk-free AAA sovereign bond and the duration-matched risky bond whose default risk is fully hedged using a maturity-matched CDS—consider the following: the CDS-bond basis represents the yearly expected return of a portfolio that keeps a long position in the sovereign risk-free bond and a short position in the hedged risky bond, holding both positions to maturity. Under the assumptions that (1) the CDS fully hedges the bond's credit risk, (2) AAA sovereign bonds are default-free, and (3) holding CDS contracts provides no additional services, we can express the CDS-bond basis of bond n as follows, based on equation (4):

$$b_t(n) = y_{T,t} - (y_{i,t} - CDS_{i,t}) = [\boldsymbol{Z}_t(n) - \boldsymbol{Z}_t(T)] \times \bar{\boldsymbol{\lambda}}_t \tag{7}$$

The CDS-bond basis thus directly maps to a bond's convenience yield relative to that of safe sovereigns. Once we make specific assumptions about the number and type of service

flows in the matrix $\boldsymbol{Z}_t$, we can estimate the average service value $\bar{\lambda}_t(k)$ for each of the K services using cross-sectional regressions of the basis on the spread in services between bond n and the duration matched sovereign T.

To estimate equation (7), we construct service spreads by measuring the difference in each service provision between bond n and its duration-matched safe sovereign T. We directly observe collateral values, risk-based capital requirements, and duration for both corporate bonds and sovereigns across all maturities. Crucially, hedging a bond's credit risk with a CDS does not affect its service flows. The hedged bond retains the same haircut in the collateral and regulatory framework as the underlying bond, and similarly for other service characteristics. For liquidity, we measure bid-ask spreads for both bond types, using linear interpolation between the closest-duration sovereigns when an exact duration match is unavailable.[19]

To ensure comparability across services and time periods, we standardize each service measure by subtracting its cross-sectional mean and dividing by its standard deviation before calculating spreads. This normalization allows our estimated coefficients λ_k to be interpreted as the basis points earned by a zero-investment portfolio with one standard deviation of exposure to service k and zero exposure to all other services.[20] The caveat of this approach is that it does not capture changes in aggregate service supply, focusing instead on the relative value of different service types.

The advantage of using the CDS-bond basis rather than bond yields or hedged bond yields is that it allows us to sidestep the difficulties of estimating a credit-risk model or term-premium model, making our decomposition model-free. The disadvantage is that we cannot capture the value of services along dimensions where the basis exhibits no variation. For instance, if high-duration bonds provide service flows to long-term investors relative to short-term bonds, we cannot identify this value because the duration spread in the basis is

[19]This liquidity measure assumes that CDS contracts are sufficiently liquid that their own liquidity does not affect the basis.

[20]To see this, let Z_{st} be the service spread. Notice that the OLS coefficient implies that $\hat{\boldsymbol{\lambda}}_t = (Z_{st}^\top Z_{st})^{-1} Z_{st}^\top \boldsymbol{b}_t$. Define $W_t^\top = (Z_{st}^\top Z_{st})^{-1} Z_{st}^\top$, the $K \times N$ matrix of portfolio weights. The service flows of these portfolios are $W_t^\top Z_{st} = I$, where I is the identity matrix.

zero by construction for all duration-matched bond pairs. Consequently, our approach can only capture the value of services that vary in the cross-section orthogonally to other bond characteristics that map to variations in the CDS-bond basis. This limitation means we potentially identify a lower bound on total convenience yields, isolating only those service flows that generate cross-sectional dispersion beyond what is captured by duration matching and credit hedging.

We assume that measurement error and idiosyncratic shocks affect the observed CDS-bond basis. Therefore, we map equation 7 to the following cross-sectional regression for each month t:

$$b_t(n) = \lambda_{lt} Liquidity_t^s(n) + \lambda_{ct} Collateral_t^s(n) + \lambda_{rt} RegValue_t^s(n) + \varepsilon_t(n) \tag{8}$$

where $b_t(n)$ is the CDS-bond basis of each portfolio n, the superscript s stands for the spread in service between each portfolio n and the duration-matched AAA sovereign, and the services are defined as above.[21] We interpret the estimated $\boldsymbol{\lambda}_t$ as a measure of the value of the three services described above—specifically, the yield investors are willing to forgo to hold a portfolio that, all else constant, is one standard deviation higher service flow.

The estimated premium for each service flow enables us to decompose the convenience yield of any bond or bond portfolio for which we can measure the specific service flows. One portfolio of particular interest is the AAA sovereign bond portfolio, which serves as the safe asset in the euro area. We decompose its convenience yield as:

$$cy_t(T) = \sum_k \hat{\lambda}_{kt} \times \bar{z}_{kt}(T) \tag{9}$$

where $\bar{z}(T)_{kt}$ represents the face-value weighted average of service k across all outstanding AAA sovereign bonds with maturity T.

Table 2 presents the average service values for the full sample.[22] Column (5) demonstrates that premiums for all services are positive on average. Bonds with one standard deviation higher liquidity have, on average, an 11 bps higher (less negative) CDS-bond basis, or equivalently, lower credit spreads. The effect is 12 bps for collateral and 15 bps RBC.

[21] Recall that we define $RegValue_t(n) = RBC_t(n) + Duration_t(n) \times RBC_t(n)$.

[22] The coefficients are the average coefficients from the cross-sectional regressions.

Note that conditional on RBC, an additional one standard deviation in duration (which averages 5 years) increases the basis by another 7 bps. These effects are economically significant relative to the average CDS-bond basis of 34 bps.

The premium for each service is not constant over time. In Figure 7, we report the time series of each λ_k estimate with 5% confidence intervals. Several interesting patterns emerge. First, all services exhibit a pronounced spike in March 2020, though the increase is particularly strong for the RBC component, consistent with investors' rapid need toward satisfying regulatory requirements and seeking safety during the onset of the COVID-19 shock. Second, beginning in 2022—when the ECB initiated the interest-rate tightening cycle—we observe a clear rise in the value of both collateral and liquidity services. Notably, the collateral premium subsequently declined again once the ECB started normalizing policy rates in 2024, mirroring the reduced scarcity value of high-quality collateral in a lower-rate environment. Third, the combined RBC-duration service, which captures the additional value associated with longer-maturity securities, stands out as the most stable component over the full sample, showing comparatively limited fluctuations despite major shifts in monetary and market conditions.

We plot the AAA Treasury convenience yield decomposition resulting from our estimates in Figure 8. Figure 8a plots the same quantities in levels and the negative of the CDS-bond basis.[23] Figure 8b shows the contribution of each service to the explained part of convenience yields.

For most of our sample period, the explained convenience yield is mainly driven by regulatory capital value. This service flow accounts for, on average, 50% of the convenience yields in our sample, highlighting its dominant role across periods. While the relative importance of liquidity has increased over the last four years—reflecting tighter monetary policy and greater demand for liquid assets—its contribution remains below that of regulatory capital value. Notably, even during periods of elevated liquidity demand, the regulatory component

[23]Recall that the CDS-bond basis is negative most of the time, as investors are willing to forgo returns to hold actual Treasuries rather than synthetic risk-free bonds. By including the negative of the CDS-bond basis, we therefore obtain a positive measure of the convenience investors attach to safe Treasuries.

continues to be the primary driver of the convenience yield.

It is important to note that the negative CDS-bond basis need not match the sum of estimated services by construction. Since each service is normalized to have an average of zero at each point in time, alignment between the sum of services and the negative basis requires that the average negative basis equal the average service spread between corporate bonds and AAA sovereigns. Furthermore, our estimation excludes a constant term. Including a constant would capture the component of AAA sovereign bond value *not* attributable to the measured services. However, because regulatory capital requirements (RBC) take a constant value of one for all sovereign bonds, a constant would mechanically absorb part of the RBC coefficient, leading to misspecification. Consequently, the fact that estimated services explain over 90% of the negative basis validates our modeling approach rather than reflecting a mechanical relationship.

6 Investor Specific Valuation of Service Flows and Expected Returns

Our model predicts that investors with higher demand for service flows will accept lower returns, earning negative alphas relative to the market benchmark. Conversely, sectors with lower demand for service flows should earn higher returns and positive alphas. Ideally, we would like to estimate investor valuation for each service directly from holdings data. However, this direct identification is notably difficult and requires valid instruments that vary each service orthogonally to other drivers of demand. Such well-identified estimates are typically limited to specific time periods or particular settings where appropriate variation exists, making it difficult to obtain estimates across our full sample period. Before we explore plausible sources of variation in services in the next section, we first seek to shed light on which investors' demand is most important in explaining convenience yields.

For that purpose, we adopt an indirect approach based on portfolio performance. By constructing portfolios that mimic each investor sector's holdings and examining their alphas, we can identify which sectors value service flows the most. If an institutional investor's portfolio systematically underperforms benchmark asset pricing models, by revealed prefer-

ence the investor likely values service flows, thereby bidding up prices and depressing returns on their preferred assets.

Our empirical strategy constructs portfolios with high exposure to each investor type's holdings while maintaining neutral exposure to traditional risk sources, as represented by $\boldsymbol{\delta}$ in our model. Recognizing that credit and duration risk are the primary drivers of bond returns, we employ a triple-sorting procedure. First, we sort bonds into rating and maturity buckets. Within each bucket, we then sort bonds by the share of amount outstanding held by each investor class. Bonds in the top 30% by holdings share are classified as "high," while those in the bottom 30% are classified as "low." Portfolio returns are calculated as the value-weighted average return within each bucket. We then construct a long-short portfolio for each investor type that takes long position in all high holdings share portfolios and short position in all low holdings share portfolios. To align portfolios with corresponding returns, we use holdings information available at time $t-1$ and returns at time t. Portfolios are rebalanced quarterly, returns are calculated weekly, and excess returns use the weekly EURIBOR rate as the risk-free rate.[24] This approach builds on the idea that portfolios exhibit strong clienteles that affect asset returns [Balasubramaniam et al., 2023]. Because our portfolios are designed to be orthogonal to credit and duration risk, they can be viewed as the institutional version of holdings-based factors along dimensions beyond these two primary risks.

Figure 9 shows the portfolio returns of the triple-sorted portfolios for all investor classes, plus the market portfolio. As one can see, even though they are rating- and duration-neutral, these portfolios have very different returns. The ICPF-based portfolio exhibits the lowest realized return in the sample, followed by the bank-based one. The RoW-portfolio is the one with the largest realized returns, whereas the mutual fund-based portfolio shows relatively flat realized returns.

We can now formally test whether portfolio holdings help to price the cross-section of bond returns. To do so, we run the following time series regression for each triple-sorted long-short portfolio i:

$$r_{it} = \alpha_i + \beta_{it} r_{m,t} + \beta_{it} r_{term,t} \varepsilon_{it} \tag{10}$$

[24] Weekly returns are obtained from iBoxx.

where $r_{m,t}$ is the market factor (CAPM) which is the value-weighted portfolio of all assets in excess of the risk-free rate, and $r_{term,t}$ is a term factor, which is the 10-year minus 1-year AAA Treasury returns.

We note that data from the Covid-19 period should be treated with caution for two main reasons. First, there is an increase in correlation across various asset classes during the crisis period, which could potentially obscure the normal relationships we aim to investigate. Second, there is likely to be a shift in the premia for bond services during periods of uncertainty, which may affect our results. Specifically, we observed a tendency for the alphas of banks and pension funds to become less negative and those of mutual funds and the rest of the world to become less positive during the Covid-19 period. However, it is important to note that these changes in alphas were not statistically significant, and the number of observations during this period was very limited (8 weeks). Therefore, conclusions from this period should be viewed carefully.

Table 3 consolidates these findings. Portfolios tilted towards insurance and pension fund holdings show significantly negative weekly alphas of -0.020%, which annualizes to -1.03%. Bank alphas, while not statistically significant, lean negatively as well, but at a reduced magnitude. Mutual funds and ECB holdings do not show significant alpha, contrasting with the significantly positive alpha for the rest of the world holdings, at 0.021% weekly or 1.10% annually. These outcomes are consistent with the asset pricing model's prediction that heterogeneous preferences for service flows are a critical driver of bond return differentials.

Furthermore, we interpret these results as strong evidence that ICPF is the sector that values regulatory services most and that their demand for high regulatory value assets is a key driver of convenience yields in our sample. This interpretation rests on three findings: first, the ICPF mimicking portfolio exhibits significant negative alphas; second, regulatory value commands the largest premium among all services in bonds; and third, the regulatory value service was explicitly designed to capture the regulatory constraints faced by this sector. Together, these results suggest that ICPF demand for regulatory compliance drives a substantial portion of bond convenience yields.

7 Policy-Driven Changes to Service Flows

So far, we have analyzed and estimated the drivers of convenience yields in the cross-section of European bonds. To do so, we had to make explicit assumptions about the services that investors value. However, without exogenous variation in services or preferences, we cannot gauge the causal impact of services on prices or portfolio allocation. In the remainder of this paper, we exploit policy shocks that provide exogenous variation in services or preferences to validate our empirical approach. We study three types of policy shocks, each targeting a different service. Our objectives are threefold: first, to provide causal evidence that the services we measure impact convenience yields and portfolio allocation; second, to demonstrate that investors' private valuations for services are heterogeneous across sectors; third, to show that policy decisions have substantial effects on both convenience yields and portfolio allocation. In this way, the empirical results that follow allow us to test the predictions developed in Section 3.

7.1 Regulatory Capital Requirements in the Insurance Sector

First, we turn our attention to the insurance sector, which underwent significant regulatory changes in January 2016, when the Solvency II framework became fully applicable in the EU.[25] Solvency II harmonized the regulation of insurance companies across Europe, which had previously been subject to national rules. In particular, regulators specified common standards for the calculation of insurers' "Solvency Capital Requirement" (SCR)—capital buffers designed to withstand losses emanating from different risk sources. As a result, bonds differ in how much capital they implicitly require on the holder's balance sheet. To the extent that equity is more expensive than debt, we hypothesize that—among two otherwise

[25]Key legal acts included the "Solvency II Directive" 2009/138/EC and the Delegated Regulation (EU) 2015/35. As any Directive, Solvency II had to be transformed into national legislation in each Member State separately, and the implementation timelines varied by country. By January 1, 2016, all aspects of the framework—including technical details specified in the 2015 Delegated Regulation—had to be fully implemented. Due to potential anticipation effects and varying timelines, the estimates in this section should not be interpreted as causal.

identical bonds—insurers prefer the one that requires less capital. Our model then suggests that insurers may be willing to forgo yields to hold such assets, resulting in portfolios with high convenience yields due to capital constraints.

To test our model-implied Prediction 2, we interpret the implementation of Solvency II as a positive shock to insurance companies' appetite for (a) bonds with low risk-based capital charges, and (b) bonds with durations around 20 years [Jansen, 2025]. We explain our reasoning in the following paragraphs:

The basic SCR, as defined in Art. 87 of Delegated Regulation (EU) 2015/35, is a function of the capital charges arising from each of the following "risk modules" and their correlations: (a) *Underwriting risk*, which refers to the risks that are inherently associated with the insurance business, e.g., the risk of claim settlements, natural disasters, or longevity/mortality risk in the case of life insurers; (b) *Market risk* that arises from fluctuations in the market value of insurers' assets and liabilities; and (c) *Counterparty risk*. Since underwriting risk depends purely on insurers' liabilities, for the purpose of our analysis, we focus on (b), and more specifically on the so-called *spread risk* and *interest rate risk* sub-modules.

