# Dangerous Liaisons? Debt Supply and Convenience Yield Spillovers in the Euro Area*

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**Abstract**

The literature established that a sovereign bond's "convenience yield" premium diminishes when that country issues more debt. But how is this convenience yield affected when *another* country issues sovereign debt? Using high-frequency identification and debt management offices' communication, we find that an increase in German or French debt reduces convenience yields across the eurozone. Spillovers to low-risk countries are one-for-one while