First, *spread risk* is defined in Art. 176 of the above regulation, which specifies a bond-specific *stress* function that takes values between 0 and 1, decreases with the bond's credit quality and increases with modified duration.[26] The *stress* value reflects the hypothetical adverse-scenario loss in the bond's value that the insurer's capital needs to withstand. Hence, bonds with a higher *stress* value command more capital per unit of market value held. Importantly, any sovereign bond issued by Member States is assigned a *stress* value of zero, i.e., they carry no spread risk-related capital charges. As described in Section 4.3 above, we use $RBC_t(n) = 1 - stress_t(n)$ as a measure of the risk-based regulatory capital value of bond n at time t.[27]

[26] We report the exact formula in Appendix F.

[27] It is worth noting that according to Art. 83(4) of the Delegated Regulation, insurers can engage in *risk mitigation* techniques that lower their implied capital requirements if they comply with certain conditions (specified in Arts. 209–215 of the same Regulation). For example, if an insurer hedges a bond's credit risk by holding the corresponding CDS, the hypothetical adverse-scenario net loss (and thus the required capital under the spread risk module) is reduced. However, holding CDS will give rise to additional capital requirements through the *counterparty risk* module in most cases. As a result, to maintain low overall capital

Second, to capture changes in the *interest rate risk* sub-module, we closely follow Jansen [2025], who argues that Solvency II incentivized European insurers—particularly in countries that had previously used historical cost accounting—to hold bonds with durations around 20 years. In these countries, insurers' liabilities had largely been insensitive to long-term interest rate fluctuations. Solvency II, however, introduced fair value accounting and a discounting method based on the "ultimate forward rate" (UFR), prompting insurers in these countries to rebalance their sovereign bond portfolios toward 20-year bonds and away from longer and shorter maturities.[28] The argument is based on the fact that insurance companies and pension funds are exposed to large negative duration mismatches between their assets and liabilities [Domanski et al., 2015; Koijen and Yogo, 2022b].[29] This means that when long-term interest rates decline, the value of liabilities typically increases by more than the value of assets, which pushes insurers closer towards their solvency constraints. To hedge this risk (and keep implied capital requirements low), insurers must match the duration of their asset portfolio to that of their liabilities. Moreover, since the UFR made liabilities "more sensitive to changes in the 20-year rate, but less sensitive to changes in longer maturity rates" [Jansen, 2025], 20-year bonds became more attractive than other maturities to minimize regulatory capital requirements.

We start by examining whether the EU-wide application of the Solvency II framework in January 2016 influences the convenience yield of bonds with high RBC value differently than those with lower regulatory value, especially in the 20-year duration segment. Specifically,

requirements, bonds with high RBC value are generally preferable. In practice, hedging bond credit risk via CDS is rarely relevant for insurers anyway. Their bond portfolios are typically investment-grade and well diversified, whereas CDS are issuer-specific and require complex matching and accounting procedures.

[28] We confirm these results from Jansen [2025] in our own sample and report the results of this replication exercise in Appendix G.

[29] Although pension funds in the EU are not subject to a harmonized regulatory framework like Solvency II, their negative duration gap (and hence the risk of underfunding when interest rates are low) suggests that they are subject to qualitatively similar constraints.

we estimate the following model:[30]

$$b_t(n) = \beta \times HighRBC_t(n) \times 20y_t(n) \times Post_t + \alpha_{r\times m} + \alpha_t + u_t(n) \tag{11}$$

In this equation, $b_t(n)$ represents the CDS-bond basis of bond n and $HighRBC_t(n)$ is a dummy indicating whether bond n's risk-based capital relief exceeds the cross-sectional median at time t. $20y_t(n)$ is another dummy that is 1 if bond n has a modified duration between 15–25 years at time t, as in Jansen [2025]. Finally, the dummy variable $Post_t$ is equal to 1 for all months after (including) January 2016, and zero otherwise. We also include month and rating-by-time-to-maturity fixed effects, and we estimate the triple-difference model in the period from January 2015 – December 2016.

Prediction 2 in our model states that when demand for a specific service increases, bonds that provide more of that service will experience an increase in convenience yields. This maps directly to our hypothesis that β will be positive: following the Solvency II shock, bonds with high regulatory capital value should exhibit increased convenience yields relative to low-RBC bonds, conditional on having a duration of around 20 years.[31]

The results reported in Table 4 confirm our prior. Specifically, column (1) shows that after the Solvency II reform and conditional on having a duration around 20 years, the CDS-bond basis is approximately 20 basis points higher for bonds with above-median RCB value compared to those below the median. This result is highly statistically significant and persists qualitatively even if we replace the $20y$ dummy by modified duration as a continuous variable (see column (2)).

Our model further implies that if investors experience a positive change in their taste for specific services, they rebalance their portfolios towards assets providing these services. Therefore, we next analyze portfolio rebalancing behavior. Specifically, for each investor

[30]The regression we estimate is fully saturated, but we omit some interaction effects and standalone coefficients here for brevity.

[31]Conditioning on duration is important because the formula to calculate RBC assigns different weights to bonds based on their duration. Therefore, omitting the interaction with duration would imply that RBC largely proxies inversely for duration. An equivalent interpretation of our finding is that, conditional on duration, the CDS-bond basis of safer bonds (including sovereigns) increases after Solvency II implementation relative to that of riskier bonds.

sector i we estimate[32]

$$x^i_{ct}(n) = \beta^i \times HighRBC_t(n) \times 20y_t(n) \times Post_t + \alpha_c + \alpha_{r\times m} + \alpha_t + u_{ict}(n), \qquad (12)$$

where $x^i_{ct}(n)$ is the portfolio weight of bond n in the portfolio of investor type i from country c in quarter t, and all other variable definitions remain unchanged. The regression includes investor country, time, and rating-by-time-to-maturity fixed effects, and our estimation window is 2014Q4 – 2016Q4. Following Jansen [2025], we only include investor countries that had applied historical cost accounting prior to Solvency II, which should amplify the incentive to rebalance toward longer maturities, especially around the 20-year mark. Our hypothesis is that β^i is positive for ICPF, as they rebalance toward high-RBC bonds (conditional on 20-year duration) in response to the implementation of Solvency II on January 1, 2016. Strikingly, as column (3) of Table 5 shows, our estimate is positive and significant *only* for ICPF—consistent with the implicit assumption that Solvency II and our RBC measure are specific to this sector. Numerically, the estimate means that, after Solvency II became binding, the portfolio share of high-RBC bonds increased by 1.2 basis points more than that of low-RBC bonds (within the set of 20-year bonds). Given that ISIN-level portfolio shares are numerically quite small, this estimate corresponds to an economically meaningful increase of 33% relative to the average portfolio share of 3.5 basis points.

In conclusion, the results presented in this subsection serve two purposes: (a) they validate the argument in Jansen [2025] about how Solvency II (and, in particular, the introduction of the UFR in discounting insurers' liabilities) affected insurers' regulatory incentives to hold long-term, safe bonds; and (b) they validate our measure of risk-based regulatory capital value as a quantifiable service that ICPF value and that gives rise to convenience yield.

7.2 Collateral Value for the Banking Sector

We now turn our attention to banks and the fact that they are the only institutions that can borrow directly from the ECB by pledging high-quality bonds (incl. corporate bonds)

[32]Again, the underlying regression we estimate is fully saturated, but we only report the coefficients of interest here for brevity.

as collateral. Therefore, ECB collateral eligibility is a service that banks are particularly likely to value. In line with this hypothesis, banks clearly emerge as the sector that holds bonds of the highest collateral value (i.e., the lowest haircuts) in Figure 6 above. After a strong drop in December 2018, euro area banks replenished their collateral pools by buying disproportionately more collateral-eligible bonds.

The striking drop in the average collateral value of banks' bond holdings in December 2018 was caused by the loss of eligibility of a large set of German bank bonds, providing us with a useful policy experiment that can help understand the drivers of bond convenience yields. More precisely, in December 2017, the ECB announced that (statutorily) *subordinated* unsecured bank bonds (sUBB) issued before April 16, 2018 would cease to be eligible for ECB collateral after December 31, 2018. Due to differences in the national implementation of Directives across European Union (EU) Member States, this shock only affected sUBBs issued by German banks.[33]

This change in collateral eligibility offers a clean shock for studying the value of pledgeability and how it maps to the CDS-bond basis. The most useful aspect of this experiment is that the loss of eligibility occurs orthogonally to other bond characteristics, such as credit risk and residual maturity. Using the publicly available EADB data, we can identify the set of German sUBBs and interpret the outright loss of their collateral value as a reduction in the service flows that these bonds provide. To test this hypothesis formally, we compare the average CDS-bond basis of eligible German sUBBs issued before April 2018 (the "treatment group") with that of a control group (consisting of eligible bank bonds from other EA countries), before and after the loss of eligibility at the end of 2018. Specifically, we estimate the DiD equation

$$b_t(n) = \beta\, German(n) \times Post_t + \alpha_t + \alpha_n + \alpha_{r\times m} + \varepsilon_t(n), \tag{13}$$

where $b_t(n)$ denotes the CDS-bond basis of bond n in month t, $German(n)$ is a dummy variable identifying bonds issued by German banks, and $Post_t$ is a dummy variable equal to one for all months after (and including) December 2018, and zero otherwise. α_t, α_n,

[33]See Appendix E for a more detailed account of the collateral framework amendment regarding sUBBs, including a timeline of events.

and $\alpha_{r\times m}$ are placeholders for time, bond, and rating $\times$ residual maturity fixed effects, respectively.[34] Since bank bonds often exhibit small lot sizes, we weight observations by outstanding amounts to reduce the impact of small issuances. We estimate equation (13) during the period June 2018 – June 2019 and present the results in Table 6. In line with our hypothesis that collateral eligibility is a major driver of convenience yield, the loss of eligibility of German sUBB leads to a statistically significant drop in the CDS-bond basis of 4–7 basis points relative to bank bonds from other countries. The baseline estimate is robust to using variation within rating $\times$ maturity buckets and even within ISINs for identification. Given an average pre-shock CDS-bond basis of -40 basis points, even our smallest estimate corresponds to an economically meaningful 10% reduction in convenience yield.[35]

To complement our analysis of the impact of ECB collateral eligibility on bond prices, we now look at the quantity response, i.e., the portfolio rebalancing behavior of European banks. As Figure 10 illustrates, banks started decreasing their aggregate holdings of German sUBB relative to other eligible senior bank bonds immediately after the ECB announced in December 2017 that German bonds would lose eligibility one year later. More precisely, between the start of 2017 and the actual loss of eligibility at the end of 2018, banks' holdings of German sUBB (as a share of their total outstanding amount) fell by almost 5% whereas holdings of other eligible bank bonds rose by 5%.

For a formal test, we again employ a DiD design and estimate the following equation, where we only focus on collateral-eligible senior bank bonds issued before April 2018 to keep the treatment and control group as similar as possible:

$$\frac{B_{it}(n)}{\sum_n B_{it}(n)} = \beta_i German(n) \times Post_t + \gamma_i German(n) + \alpha_c + \alpha_t + \alpha_{r\times m} + \varepsilon_{it}(n) \qquad (14)$$

To ensure a tight correspondence between the empirical specification and the theoretical

[34]Specifically, we construct twelve rating-maturity buckets where each bucket is a combination of one of three rating categories (AAA–A, BBB, or high-yield) with one of four residual maturity categories (1-3y, 3-5y, 5-10y, 10-30y). The corresponding fixed effects control for duration and credit risk. In a benchmark model with no demand for service flows, these would be the two main sources of risk driving investors' portfolio allocation and prices.

[35]We also verified that, before the loss of eligibility, the average CDS-bond basis of both treatment and control group followed parallel trends, strengthening our identifying assumption.

model predictions in equation (2), $B_{it}(n)$ denotes the market value of investor i's holdings of bond n in quarter t, so the left-hand side expression can be interpreted as the weight of bond n in investor i's portfolio of bank bonds. As in the previous equation, $German(n)$ is a dummy variable identifying bonds issued by German banks, and $Post_t$ is a dummy variable equal to one for all quarters after (and including) December 2017, and zero otherwise. α_c, α_t, and $\alpha_{r\times m}$ denote investor country, time, and rating $\times$ residual maturity fixed effects, respectively. Controlling for unobservable time-invariant investor country characteristics via α_c is particularly important here, since the loss of eligibility is country-specific and it is well known that investors' portfolios exhibit "home bias". We estimate equation (14) separately for each investor sector during the period 2016Q4 – 2018Q4.

The results are summarized in Table 7. The statistically significant estimate of interest in column (1) implies that European banks reduced the share of German bank bonds in their bank bond portfolios by 4.5 basis points on average (compared with the control group) in response to the announced loss of collateral eligibility. Since the average portfolio share at the bond level in the estimation sample amounts to 0.3%, the estimate corresponds to a significant reduction of 15% for the average bond. Crucially, we do not find the same rebalancing response for the other investor sectors (which arguably do not value ECB collateral eligibility).

Taken together, these results confirm Prediction 3 above and suggest that the "service flow" of collateral eligibility is a major component of convenience yields in euro area bonds.

7.3 Corporate QE as a Shock to Bond Liquidity

Finally, we study the effect of corporate QE announcements on corporate bond prices and convenience yields. We show evidence that bonds eligible for the ECB purchases experienced an increase in their liquidity service—a service especially valued by mutual funds.

We study the Corporate Sector Purchase Program (CSPP), announced in March 2016 and launched in June 2016, which introduced large-scale net purchases of investment-grade non-bank corporate bonds in the euro area. In total, the ECB accumulated more than €400 billion by 2023, or approximately 15% of the total European corporate bond market.

Various criteria determined the eligibility of the bonds to be purchased under the CSPP.

Specifically, the CSPP was limited to investment-grade non-bank corporate bonds issued in the euro area. Only bonds with a remaining maturity of between 6 months and 31 years and with a yield to maturity (YTM) above the ECB's deposit facility rate were CSPP-eligible.

The exogenous nature of the CSPP announcement allows us to employ a difference-in-differences (DiD) identification strategy to study the impact of the program on bond yields and their decomposition into credit spreads, CDS spreads, and the CDS-bond basis for eligible versus ineligible bonds. Our main specification is:

$$y_t(n) = \theta \, Treat_t(n) \times Post_t + \alpha_{r \times m} + \alpha_t + u_t(n) \tag{15}$$

For each bond n and month t the dependent variables $y_t(n)$ are: corporate bond yields, credit spreads, CDS-spread, or the CDS-bond basis. $Treat_t(n)$ is a dummy equal to 1 if the bond is eligible to be purchased under the CSPP,[36] and $Post_t$ is a dummy equal to 0 for the period preceding the announcement date of the respective purchase program, and 1 after it. We include month and rating $\times$ maturity fixed effects, just as in the previous subsection.

The identifying assumption is that, in the absence of the ECB purchases, corporate bond yields, credit spreads, CDS spreads, and CDS-bond basis of the treatment group and the control group would have maintained parallel trends. Regardless of the parallel trend assumption, one could still worry that eligible and ineligible bonds are fundamentally different, and that ECB decisions could potentially be concurrent with other news that affect the two groups differently. For example, the announcement of ECB purchase programs is usually a response to the deterioration of an economic scenario. Since eligible bonds are, in general, of higher credit quality than non-eligible bonds, they might be less exposed to macroeconomic

[36]The eligibility criteria for the CSPP can be summarized in the following: a) to be rated by accepted external credit assessment institutions and third-party rating tools and to have a minimum rating of BBB-; b) to have initial maturity of 367 days or more and the minimum remaining maturity to be six months and the maximum remaining maturity 30 years and 364 days; c) to be euro-denominated; d) to be issued in the euro area; e) the issuer to be established in the euro area and the place of settlement to be in the euro area; and f) to have either a fixed and unconditional principal amount or an unconditional principal amount that is linked, on a flat basis, to only one euro area inflation index at a single point in time, containing no other complex structures. Further criteria are included with respect to acceptable markets and coupon payments, but they do not apply for our analysis as the sample used in the analysis is already restricted.

risks. Therefore, the ex-post credit spread gap between the groups might just be the consequence of a higher risk premium. We believe that the CDS-bond basis analyses are not subject to this critique. Any variation in the risk premium that affects default should be reflected in the CDS-spreads, since the payoff of the CDS is directly linked to the default probability. Furthermore, our empirical methodology mitigates concerns about the mismeasurement of the default component of credit spreads. Any friction that could affect CDS spreads and is not related to default risk, such as counterparty risk, would have to affect treatment and control group differently in order to affect our results. This is not likely to be the case.

To estimate the baseline equation (15), we define six months before the announcement date as the pre-period and six months after as the post-period. We differ from other studies (most importantly, Todorov [2020]) and include a longer window around the event. Our longer window is crucial to connect these results to the portfolio rebalancing exercise that follows. Holdings are unlikely to change significantly in very short windows, especially when considering long-term investors such as insurance companies and pension funds. Therefore, our exercise is only valid because we observe a persistent price impact from the CSPP announcement.

In Table 8, we examine the impact of the CSPP in March 2016. We find that the CSPP decreased the credit spread of eligible bonds with respect to ineligible bonds by 22.1 basis points, consistent with our Prediction 3. In columns (3) and (4), it is shown that the decrease in credit spreads is explained mainly by the non-default component of the spread, the CDS-bond basis, and less by the default component, the CDS spread.[37]

Our last step is to understand *why* ECB eligibility caused an increase in the convenience yield of eligible bonds. To unveil the mechanism through which the corporate QE program of the ECB affect corporate bond prices, we need to look at the response of different investors around the program announcement.

For that reason, we estimate the effect of the ECB corporate QE program on portfolio rebalancing, using micro-level holdings data. Holdings information at the ISIN-level allows

[37]We verify the parallel trend assumption in Appendix H.1.

us to analyze the heterogeneous investor composition and infer how different investors value the QE-eligibility feature.

Specifically, we use a DiD specification where the dependent variable is the portfolio share $x_{it}^{c}(n)$ for each investor type i, in country c, in asset n, and quarter t.

$$x_{it}^{c}(n) = \psi_i Treat(n) \times Post_t + \alpha_{r\times m} + \alpha_{c\times t} + \varepsilon_{i,t}(n) \tag{16}$$

where the time-varying outside option of investors in country c is captured by $\alpha_c \times \alpha_t$.

Maturity $\times$ rating fixed effects are meant to capture duration and credit risk. Holder country $\times$ quarter fixed effects are meant to capture investor-specific demand (which is likely to be country-specific) and time-varying outside options.

The results are reported in Table 9. They show that the CSPP announcement caused an increase in holdings for eligible bonds only for mutual funds, while all other investor sectors decreased their holdings of eligible bonds relative to ineligible. This finding aligns with the hypothesis that mutual funds strategically maintain eligible bonds, even when they appear relatively expensive compared to other bonds with similar credit and duration risks.

These results are striking, as we observe that mutual funds buy more eligible bonds as they become more expensive, even though the mutual fund sector is believed to be very price elastic (Koijen et al. [2021]). We explain this pattern by arguing that QE announcements affect prices not only through supply changes, but also by altering the liquidity properties of eligible bonds.[38] In particular, because mutual funds place particular value on liquidity, and they are the ones who rebalance most strongly toward eligible bonds, we view this as evidence that QE fundamentally changes the liquidity services of eligible bonds. We provide comprehensive additional evidence for this interpretation in our companion paper Corell et al. [2025].

[38]The liquidity concept here is broader than the bid-ask spreads we measured in the previous section. It encompasses the expectation that the ECB will step in to purchase these bonds, especially in times of distress.

8 Conclusion

The bond market serves as a crucial financing source for corporations and governments. This paper demonstrates that investors value bonds not only for their cash flows but also for the additional services they provide. Using comprehensive data on euro area corporate and sovereign bonds, we decompose convenience yields into three measurable service flows—liquidity, collateral value, and regulatory capital relief—and show how heterogeneous investor preferences for these services drive cross-sectional return patterns and portfolio allocations.

Our findings reveal that regulatory capital value is the dominant driver of convenience yields in the euro area bond market. During most of our sample period, it explains 40–60% of AAA sovereign convenience yields, reflecting the significant influence of insurance corporations and pension funds in driving convenience yields.

The policy implications are far-reaching. We provide compelling evidence that monetary and regulatory policies transmit to asset prices through service flows. The ECB's corporate QE program illustrates this vividly: around 60% of the observed price impact operates through convenience yields rather than credit risk reduction, fundamentally altering the liquidity characteristics of eligible bonds. Similarly, when the ECB modified its collateral framework in 2018, we observe immediate effects on both bond prices and portfolio allocations as banks rebalanced toward securities with higher collateral value.

These results suggest three key implications for policymakers. First, regulatory design should consider the unintended consequences of capital requirements on asset pricing and market stability. Second, central banks possess powerful tools to influence specific market segments through service flows, opening new avenues for monetary policy. Third, our findings extend the financial repression literature by showing that the focus should not be solely on banks holding sovereign debt, but on long-term investors like insurance companies and pension funds who are directly compelled by regulatory frameworks to hold certain assets. This regulatory-induced demand has large cross-sectional effects on bond prices, fundamentally affecting the cost of capital for governments and corporations.

From a methodological perspective, our work demonstrates the importance of incorporating service flows into asset pricing models. Traditional approaches that focus solely

on risk-return trade-offs may systematically misprice assets and misunderstand return predictability. Our framework provides a foundation for analyzing other asset classes where investors value characteristics beyond cash flows.

In conclusion, service flows are fundamental drivers of asset prices with significant implications for monetary policy transmission, financial stability, and market efficiency. By providing a framework for measuring the value of these service flows, we open new avenues for understanding how financial markets function and how policy interventions can achieve more targeted outcomes.

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Figures

Figure 1: Average credit and CDS spread for euro area bonds by rating. This plot presents average credit and CDS spreads (weighted by outstanding amounts) for each rating category, separately for corporate and sovereign bonds. *AAA – A* includes all bonds with a rating of at least *A*-; *BBB* includes bonds with ratings between *BBB+* and *BBB*-; and *HY* includes all rated bonds with a rating of *BB+* or below. For this plot, we excluded bonds of three Italian banks (Banco Popolare, Banca Monte dei Paschi di Siena, and UBI Banca) that exhibited excessively volatile CDS spreads in 2012–2013, possibly related to the ECB's OMT announcement.

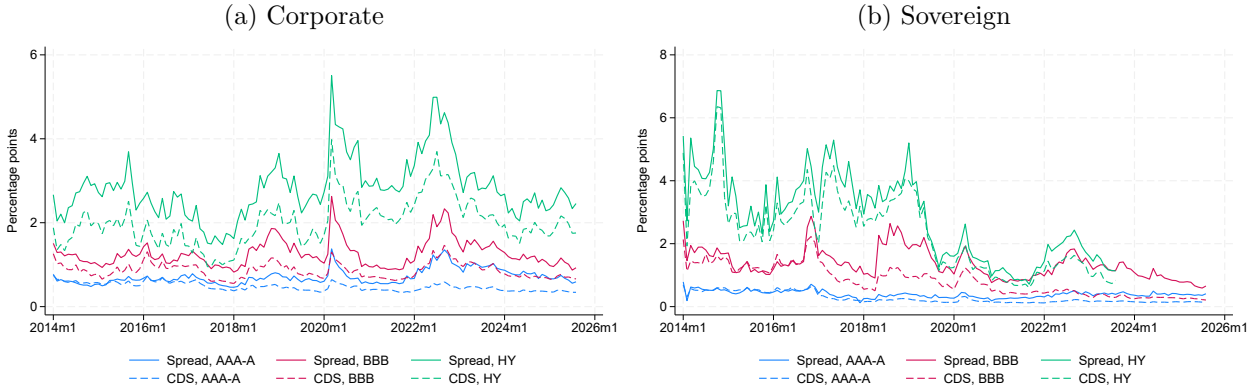
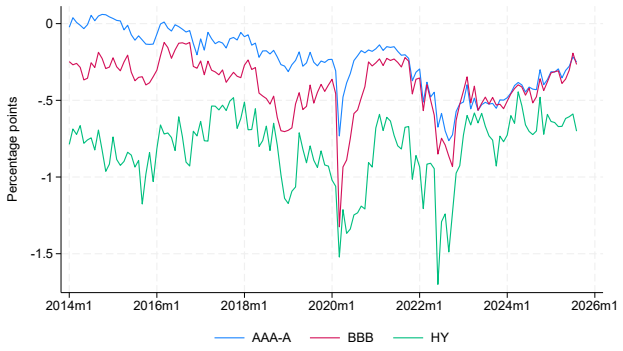


Figure 2: Average CDS-bond basis for euro area bonds by rating. This plot presents the average CDS-bond basis (weighted by outstanding amounts) for each rating category, separately for corporate and sovereign bonds. *AAA – A* includes all bonds with a rating of at least *A*-; *BBB* includes bonds with ratings between *BBB+* and *BBB*-; and *HY* includes all rated bonds with a rating of *BB+* or below. For this plot, we excluded bonds of three Italian banks (Banco Popolare, Banca Monte dei Paschi di Siena, and UBI Banca) that exhibited excessively volatile CDS spreads in 2012–2013, possibly related to the ECB's OMT announcement.

(a) Corporate



(b) Sovereign

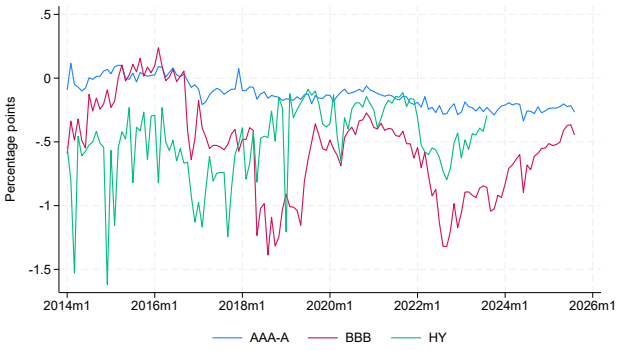


Figure 3: Sovereign bond share by investor sector. This plot shows how the proportion of sovereign bonds within each investor sector's bond portfolio evolves over time, expressed as the share of total bond holdings (face value). *MF* stands for mutual funds, *ICPF* for insurance corporations and pension funds, *Other* includes non-financial corporations, households, and government agencies, and *RoW* (rest of the world) is calculated as a residual to match total outstanding amounts. The sample period is 2011Q4–2025Q2.

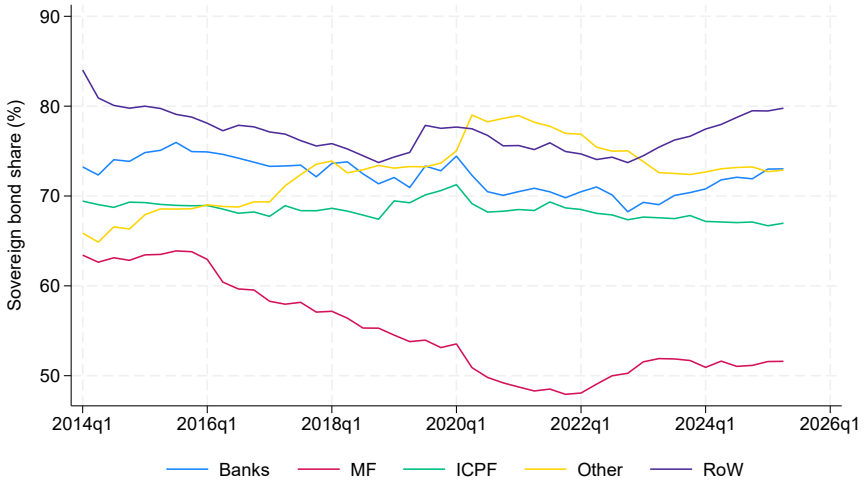
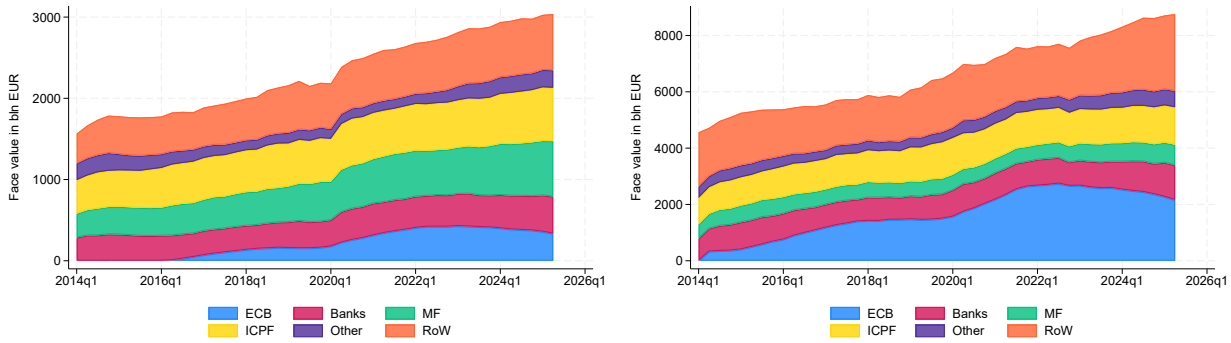


Figure 4: Sectoral holdings of euro area corporate and sovereign bonds. This plot presents the total outstanding face value (in bln EUR) of euro area corporate (left-hand side) and sovereign (right-hand side) bonds over time, split by investor sectors. *MF* stands for mutual funds, *ICPF* for insurance corporations and pension funds, *Other* includes non-financial corporations, households, and government agencies, and *RoW* (rest of the world) is calculated as a residual to match total outstanding amounts. The sample period is 2011Q2–2025Q2.

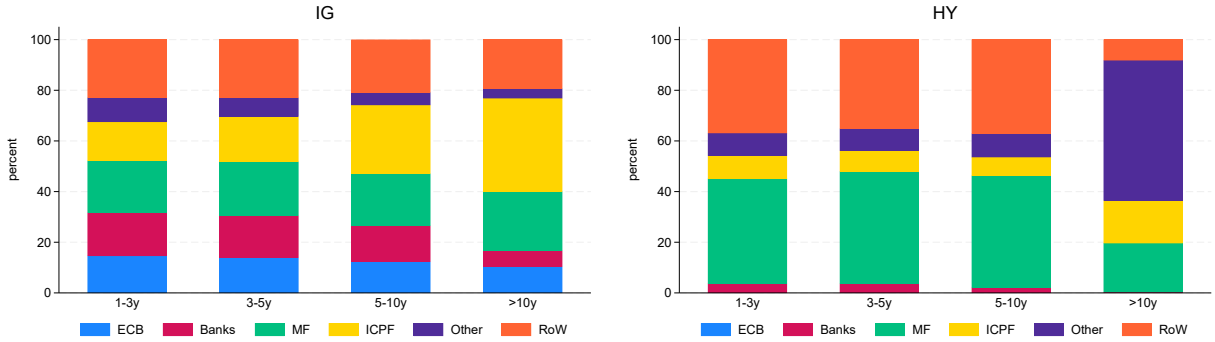


(a) Corporate bonds

(b) Sovereign bonds

Figure 5: Investor composition of euro area bonds by rating and maturity. This plot illustrates the sectoral holder composition of euro-denominated, EA-issued bonds in 2024Q4, for different residual maturity brackets (x-axis) and rating categories. The top panels distinguish between investment grade (IG) and high-yield (HY) corporate bonds, where IG bonds have a credit rating of at least *BBB-*. The bottom panel splits the sample into sovereign bonds with a *AAA* rating vs. all other sovereign bonds.

(a) Corporate



(b) Sovereign

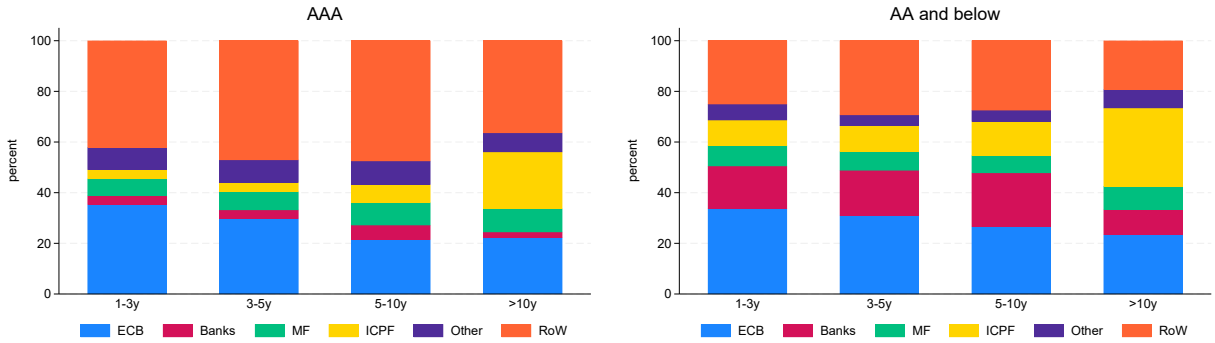
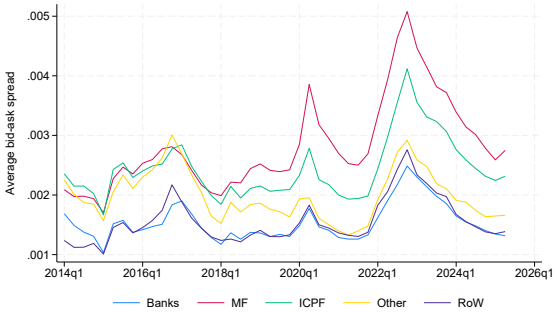
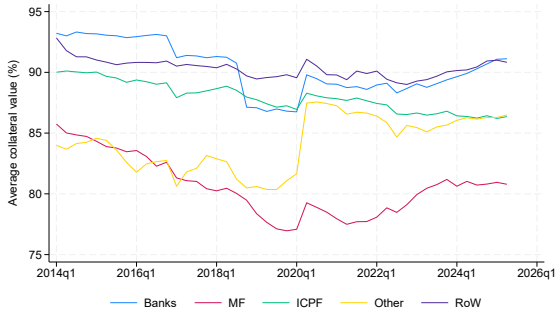


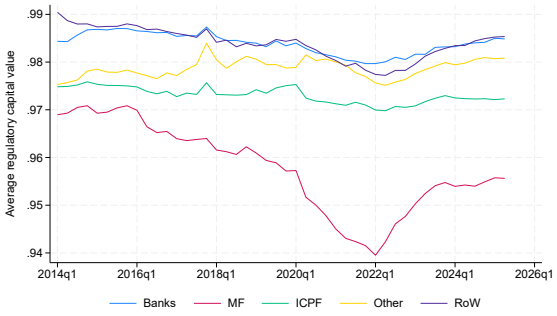
Figure 6: Average service content by investor sector over time. This plot shows the average service content of each investor sectors' bond portfolio over time for four services—liquidity value, collateral value, risk-based capital value (RBC), and modified duration. Panel (a) shows the average bid-ask spread, measured as $\frac{ask-bid}{bid}$; collateral value in panel (b) is measured as $1-haircut \in [0,1]$; RBC value in panel (c) is measured as $1-stress \in [0,1]$, where the $stress$ parameter is defined in Appendix F. Panel (d) shows the average modified duration of each sector's bond portfolio. To calculate the sectoral averages, bond-level observations have been weighted by the face value held. The sample period is 2011Q4–2025Q2.



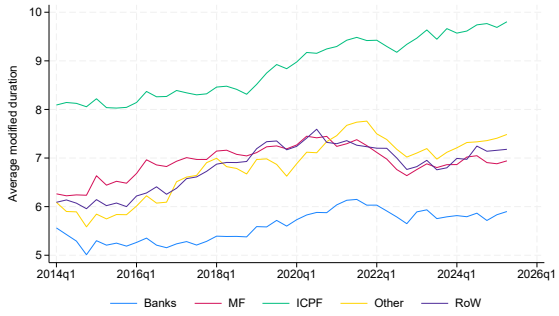
(a) Bid-ask spread



(b) Collateral value

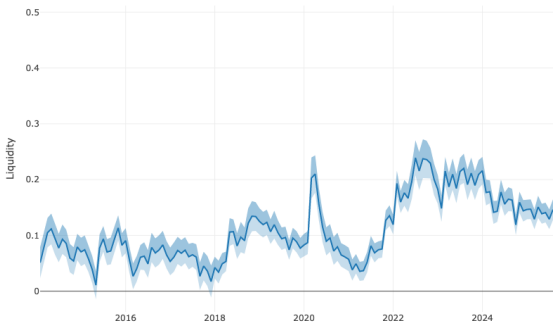


(c) RBC value

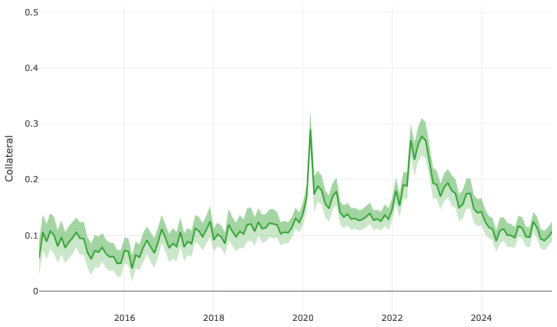


(d) Duration

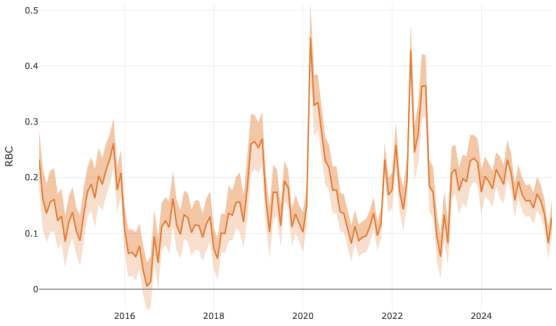
Figure 7: Service value estimates This plot shows the monthly service value estimated from equation 8 with 5% confidence interval.



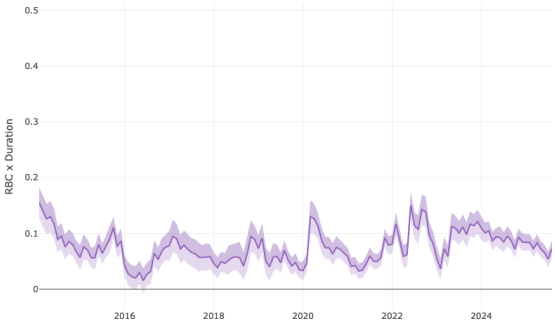
(a) Liquidity



(b) Collateral

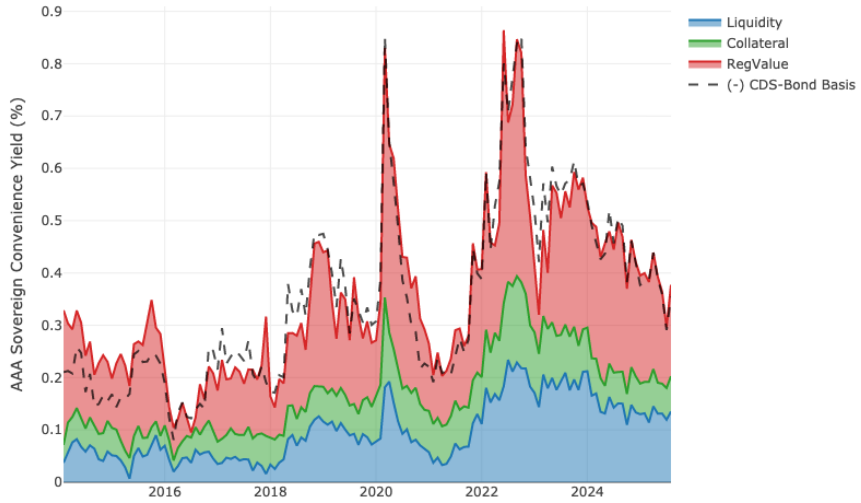


(c) RBC

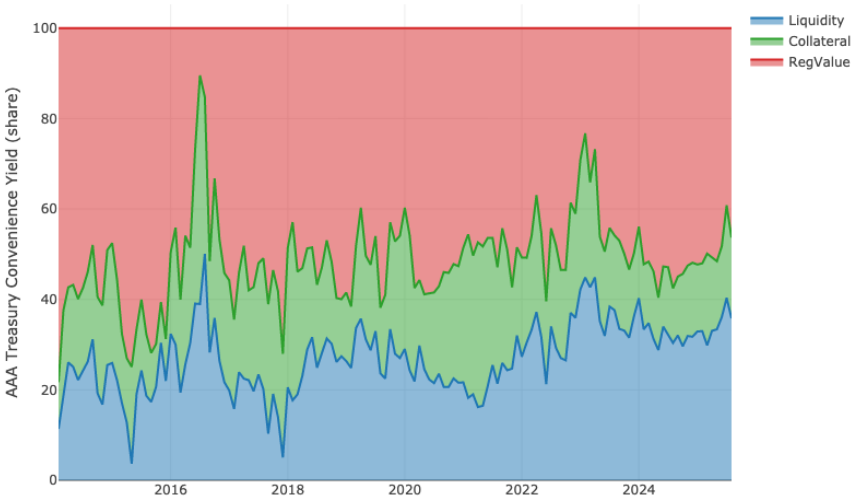


(d) RBC × Duration

Figure 8: Contributions of service flows to AAA sovereign bonds convenience yield. Panel (a) shows the contribution of each service, which is the value estimated in (8) times the average service, $Z(T)$, of all AAA sovereign bonds outstanding. Panel (b) shows the relative contribution of each service.



(a) Contribution of services to Treasury convenience yields.



(b) Relative contribution of services to Treasury convenience yields.

Figure 9: Cumulative Returns of Market-Neutral Long-Short Triple-Sorted Portfolios. This graph depicts the cumulative excess returns of market-neutral long-short portfolios, which are constructed by first categorizing bonds into maturity and rating groups and then sorting by the proportion held by each investor class. The triple-sorted portfolios take long positions in the top 30% and short positions in the bottom 30% of these classifications. Portfolios are scaled to match the market factor's standard deviation, are balanced quarterly with weekly returns and cumulated with the inclusion of Euribor as the risk-free rate to account for the return generated by the long-short strategy.

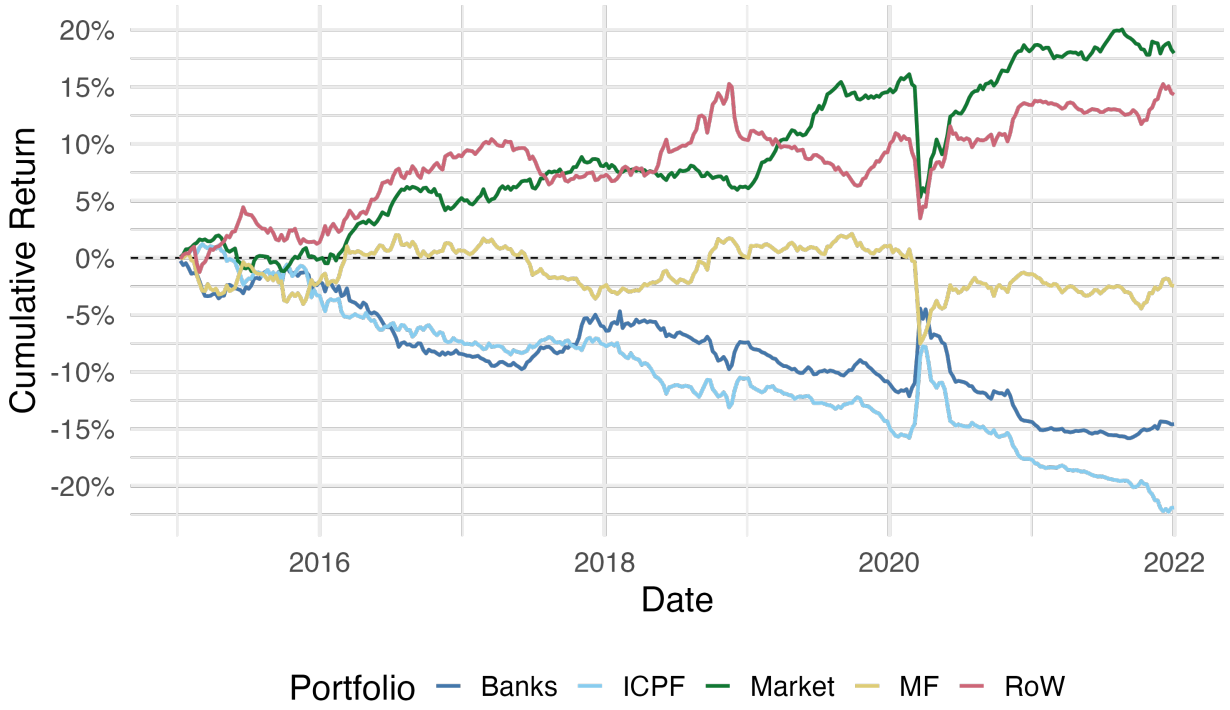
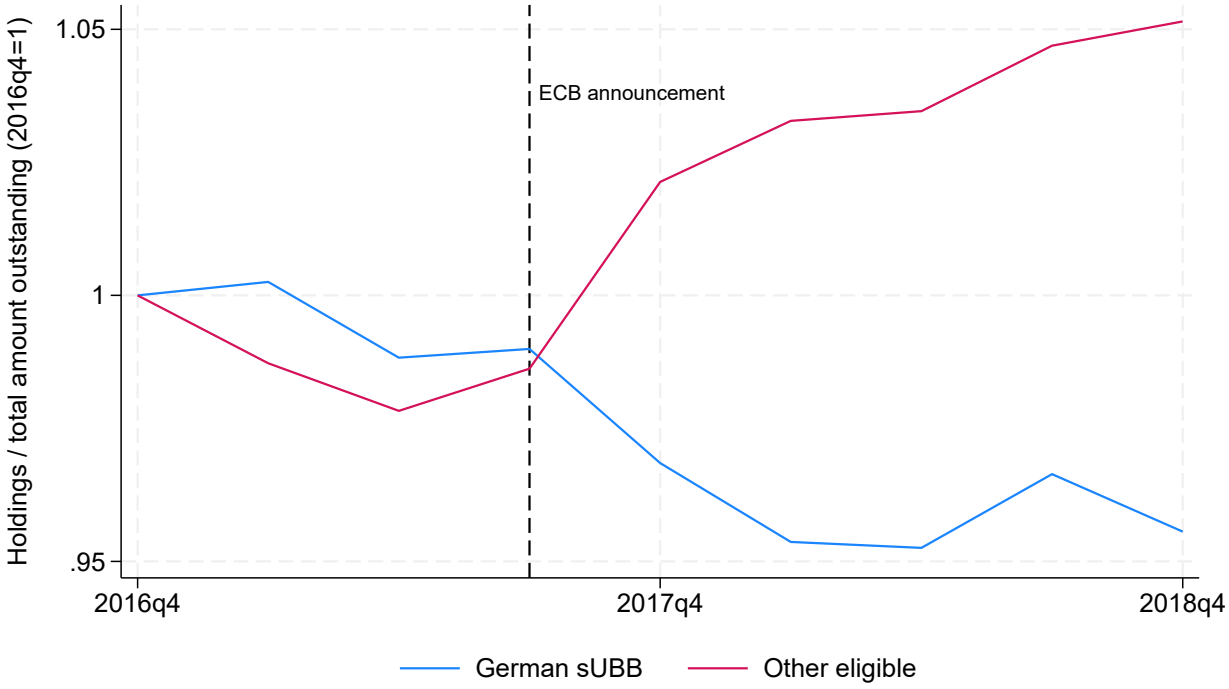


Figure 10: Banks' holdings of bank bonds around loss of collateral eligibility. This plot displays the nominal value of banks' total holdings of German sUBB (blue) and those of other collateral-eligible bank bonds (pink), each divided by their total amount outstanding and normalized to their respective 2016Q4 holdings. In December 2017, German sUBB were announced to lose ECB collateral eligibility one year later, at the end of 2018.



Tables

Table 1: Summary Statistics. This table contains descriptive statistics about key variables used during our analysis, separately for corporate and sovereign bonds. *Modified duration* measures the percentage bond price change in response to a change in yields. Due to the presence of non-zero coupon bonds, modified duration is weakly smaller than *residual maturity*. *Credit spreads* are the difference between a bond's yield to maturity and the duration-matched AAA sovereign bond yield. The *CDS-bond basis* is the difference between a bond's CDS spread and credit spread. *Collateral value* is calculated as $1 - haircut$, *regulatory capital value* as $1 - stress$, where the stress parameter is an increasing function of duration and credit risk, defined in Art. 176 of Delegated Regulation (EU) 2015/35. *Bid-ask spreads* are calculated as $\frac{ask-bid}{bid} \times 100$. The sample period is January 2014 – August 2025.

(a) Corporate bonds

	Mean	SD	p10	Median	p90	N
Amount outstanding (bln EUR)	0.33	0.63	0.01	0.05	1.00	468,795
Residual maturity (years)	6.08	5.22	1.62	4.66	11.68	468,795
Modified duration (%)	5.44	4.15	1.58	4.39	10.22	468,795
Yield to maturity (%)	1.71	1.53	0.03	1.21	3.92	468,795
Credit spread (%)	1.10	0.68	0.44	0.97	1.90	468,795
CDS-bond basis (%)	-0.40	0.55	-1.08	-0.39	0.20	468,795
Collateral value	0.60	0.41	0.00	0.85	0.95	468,795
Regulatory capital value	0.93	0.05	0.87	0.94	0.98	468,795
Bid-ask spread (%)	0.49	0.47	0.14	0.38	0.93	153,833

(b) Sovereign bonds

	Mean	SD	p10	Median	p90	N
Amount outstanding (bln EUR)	7.35	10.16	0.04	1.43	22.37	105,988
Residual maturity (years)	11.84	10.29	2.16	8.32	26.83	106,010
Modified duration (%)	10.27	8.46	2.09	7.64	22.02	106,010
Yield to maturity (%)	1.51	1.50	-0.30	1.25	3.57	106,010
Credit spread (%)	0.75	0.80	0.03	0.57	1.65	106,010
CDS-bond basis (%)	-0.29	0.46	-0.88	-0.22	0.16	106,010
Collateral value	0.91	0.20	0.90	0.95	0.99	106,010
Regulatory capital value	1.00	0.00	1.00	1.00	1.00	106,010
Bid-ask spread (%)	0.22	0.41	0.02	0.08	0.60	68,953

Table 2: Average value of services. This table shows the results of the Fama-Macbeth regression of the CDS-bond basis on the proxy of four service flows in consideration.

	CDS-bond basis (%)				
	(1)	(2)	(3)	(4)	(5)
Liquidity	0.202***				0.110***
	(0.008)				(0.005)
Collateral		0.245***			0.122***
		(0.009)			(0.004)
RCB			0.197***		0.161***
			(0.008)		(0.006)
Duration:RBC				−0.082***	0.075***
				(0.004)	(0.002)
Avg. R^2	0.273	0.29	0.269	0.132	0.403
Observations	201,898	201,898	201,898	201,898	201,898
Note:					*p<0.1; **p<0.05; ***p<0.01

Table 3: Regression Analysis of Triple-Sorted Portfolios. This table presents the coefficients obtained from a CAPM regression for portfolios sorted based on holdings, maturity, and credit ratings across different investor classes. Panel A excludes the eight-week Covid-19 disruption period in March and April 2020, while Panel B incorporates these weeks with an additional dummy variable to account for the pandemic's impact. The term *Combination* refers to an equally weighted portfolio of the Banks, Insurance Companies, Pension Funds (ICPF), and Mutual Funds (MF) portfolios.

	Panel A: Excluding Covid period				
	Banks	ICPF	MF	RoW	Combination (Banks+ICPF+MF)
	(1)	(2)	(3)	(4)	(5)
α	−0.011	−0.020***	0.004	0.021**	−0.009**
	(0.007)	(0.007)	(0.007)	(0.008)	(0.004)
β_m	−0.076***	−0.075***	0.104***	0.071**	−0.016
	(0.027)	(0.027)	(0.026)	(0.030)	(0.013)
β_{term}	0.019	0.035***	−0.028**	−0.042***	0.009
	(0.013)	(0.013)	(0.012)	(0.014)	(0.006)
Observations	356	356	356	356	356
R^2	0.022	0.027	0.045	0.026	0.007
Adjusted R^2	0.016	0.022	0.039	0.020	0.001

	Panel B: All periods with Covid dummy				
α	−0.009	−0.020***	0.005	0.023***	−0.008**
	(0.007)	(0.007)	(0.007)	(0.008)	(0.004)
$\beta_{m,\text{No Covid}}$	−0.077***	−0.076***	0.104***	0.069**	−0.016
	(0.027)	(0.027)	(0.026)	(0.030)	(0.013)
$\beta_{term,\text{No Covid}}$	0.019	0.035***	−0.027**	−0.042***	0.009
	(0.013)	(0.013)	(0.012)	(0.014)	(0.006)
$\beta_{m,\text{Covid}}$	−0.326***	−0.395***	0.304***	0.260***	−0.139***
	(0.034)	(0.034)	(0.032)	(0.037)	(0.016)
$\beta_{term,\text{Covid}}$	0.002	0.222***	−0.026	−0.080	0.066**
	(0.065)	(0.065)	(0.061)	(0.071)	(0.031)
Observations	364	364	364	364	364
R^2	0.406	0.389	0.394	0.228	0.261
Adjusted R^2	0.399	0.382	0.387	0.219	0.253

Note: *p<0.1; **p<0.05; ***p<0.01

Table 4: CDS-bond basis and regulatory value. This table displays the results of estimating equation (11). *Post* is a dummy variable equal to one for all months after (including) January 2016, when the Solvency II regulation entered into force. $HighRBC$ is a binary variable that indicates whether a bond's regulatory value (defined as $1 - stress$) exceeds the monthly sample median. $20y$ is a dummy variable equal to 1 iff the modified duration of the bond lies within 15–25 years [Jansen, 2025], and *Duration* is the modified bond duration in years. The sample period is January 2015 – December 2016, at monthly frequency. The regression we estimate is fully saturated, but we omit some interaction effects and standalone coefficients here for brevity.

	Dependent variable: CDS-bond basis	
	(1)	(2)
High RBC=1 × 20y=1 × Post=1	0.207***	
	(0.0362)	
High RBC=1 × Post=1 × Duration		0.00453***
		(0.00155)
High RBC=1 × Post=1	-0.0712***	-0.0941***
	(0.00691)	(0.0111)
20y=1 × Post=1	-0.164***	
	(0.0295)	
Post=1 × Duration		-0.00624***
		(0.00123)
Time FE	✓	✓
Rating x Maturity FE	✓	✓
R^2	0.14	0.14
Observations	87,829	87,829

Table 5: Sectoral holdings and regulatory value. This table displays the results of estimating equation (12) separately for four investor sectors: Banks, mutual funds, insurance companies & pension funds, and others (incl. households and non-financial corporations). The sample includes only investor sectors from countries where insurers did not have to mark-to-market their liabilities to determine regulatory capital requirements prior to Solvency II (i.e., they relied on historical cost accounting). These countries are Austria, Belgium, Finland, France, Germany, Greece, Italy, Portugal, Slovakia, and Spain [Jansen, 2025]. *Post* is a dummy variable equal to one for all quarters after (including) 2015Q4, when the Solvency II regulation entered into force. $HighRBC$ is a binary variable that indicates whether a bond's regulatory value (defined as $1-stress$) exceeds the monthly sample median. $20y$ is a dummy variable equal to 1 iff the modified duration of the bond falls within 15–25 years [Jansen, 2025]. The sample period is 2014Q4 – 2016Q4, at quarterly frequency. The dependent variable has been rescaled to be measured in basis points.

	Dependent variable: Portfolio share			
	(1) Banks	(2) MF	(3) ICPF	(4) Other
High RBC=1 × 20y=1 × Post=1	-0.263	-0.534	1.193**	-0.375
	(0.877)	(0.799)	(0.529)	(0.696)
High RBC=1 × Post=1	-0.0112	-0.363***	-0.275***	-0.0571
	(0.101)	(0.105)	(0.0900)	(0.0733)
20y=1 × Post=1	-0.553	-0.227	-0.430	-0.222
	(0.810)	(0.726)	(0.449)	(0.638)
Time FE	✓	✓	✓	✓
Rating x Maturity FE	✓	✓	✓	✓
Holder country FE	✓	✓	✓	✓
R^2	0.12	0.15	0.17	0.08
Observations	83,802	98,031	110,040	115,537

Standard errors in parentheses * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 6: The effect of ECB collateral eligibility on convenience yield. This table displays the results of estimating equation (13), where each bond-month observation is weighted by its outstanding amount. The sample consists of senior unsecured bank bonds issued before April 2018 by euro area banks (which were eligible to be pledged as collateral with the ECB). The binary treatment variable *German* identifies German bank bonds that became ineligible for use as ECB collateral after December 2018. The indicator variable *Post* is equal to one for all observations after that event, and zero before. The sample period is June 2018 – June 2019, at monthly frequency. Standard errors are clustered at the bond-level.

	Dependent variable: CDS-bond basis			
	(1)	(2)	(3)	(4)
German=1 × Post=1	-0.0364	-0.0401*	-0.0434*	-0.0699***
	(0.0226)	(0.0218)	(0.0226)	(0.0139)
German=1	0.0195	0.0228	0.0384	
	(0.0418)	(0.0414)	(0.0350)	
Post=1	-0.0594***			
	(0.0165)			
Time FE		✓	✓	✓
ISIN FE				✓
Rating x Maturity FE			✓	
R^2	0.01	0.03	0.15	0.85
Observations	16,940	16,940	16,940	16,894

Standard errors in parentheses

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

Table 7: The effect of ECB collateral eligibility on sectoral bank bond holdings. This table displays the results of estimating equation (14) separately for five holdings sectors: Banks, mutual funds, insurance companies & pension funds, others (incl. households and non-financial corporations), and rest of the world (i.e., non-euro area holdings estimated as the residual). The sample consists of senior unsecured bank bonds issued before April 2018 by euro area banks (which were eligible to be pledged as collateral with the ECB). The binary treatment variable *German* identifies German bank bonds that became ineligible for use as ECB collateral after December 2018. The indicator variable *Post* is equal to one for all observations after the announcement in December 2017, and zero before. The sample period is 2016Q4 – 2018Q4, at quarterly frequency. The dependent variable has been rescaled to be measured in basis points. Standard errors are clustered at the bond-level.

	Dependent variable: Portfolio share				
	(1) Banks	(2) MF	(3) ICPF	(4) Other	(5) RoW
German=1 × Post=1	-4.532***	-0.686	-3.018	-0.661	-1.289
	(1.090)	(2.122)	(1.912)	(1.043)	(0.827)
German=1	-6.172***	-12.43***	-16.93***	-9.515***	-14.30***
	(1.201)	(2.765)	(2.090)	(1.197)	(1.497)
Time FE	✓	✓	✓	✓	✓
Holder country FE	✓	✓	✓	✓	✓
Rating x Maturity FE	✓	✓	✓	✓	✓
R^2	0.40	0.21	0.19	0.17	0.10
Observations	26,860	21,351	24,221	27,677	10,888

Standard errors in parentheses

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

Table 8: The effect of the CSPP on corporate bond spreads. This table displays the results of estimating equation (15) for different outcome variables related to bond yields. The first row of each panel contains difference-in-differences estimates of the price impact of the respective corporate QE program. By construction, the difference between the estimated impact on CDS spreads (column 3) and credit spreads (column 2) equals the estimated impact on the CDS-bond basis (column 4). The sample period is September 2015 – September 2016.

	(1) Bond Yield	(2) Credit Spread	(3) CDS Spread	(4) CDS - Bond Basis
Post=1 × CSPP eligible=1	-0.254***	-0.221***	-0.0898***	0.131**
	(0.0455)	(0.0369)	(0.00527)	(0.0481)
CSPP eligible=1	-0.0269	-0.0413	-0.240***	-0.199***
	(0.0713)	(0.0720)	(0.0599)	(0.0546)
Time FE	✓	✓	✓	✓
Rating x Maturity FE	✓	✓	✓	✓
R^2	0.53	0.38	0.46	0.11
Observations	37,999	37,999	37,999	37,999

Standard errors in parentheses

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

Table 9: The effect of corporate QE on sectoral corporate bond holdings. This table displays the results of estimating equation (16) separately for five holdings sectors: Banks, mutual funds, insurance companies & pension funds, others (incl. households and non-financial corporations), and rest of the world (i.e., non-euro area holdings estimated as the residual). The CSPP announcement date defining the *Post* dummies is 2016Q1. The dependent variable has been rescaled to be measured in basis points. Standard errors are clustered at the firm and quarter level. The sample period is 2015Q1 – 2016Q4.

	Dependent variable: Portfolio share				
	(1) Banks	(2) MF	(3) ICPF	(4) Other	(5) RoW
Post=1 × CSPP eligible=1	-0.335	0.271**	-0.00468	-0.444***	-0.408
	(0.189)	(0.0814)	(0.0742)	(0.0910)	(0.254)
CSPP eligible=1	-2.533**	-0.967*	0.362	-1.430**	1.715*
	(0.661)	(0.361)	(0.410)	(0.348)	(0.650)
Holder country x Time FE	✓	✓	✓	✓	✓
Rating x Maturity FE	✓	✓	✓	✓	✓
R^2	0.29	0.22	0.25	0.15	0.02
Observations	45,888	71,403	74,935	74,312	20,335

Standard errors in parentheses

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

Appendix

Appendix A Model Derivations and Proofs

Appendix A.1 Optimal Portfolio Choice

Investor i chooses portfolio weights $\boldsymbol{x}_{it}$ to maximize expected utility

$$\mathbb{E}_t\Big[-\exp\Big(-A_i w_{i,t+1} - \boldsymbol{x}_{it}'\boldsymbol{Z}_t\tilde{\boldsymbol{\lambda}}_{it}\Big)\Big], \tag{A.1}$$

where next-period wealth satisfies

$$w_{i,t+1} = w_{i0}\big(1 + r_t^f + \boldsymbol{x}_{it}'\boldsymbol{r}_{t+1}\big)$$

and excess returns are normally distributed according to

$$\boldsymbol{r}_{t+1} = \boldsymbol{\mu}_t + \boldsymbol{\epsilon}_{t+1}, \qquad \boldsymbol{\epsilon}_{t+1} \sim \mathcal{N}(\mathbf{0}, \Sigma_t).$$

Under CARA preferences and normal returns, maximizing expected utility is equivalent to maximizing a mean–variance objective augmented by service flows. Substituting for wealth and collecting all terms that depend on $\boldsymbol{x}_{it}$, investor i solves

$$\max_{\boldsymbol{x}_{it}} \left\{\boldsymbol{x}_{it}'\boldsymbol{\mu}_t + \boldsymbol{x}_{it}'\boldsymbol{Z}_t\tilde{\boldsymbol{\lambda}}_{it} - \frac{a_i}{2}\boldsymbol{x}_{it}'\Sigma_t\boldsymbol{x}_{it}\right\}, \tag{A.2}$$

where $a_i = A_i w_{i0}$ is relative risk aversion.

The first-order condition yields

$$\boldsymbol{x}_{it} = \frac{1}{a_i}\Sigma_t^{-1}\left(\boldsymbol{\mu}_t + \boldsymbol{Z}_t\tilde{\boldsymbol{\lambda}}_{it}\right), \tag{A.3}$$

which corresponds to equation (2) in the main text.

Market Clearing and Expected Excess Returns Let $\tilde{w}_{i0} = w_{i0}/w_0$ denote investor i's share of total wealth. With the risk-free asset in zero net supply, market clearing for risky assets implies that the market portfolio satisfies

$$\boldsymbol{x}_{mt} = \int_i \tilde{w}_{i0}\boldsymbol{x}_{it}\, di. \tag{A.4}$$

Imposing the common risk-aversion assumption $a_i = a$ and defining $\boldsymbol{\lambda}_{it} = \tilde{\boldsymbol{\lambda}}_{it}/a$, aggregation yields

$$\boldsymbol{x}_{mt} = \frac{1}{a}\Sigma_t^{-1}\left(\boldsymbol{\mu}_t + \boldsymbol{Z}_t\bar{\boldsymbol{\lambda}}_t\right), \tag{A.5}$$

where

$$\bar{\boldsymbol{\lambda}}_t = \int_i \tilde{w}_{i0}\boldsymbol{\lambda}_{it}\, di$$

is the wealth-weighted valuation of service flows.

Multiplying both sides by Σ_t and rearranging gives

$$\boldsymbol{\mu}_t = a\,\Sigma_t\boldsymbol{x}_{mt} - \boldsymbol{Z}_t\bar{\boldsymbol{\lambda}}_t. \tag{A.6}$$

Define the market excess return as

$$r_{m,t+1} = \boldsymbol{x}'_{mt}\boldsymbol{r}_{t+1},$$

with expected excess return

$$\mu_{mt} = \boldsymbol{x}'_{mt}\boldsymbol{\mu}_t$$

and variance

$$\sigma^2_{mt} = \boldsymbol{x}'_{mt}\Sigma_t\boldsymbol{x}_{mt}.$$

Let $\boldsymbol{\beta}_t$ denote the vector of market betas,

$$\boldsymbol{\beta}_t = \frac{\Sigma_t\boldsymbol{x}_{mt}}{\sigma^2_{mt}}. \tag{A.7}$$

Substituting equation (A.6) into the definition of μ_{mt} yields

$$\mu_{mt} = a\,\sigma^2_{mt} - \boldsymbol{x}'_{mt}\boldsymbol{Z}_t\bar{\boldsymbol{\lambda}}_t. \tag{A.8}$$

Under the normalization imposed in the main text,

$$\boldsymbol{x}'_{mt}\boldsymbol{Z}_t = \boldsymbol{0},$$

the market risk premium satisfies

$$\mu_{mt} = a\,\sigma^2_{mt}, \qquad a = \frac{\mu_{mt}}{\sigma^2_{mt}}.$$

Plugging this expression for a back into equation (A.6) yields

$$\boldsymbol{\mu}_t = \frac{\mu_{mt}}{\sigma^2_{mt}}\Sigma_t\boldsymbol{x}_{mt} - \boldsymbol{Z}_t\bar{\boldsymbol{\lambda}}_t \tag{A.9}$$

$$= \boldsymbol{\beta}_t\,\mu_{mt} - \boldsymbol{Z}_t\bar{\boldsymbol{\lambda}}_t, \tag{A.10}$$

which corresponds to equation (4) in the main text.

Appendix A.2 Proofs of Model Predictions

Throughout, we maintain the normalization $\boldsymbol{x}'_{mt}\boldsymbol{Z}_t = \mathbf{0}$ imposed in the main text, and we use the equilibrium expected return relation

$$\boldsymbol{\mu}_t = \boldsymbol{\beta}_t\, \mu_{mt} - \boldsymbol{Z}_t \bar{\boldsymbol{\lambda}}_t, \tag{A.11}$$

together with the definition of the convenience value (convenience yield) of asset n,

$$cy_t(n) = \boldsymbol{Z}_t(n)\, \bar{\boldsymbol{\lambda}}_t. \tag{A.12}$$

We also use the portfolio-tilt representation

$$\boldsymbol{x}_{it} = \boldsymbol{x}_{mt} + \frac{1}{a}\Sigma_t^{-1}\boldsymbol{Z}_t \left(\boldsymbol{\lambda}_{it} - \bar{\boldsymbol{\lambda}}_t\right), \tag{A.13}$$

which follows from equation (2) and market clearing.

Proof of Prediction 1. Fix t and the equilibrium price of services $\bar{\boldsymbol{\lambda}}_t$. From equation (5), the convenience yield of asset n is

$$cy_t(n) = \boldsymbol{Z}_t(n)\, \bar{\boldsymbol{\lambda}}_t.$$

For any two assets n and m, it follows that

$$cy_t(n) - cy_t(m) = \left(\boldsymbol{Z}_t(n) - \boldsymbol{Z}_t(m)\right) \bar{\boldsymbol{\lambda}}_t. \tag{A.14}$$

Thus, conditional on $\bar{\boldsymbol{\lambda}}_t$, cross-sectional differences in convenience yields are driven solely by cross-sectional differences in service flows $\boldsymbol{Z}_t(\cdot)$. This proves Prediction 1. □

Proof of Prediction 2. Consider a change in investor i's valuation of service k such that $\Delta\lambda_{it}(k) > 0$. This change raises the wealth-weighted valuation of service k,

$$\Delta\bar{\lambda}_t(k) = \tilde{w}_{i0}\, \Delta\lambda_{it}(k) > 0,$$

holding all other investors' valuations fixed. From equation (5),

$$cy_t(n) = \sum_{l=1}^{K} Z_t^l(n)\, \bar{\lambda}_t(l),$$

so, holding $\bar{\lambda}_t(l)$ fixed for all $l \neq k$,

$$\Delta cy_t(n) = Z_t^k(n)\, \Delta \bar{\lambda}_t(k).$$

Therefore, if $Z_t^k(n) > Z_t^k(m)$ and $\Delta \bar{\lambda}_t(k) > 0$, then $\Delta cy_t(n) > \Delta cy_t(m)$, proving the first statement in Prediction 2.

Next, from equation (6),

$$\boldsymbol{x}_{it} = \boldsymbol{x}_{mt} + \frac{1}{a} \Sigma_t^{-1} \boldsymbol{Z}_t \left(\boldsymbol{\lambda}_{it} - \bar{\boldsymbol{\lambda}}_t \right).$$

Holding $(\boldsymbol{\mu}_t, \Sigma_t, \boldsymbol{Z}_t)$ fixed, a change in $\lambda_{it}(k)$ affects $\boldsymbol{x}_{it}$ through the kth service flow only:

$$\Delta \boldsymbol{x}_{it} = \frac{1}{a} \Sigma_t^{-1} \boldsymbol{Z}_t^k \, \Delta \lambda_{it}(k).$$

Conditional on risk exposure (i.e., within a set of assets for which the risk adjustment through Σ_t^{-1} is the same), higher Z_t^k implies a larger increase in holdings. This proves the second statement in Prediction 2. □

Proof of Prediction 3. Fix an asset n and consider an increase in its service flow k, so that $\Delta Z_t^k(n) > 0$, holding all other characteristics fixed. Let e_n be the nth unit vector in $\mathbb{R}^N$ and e_k the kth unit vector in $\mathbb{R}^K$. Then the change in the characteristics matrix is $\Delta \boldsymbol{Z}_t = \Delta Z_t^k(n)\, e_n e_k^\top$.

From equation (6),

$$\boldsymbol{x}_{it} - \boldsymbol{x}_{mt} = \frac{1}{a} \Sigma_t^{-1} \boldsymbol{Z}_t \left(\boldsymbol{\lambda}_{it} - \bar{\boldsymbol{\lambda}}_t \right),$$

so the induced change in investor i's holdings is

$$\Delta \boldsymbol{x}_{it} = \frac{1}{a} \Sigma_t^{-1} \Delta \boldsymbol{Z}_t \left(\boldsymbol{\lambda}_{it} - \bar{\boldsymbol{\lambda}}_t \right) = \frac{\Delta Z_t^k(n)}{a} \, \Sigma_t^{-1} e_n \left(\lambda_{it}(k) - \bar{\lambda}_t(k) \right).$$

Taking the nth component gives

$$\Delta x_{it}(n) = \frac{\Delta Z_t^k(n)}{a} \, [\Sigma_t^{-1}]_{nn} \left(\lambda_{it}(k) - \bar{\lambda}_t(k) \right).$$

Because Σ_t is positive definite, $[\Sigma_t^{-1}]_{nn} > 0$, and $a > 0$, the response of $x_{it}(n)$ is increasing in $\lambda_{it}(k)$. Hence investors with higher valuation for service k rebalance more strongly toward asset n than investors with lower valuations.

Finally, from equation (5),

$$cy_t(n) = \boldsymbol{Z}_t(n)\bar{\boldsymbol{\lambda}}_t,$$

so holding $\bar{\boldsymbol{\lambda}}_t$ fixed implies

$$\Delta cy_t(n) = \Delta Z_t^k(n)\,\bar{\lambda}_t(k),$$

which is positive when $\bar{\lambda}_t(k) > 0$. This proves Prediction 3. □

Appendix B Extra Descriptive Information

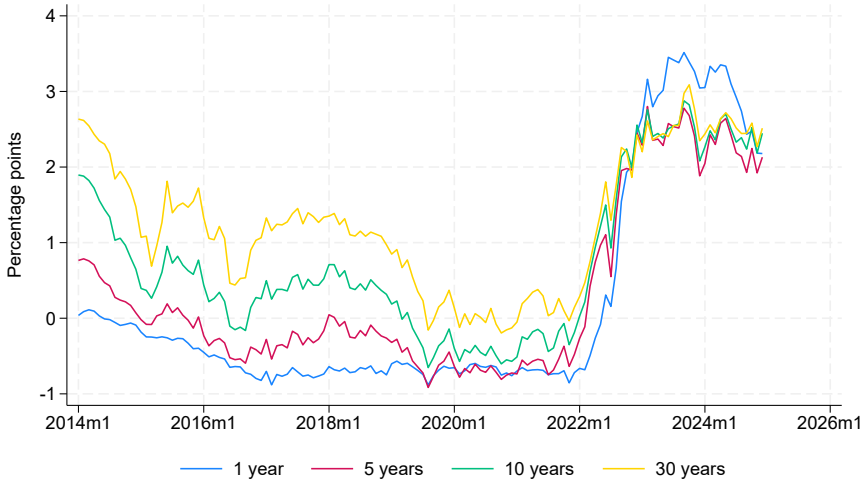


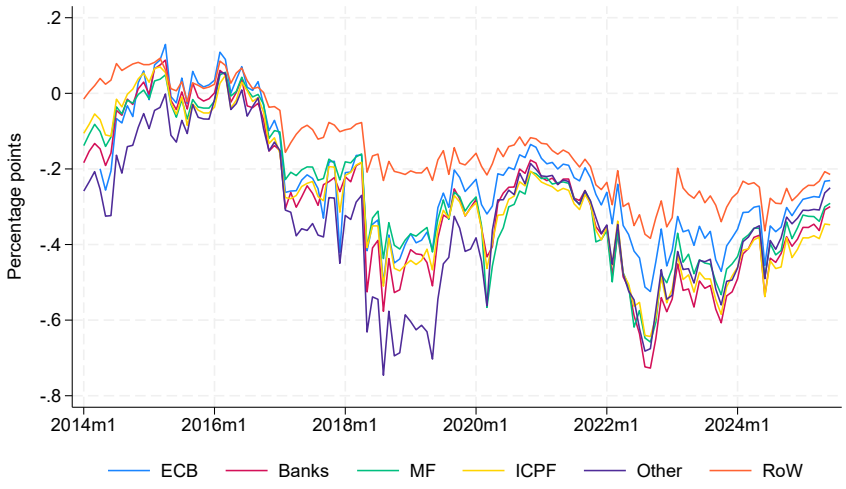
Figure B.11: ECB benchmark interest rates for different maturities. This plot presents the time series of the benchmark interest rate for 1Y, 5Y,10Y, and 30Y maturity. The ECB benchmark interest rate is provided under the euro area yield curves estimation and is used as an approximate measure of risk-free rate in the euro area. It is estimated daily by using the AAA-rated euro area central government bonds.

Appendix C Heterogeneity in convenience yields across investors

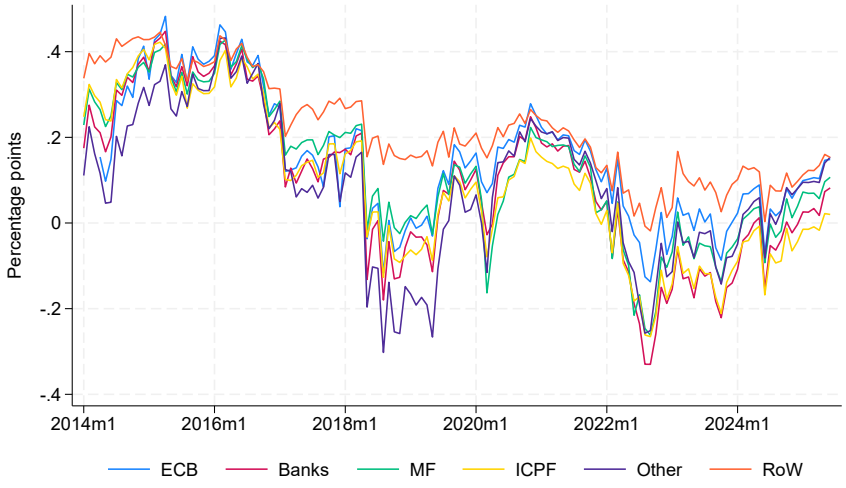
Table C.10 and Figure C.12 contain the average CDS-bond basis for each investor sector's bond portfolio.

Table C.10: CDS-bond basis by investor sector This table contains distributional summary statistics of the CDS-bond basis (calculated by subtracting a bond's credit spread from its CDS spread), separately for each investor type's portfolio. All moments are obtained by weighting observations by nominal holdings.

	Mean	SD	Min	p10	p25	p50	p75	p90	Max
ECB	-0.28	0.36	-2.89	-0.75	-0.45	-0.21	-0.03	0.10	2.68
Banks	-0.29	0.39	-3.17	-0.76	-0.47	-0.24	-0.05	0.11	2.74
ICPF	-0.29	0.39	-3.07	-0.77	-0.51	-0.24	-0.03	0.14	2.74
MF	-0.27	0.40	-3.14	-0.76	-0.48	-0.23	0.00	0.15	2.52
Other	-0.32	0.45	-3.17	-0.95	-0.58	-0.23	0.02	0.14	2.74
RoW	-0.15	0.33	-3.17	-0.57	-0.29	-0.07	0.06	0.17	2.74



(a) CDS-bond basis of portfolios of different investor classes



(b) CDS-bond basis of portfolios of different investor classes after absorbing Rating x Maturity FE

Figure C.12: Value-weighted average CDS-bond basis of each investor sector's bond portfolio Panel (a) of this plot presents the average CDS-bond basis (weighted by nominal holdings) of each investor sector's bond portfolio. Panel (b) plots the average residual from a regression of the CDS-bond basis on rating x maturity dummies for each investor sector, again weighted by nominal holdings.

Appendix D Evidence from portfolio sorting on holdings share

Table D.11: Annualized descriptive statistics for long-short portfolios. On the top panel, portfolios are sorted by holdings. On the bottom panel, portfolios are sorted by holding, maturity, and rating.

	Single Sorted Portfolios		
Investor	Mean	SD	SR
Banks	-1.821	2.988	-0.610
ECB	-0.890	2.724	-0.327
ICPF	-0.645	2.730	-0.236
MF	1.198	2.719	0.441
Other	-0.299	1.868	-0.160
RoW	0.604	1.919	0.315
Market	2.438	3.367	0.724

	Triple Sorted Portfolios		
Investor	Mean	SD	SR
Banks	-0.430	3.289	-0.131
ECB	0.167	1.580	0.106
ICPF	-0.905	3.115	-0.290
MF	0.307	3.004	0.102
Other	-0.374	2.681	-0.139
RoW	1.131	3.249	0.348

Table D.12: Regression Analysis of Single-Sorted Portfolios. This table presents the coefficients obtained from a CAPM regression for portfolios sorted based on holdings across different investor classes. Panel A excludes the eight-week Covid-19 disruption period in March and April 2020, while Panel B incorporates these weeks with an additional dummy variable to account for the pandemic's impact. The term *Combination* refers to an equally weighted portfolio of the Banks, Insurance Companies, Pension Funds (ICPF), and Mutual Funds (MF) portfolios.

	Panel A: Excluding Covid period				
	Banks	ICPF	MF	RoW	Combination (Banks+ICPF+MF)
	(1)	(2)	(3)	(4)	(5)
α	−0.001	−0.024**	0.016*	0.017**	−0.003
	(0.007)	(0.010)	(0.010)	(0.007)	(0.003)
β_m	−0.836***	−0.261***	0.542***	0.214***	−0.185***
	(0.026)	(0.037)	(0.035)	(0.027)	(0.011)
β_{term}	0.124***	0.476***	−0.365***	−0.290***	0.078***
	(0.012)	(0.018)	(0.017)	(0.013)	(0.005)
Observations	356	356	356	356	356
R^2	0.765	0.689	0.579	0.592	0.484
Adjusted R^2	0.764	0.687	0.576	0.590	0.481

	Panel B: All periods with Covid dummy				
α	−0.003	−0.027**	0.019*	0.020**	−0.004
	(0.008)	(0.012)	(0.011)	(0.008)	(0.003)
$\beta_{m,\text{No Covid}}$	−0.834***	−0.259***	0.540***	0.212***	−0.184***
	(0.030)	(0.043)	(0.041)	(0.030)	(0.012)
$\beta_{term,\text{No Covid}}$	0.124***	0.476***	−0.365***	−0.290***	0.078***
	(0.014)	(0.021)	(0.020)	(0.015)	(0.006)
$\beta_{m,\text{Covid}}$	−0.841***	−0.513***	0.756***	0.491***	−0.200***
	(0.037)	(0.054)	(0.052)	(0.038)	(0.015)
$\beta_{term,\text{Covid}}$	−0.156**	0.265**	−0.147	−0.177**	−0.012
	(0.070)	(0.103)	(0.098)	(0.072)	(0.029)
Observations	364	364	364	364	364
R^2	0.871	0.669	0.696	0.669	0.677
Adjusted R^2	0.870	0.665	0.692	0.666	0.674

Note: *p<0.1; **p<0.05; ***p<0.01

Table D.13: Regression Analysis of Triple-Sorted Portfolios. This table presents the coefficients obtained from a CAPM regression for portfolios sorted based on holdings, maturity, and credit ratings across different investor classes. In this table we do not control for the Covid period. The term *Combination* refers to an equally weighted portfolio of the Banks, Insurance Companies, Pension Funds (ICPF), and Mutual Funds (MF) portfolios.

	No Covid treatment				
	Banks	ICPF	MF	RoW	Combination (Banks + ICPF + MF)
	(1)	(2)	(3)	(4)	(5)
α	0.0005	−0.010	−0.003	0.016**	−0.004
	(0.008)	(0.008)	(0.007)	(0.008)	(0.004)
β_m	−0.235***	−0.231***	0.228***	0.179***	−0.079***
	(0.019)	(0.019)	(0.018)	(0.020)	(0.009)
β_{term}	0.047***	0.069***	−0.050***	−0.063***	0.022***
	(0.013)	(0.013)	(0.012)	(0.014)	(0.006)
Observations	364	364	364	364	364
R^2	0.303	0.285	0.322	0.177	0.175
Adjusted R^2	0.299	0.281	0.318	0.172	0.171

Appendix E ECB Collateral Eligibility

Appendix E.1 A snapshot of ECB haircuts as 06/29/2023

Table E.14: ECB haircuts for different bond categories. This table contains the haircuts that the ECB applies to the market value of securities pledged as collateral. The maximum amount a bank can borrow against a given amount of collateral is (100-haircut)% times the market value of the pledged security. The collateral framework is periodically reviewed and changes to the haircut schedule are not unusual. Per Guideline ECB/2022/49 the schedule below is effective as of 29 June 2023.

Rating	Residual Maturity	Central government		Local gov. + covered bonds		NFC		FC	
		Fix/Float	Zero	Fix/Float	Zero	Fix/Float	Zero	Fix/Float	Zero
AAA-A	0-1y	0.5	0.5	1.0	1.0	1.0	1.0	7.5	7.5
	1-3y	1.0	2.0	1.5	2.5	2.0	3.0	10.0	11.5
	3-5y	1.5	2.5	2.5	3.5	3.0	4.5	12.0	13.0
	5-7y	2.0	3.0	3.5	4.5	4.5	6.0	14.0	15.0
	7-10y	3.0	4.0	4.5	6.5	6.0	8.0	16.0	17.5
	10-15y	4.0	5.0	6.5	8.5	7.5	10.0	18.0	22.5
	15-30y	5.0	6.0	8.0	11.5	9.0	13.0	21.0	25.0
	>30y	6.0	9.0	10.0	13.0	11.0	16.0	24.0	31.5
BBB	0-1y	5.0	5.0	5.5	5.5	6.5	6.5	11.5	11.5
	1-3y	6.0	7.0	7.5	10.5	9.5	12.0	18.5	20.0
	3-5y	8.5	10.0	11.0	16.0	13.0	18.0	23.0	27.0
	5-7y	10.0	11.5	12.5	17.0	15.0	21.5	25.5	29.5
	7-10y	11.5	13.0	14.0	21.0	17.0	23.5	26.5	31.5
	10-15y	12.5	14.0	17.0	25.5	19.5	28.0	28.5	35.0
	15-30y	13.5	15.0	20.0	28.5	22.0	31.0	31.5	39.0
	>30y	14.0	17.0	22.0	32.5	25.0	35.5	34.5	43.0

Appendix E.2 The Change of Eligibility of Subordinated Unsecured Bank Bonds

The ultimate cause of the change in ECB collateral eligibility of senior unsecured bank bonds in December 2018 is the Directive of the European Union 2014/59/EU, also called the Bank Recovery and Resolution Directive (BRRD). Among other things, the directive required banks to increase their total loss-absorbing capital (TLAC) and comply with the

new minimum requirement for own funds and eligible liabilities (MREL), so that a significant share of liabilities could be written down before public funds be used in the recovery of a failing bank. In other words, banks had to issue more "bail-in-able" securities that are subordinated to deposits, covered liabilities, and other senior liabilities such as wages and taxes.

Importantly, the directive allowed three ways of implementing the new rules, leaving it open to member states to decide which approach they preferred:

- *Contractual subordination*, where the subordination is explicitly stated in the bond's terms. This effectively amounts to the creation of an entirely new asset class, sometimes called *senior non-preferred* liabilities. France and Spain were among the early adopters of this option.

- *Structural subordination*, which applies only to banks with a holding structure: Debt issued by a holding company is automatically structurally subordinated to debt issued by the operating company. This applied mostly to banks from the UK, Belgium, Switzerland, and the Netherlands.

- *Statutory subordination*, where all senior bank bonds would be subordinated by law, through a modification of national insolvency laws. Germany was the only member state to take this route.

Regardless of which approach was taken, subordinated uncovered bank bonds (sUBB), even if called "senior", are more risky than plain-vanilla senior bank debt by construction. Any exposure to potential bail-in losses during a bank's resolution could jeopardize the ECB's authority and even create conflicts of interest. This is what motivated the ECB to reconsider its collateral framework and, in particular, which bank bonds it should accept as collateral going forward. The most immediate solution would have been to simply stop accepting all subordinated UBB. However, this would have put German banks at a significant disadvantage. While, for example, French banks could have issued both senior preferred and senior non-preferred UBB (the former of which would have been eligible for collateral), German banks could not have issued any ECB-eligible UBB anymore because of statutory subordination.

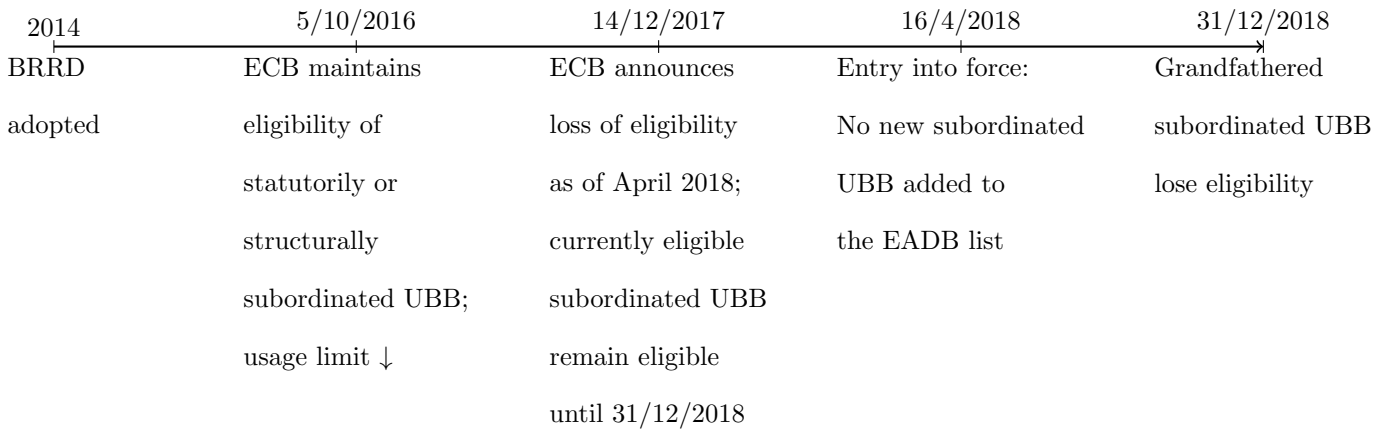


Figure E.13: Timeline of events

That is why, on October 5th, 2016 the ECB announced to *maintain* the eligibility of statutorily or structurally subordinated UBB for the time being until member states would converge to a harmonized approach. Without this temporary waiver, the sUBB in question would have become ineligible as of January 1st, 2017. Obviously, the main beneficiaries of this decision were German banks and bank holding companies which could now continue to issue ECB-eligible sUBB which, at the same time, counted towards the issuer's MREL requirement. In other words, for a while, German sUBB enjoyed the best of both worlds.[39]

However, on December 14th, 2017, the ECB announced the end of this exception: As of April 2018, no new subordinated UBB would be eligible for collateral anymore (with the exception of government-guaranteed bonds). To ease the transition, the ECB adopted a grandfathering approach for those subordinated UBB that were still eligible at the time of the announcement. Those securities would maintain their eligibility until December 31st, 2018. We summarize the most important events in Figure E.13.

Eventually, to level the playing field, the German Banking Act (Kreditwesengesetz) was amended to adopt the contractual subordination option as well.[40] This allowed German banks to issue both senior preferred and senior non-preferred bonds as of July 21st, 2018.

[39]However, the ECB lowered the usage limit of sUBB from 5% to 2.5%, i.e. the value of sUBB pledged as collateral by a bank could not exceed 2.5% of its total pledged collateral.

[40]See section 46f paragraphs 6, 7, and 9 KWG.

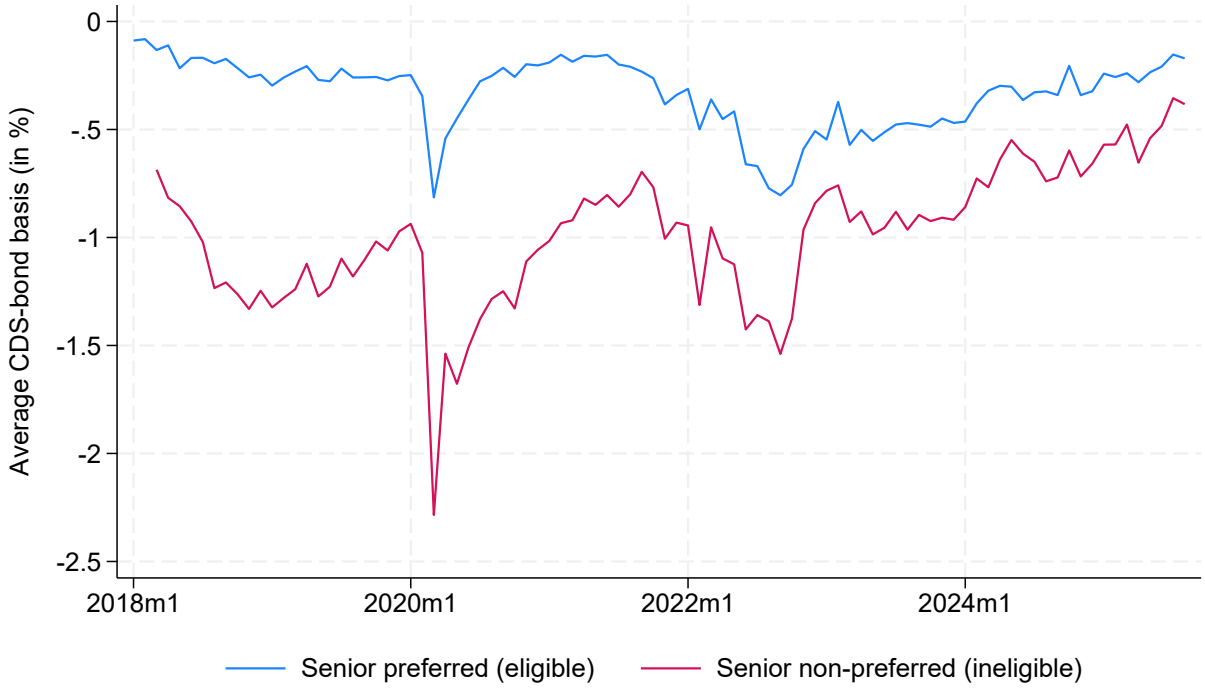


Figure E.14: Average CDS-bond basis of bank bonds of different seniority. This plot displays the average CDS-bond basis of senior preferred bank bonds (blue) vs. that of senior non-preferred bank bonds (pink). The former are generally collateral-eligible, the latter are not. To obtain the average basis, observations are weighted by outstanding amounts. Note that because the two debt classes have different seniority, the CDS spreads used to calculate the CDS-bond basis are also different.

As further evidence of our interpretation of ECB collateral eligibility as a service that banks value, Figure E.14 plots the average CDS-bond basis of senior preferred vs. senior non-preferred bonds. Note that the series only starts in 2018, after senior non-preferred bonds and, even more importantly, their corresponding CDS contracts, had been widely introduced. The plot clearly shows that senior preferred bank bonds (which are generally eligible for collateral at the ECB) have a higher CDS-bond basis than (ineligible) senior non-preferred bank bonds, even after we account for the different default risk of each asset class (by using the seniority-appropriate CDS spread when calculating the CDS-bond basis).

Appendix F Solvency II Details

The table below shows the stress parameter calculation according to Article 176 of the Solvency II Directive 2009/138/EC.

Table F.15: Credit Quality Step Stress Parameters by Duration

Duration (dur_i)	$stress_i$	Credit quality step											
		0		1		2		3		4		5 and 6	
		a_i	b_i	a_i	b_i	a_i	b_i	a_i	b_i	a_i	b_i	a_i	b_i
up to 5	$b_i \cdot dur_i$	—	0.9%	—	1.1%	—	1.4%	—	2.5%	—	4.5%	—	7.5%
More than 5 and up to 10	$a_i + b_i \cdot (dur_i - 5)$	4.5%	0.5%	5.5%	0.6%	7.0%	0.7%	12.5%	1.5%	22.5%	2.5%	37.5%	4.2%
More than 10 and up to 15	$a_i + b_i \cdot (dur_i - 10)$	7.0%	0.5%	8.4%	0.5%	10.5%	0.5%	20.0%	1.0%	35.0%	1.8%	58.5%	0.5%
More than 15 and up to 20	$a_i + b_i \cdot (dur_i - 15)$	9.5%	0.5%	10.9%	0.5%	13.0%	0.5%	25.0%	1.0%	44.0%	0.5%	61.0%	0.5%
More than 20	$\min[a_i + b_i \cdot (dur_i - 20); 1]$	12.0%	0.5%	13.4%	0.5%	15.5%	0.5%	30.0%	0.5%	46.5%	0.5%	63.5%	0.5%

Furthermore, Article 180 paragraph 2 determines specific stress calculations for certain bonds. In particular, exposures in the form of bonds and loans to the following shall be assigned a risk factor $stress_i$ of 0 %:

(a) the European Central Bank;

(b) Member States' central government and central banks denominated and funded in the domestic currency of that central government and the central bank;

(c) multilateral development banks referred to in paragraph 2 of Article 117 of Regulation (EU) No 575/2013;

(d) international organisations referred to in Article 118 of Regulation (EU) No 575/2013.

Furthermore, exposures in the form of bonds and loans that are fully, unconditionally, and irrevocably guaranteed by one of the counterparties mentioned in points (a) to (d),

where the guarantee meets the requirements set out in Article 215, shall also be assigned a risk factor stress of 0%.

Appendix G Replication/Extension of Results in Jansen [2025]

Our exercise in Section 7.1 is, in parts, complementary to Jansen [2025] who studies the impact of Solvency II—and in particular, the requirement to discount long-dated liabilities by the "ultimate forward rate" (UFR)—in detail. As a verification exercise, we replicate two key results here, namely Tables 8 and IA10 in Section 6 of Jansen [2025].

We first replicate (and slightly extend) the country-level panel regression results of Table 8. Relative to the original regressions, our approach differs in several dimensions: (a) Our sample only includes euro area countries, whereas the original analysis also includes other European countries such as Denmark, Sweden, Czech Republic, Bulgaria, Norway, Poland, and the UK; (b) our sample period is January 2010 – December 2019 (monthly), whereas the original results are based on an annual sample from 2006 – 2020; (c) instead of using CDS spreads as a control variables, we use the spread between "hedged" bond yields (i.e., yield-to-maturity minus the duration-matched CDS spread) as dependent variable; (d) as an alternative "treatment variable", we use the *Hist* dummy in some specifications that indicates whether a country relied on historical cost accounting prior to Solvency II; and (e) we do not include the full battery of control variables, as we are mainly interested in whether the main results prevail in our sample.

The results in columns (1) and (3) of Table G.16 confirm that in response to the UFR announcement, (a) hedged yields of long-term (i.e., those with a duration of more than 10 years) bonds relative to short-term bonds decrease more strongly in countries with a larger ICPF sector; and (b) hedged yields of 30-year bonds (defined as duration of 30 years or more) relative to 20-year bonds (with duration between 15–25 years) increase more strongly in said countries. In other words, 20-year bonds become more expensive relative to shorter or longer maturities, especially in countries with strong demand from the ICPF sector. The same result holds if we replace *ICPF size* by *Hist*, although the interpretation slightly

Table G.16: Effects of the UFR at the European level. This table displays the results of a replication of the results in columns (1)–(4) of Table 8 in Jansen [2025]. This table shows the effects of the UFR on hedged yield spreads of sovereign bonds for a panel of euro area countries over the period 2010m1–2019m12 (monthly). The UFR dummy equals one as of the announcement of the UFR as part of Solvency II regulation in August 2015, except for the Netherlands where the dummy equals one as of July 2012. $ICPF\ size$ equals the size of the ICPF market relative to public debt. $Hist$ is one for the following countries that used historical cost accounting to value insurers' liabilities: Austria, Belgium, Finland, France, Germany, Greece, Italy, Portugal, Slovakia, and Spain.

	10+ vs. 10- spread		30-20 spread	
	(1)	(2)	(3)	(4)
UFR=1 × ICPF size	-0.0934***		0.291***	
	(0.0245)		(0.0781)	
UFR=1 × ICPF size				
Hist=1 × UFR=1		-0.250***		0.323***
		(0.0479)		(0.101)
ICPF size	0.318***		-2.797***	
	(0.0553)		(0.256)	
Time FE	✓	✓	✓	✓
Country FE	✓	✓	✓	✓
R^2	0.61	0.59	0.60	0.49
Observations	1,628	1,316	676	676

Standard errors in parentheses

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

changes. All results inherit the caveat acknowledged by Jansen [2025] that they "should not be interpreted as causal, because by the time Solvency II was announced in August 2015, it was already evident that the UFR would be incorporated into the new regulatory framework."

Using our SHSS holdings data, we also replicate the bond-level regressions of Table IA10 in Jansen [2025] and confirm the finding that ICPF in countries with historical cost accounting before Solvency II, ICPF increase their portfolio shares of 20-year bonds after the UFR announcement relative to bonds with duration of less than 15 years. The relative portfolio shares of 30-year bonds, however, remain statistically unchanged.

These results—both in the price and the quantity space—inspire our approach in Section 7.1, where we interpret Solvency II and the UFR implementation as a shock to insurers' preference for 20-year bonds and bonds with high risk-based capital value (RBC).

Table G.17: Long-term bond holdings and the Europe-wide implementation of the UFR — historical costs. This table displays the results of a replication of the results in Table IA10 in Jansen [2025]. The dependent variable is the weight invested in bond s for ICPF-country c at time t (in terms of percentage points), with UFR equal to 1 as of 2015Q3 and zero otherwise, $30y$ an indicator variable that equals one if the time to maturity of bond s at time t is larger or equal to 30 years, and $20y$ an indicator variable that equals one if the time to maturity of bond s at time t is between 15 and 25 years. The countries included in the analysis are those that used historical costs to value their liabilities prior to the reform: Austria, Belgium, Finland, France, Germany, Greece, Italy, Portugal, Slovakia, and Spain. The quarterly sample period is 2011Q4-2025Q2. Standard errors are clustered at the country-security level.

	Dependent variable: Portfolio share			
	(1)	(2)	(3)	(4)
30y=1 × UFR=1	0.0611	0.0724	0.0773	0.00331
	(0.0570)	(0.0559)	(0.0565)	(0.0387)
20y=1 × UFR=1	0.0738*	0.0841*	0.0948**	0.102***
	(0.0445)	(0.0447)	(0.0451)	(0.0232)
Country FE		✓	✓	✓
Time FE			✓	✓
ISIN FE				✓
R^2	0.01	0.04	0.05	0.16
Observations	211,182	211,182	211,182	211,156

Standard errors in parentheses

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

Appendix H Extra Results for Corporate QE

Table H.18 presents the summary statistics for eligible and ineligible bonds to be purchased under the CSPP. The table shows that eligible bonds are significantly larger in size. Interestingly, the average credit spread of CSPP-eligible bonds was initially higher than that of ineligible bonds because the latter included bonds issued by banks, among which there are many AAA-rated issuers, partly thanks to implicit (or even explicit) government guarantees.

Table H.19: The effect of CSPP on corporate bond spreads. This table displays the results of estimating equation (15) where the outcome variables is a bond's credit spread. The first row contains difference-in-differences estimates of the price impact of CSPP. The different columns refer to different sets of fixed effects. The time period is September 2015 – September 2016.

	Dependent variable: Credit Spread				
	(1)	(2)	(3)	(4)	(5)
Post=1 × CSPP eligible=1	-0.221***	-0.253***	-0.252***	-0.198***	-0.227***
	(0.0155)	(0.00717)	(0.00717)	(0.0158)	(0.00710)
CSPP eligible=1	-0.0413***			-0.0540***	
	(0.0115)			(0.0116)	
Time FE	✓	✓	✓		
ISIN FE		✓	✓		✓
Rating x Maturity FE	✓		✓		
Rating x Maturity x Time FE				✓	✓
R^2	0.38	0.89	0.89	0.39	0.90
Observations	37,999	37,782	37,782	37,994	37,776

Standard errors in parentheses

Sample period: Sep 2015 – Sep 2016

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

Table H.20: The effect of CSPP on CDS spreads. This table displays the results of estimating equation (15) where the outcome variables is a bond's CDS spread. The first row contains difference-in-differences estimates of the price impact of CSPP. The different columns refer to different sets of fixed effects. The time period is September 2015 – September 2016.

	Dependent variable: CDS Spread				
	(1)	(2)	(3)	(4)	(5)
Post=1 × CSPP eligible=1	-0.0898***	-0.110***	-0.110***	-0.0889***	-0.106***
	(0.0118)	(0.00495)	(0.00495)	(0.0120)	(0.00475)
CSPP eligible=1	-0.240***			-0.240***	
	(0.00883)			(0.00884)	
Time FE	✓	✓	✓		
ISIN FE		✓	✓		✓
Rating x Maturity FE	✓		✓		
Rating x Maturity x Time FE				✓	✓
R^2	0.46	0.92	0.92	0.47	0.93
Observations	37,999	37,782	37,782	37,994	37,776

Standard errors in parentheses

Sample period: Sep 2015 – Sep 2016

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

Table H.21: The effect of CSPP on the CDS-bond basis. This table displays the results of estimating equation (15) where the outcome variables is a bond's CDS-bond basis. The first row contains difference-in-differences estimates of the price impact of CSPP. The different columns refer to different sets of fixed effects. The time period is September 2015 – September 2016.

	Dependent variable: CDS - Bond Basis				
	(1)	(2)	(3)	(4)	(5)
Post=1 × CSPP eligible=1	0.131***	0.143***	0.142***	0.109***	0.121***
	(0.0138)	(0.00742)	(0.00743)	(0.0142)	(0.00748)
CSPP eligible=1	-0.199***			-0.186***	
	(0.0103)			(0.0104)	
Time FE	✓	✓	✓		
ISIN FE		✓	✓		✓
Rating x Maturity FE	✓		✓		
Rating x Maturity x Time FE				✓	✓
R^2	0.11	0.79	0.79	0.12	0.79
Observations	37,999	37,782	37,782	37,994	37,776

Standard errors in parentheses

Sample period: Sep 2015 – Sep 2016

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

Appendix H.1 Parallel trends

To assess the validity of the parallel trends assumption and provide evidence of the dynamic impact of the ECB's corporate QE program for different time periods, we set up a Granger causality test, as suggested in Angrist and Pischke [2009]. We split the *Post* dummy into monthly dummies and run the following specification:

$$y_t(n) = \sum_{\tau} \theta_{0,\tau} \times \mathbb{1}_{\tau=t} \times Eligible_t(n) + \alpha_{R\times M} + \alpha_t + \epsilon_t(n) \tag{H.1}$$

We chose the month before the program announcement as reference date. Figure H.15 shows the dynamic DiD coefficient estimates with 95% confidence intervals for the credit

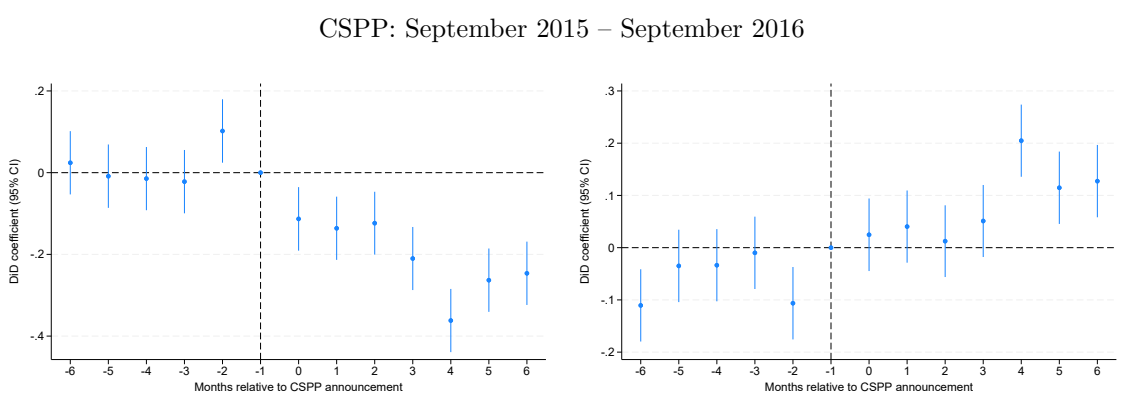


Figure H.15: DiD coefficients around the CSPP announcement. This figure contains the monthly point estimates in equation (H.1) where the dependent variables are credit spreads (left-hand panel) and the CDS-bond basis (right-hand panel).

spread (left-hand side) and for the CDS-Bond basis (right-hand side).

The impact of the CSPP announcement on the credit spread is clear. We observe that all coefficients are not statistically significant and close to zero until the month before the program announcement, whereas they become negative and statistically significant in the months that follow. The fact that we do not observe significant differences in the pre-period is strong evidence that the parallel trends assumption holds.

Regarding the CDS-Bond basis, we observe a positive significant result after the announcement of the CSPP, but no effect in the pre-period.

Table H.18: Summary statistics. This table contains information about the distribution of key variables prior to the CSPP announcement in March 2016, separately for eligible and ineligible corporate bonds. Outstanding amounts are measured in EUR million, and all remaining variables in percentage points. The sample period here is September 2015 – February 2016.

	Amount outstanding		Credit spread		CDS-bond basis	
	ineligible	eligible	ineligible	eligible	ineligible	eligible
Mean	248	647	1.05	1.12	-0.17	-0.32
SD	635	483	0.76	0.51	0.56	0.31
p10	10	100	0.28	0.63	-0.74	-0.67
p50	36	600	0.92	1.04	-0.17	-0.33
p90	750	1,050	1.93	1.74	0.44	0.03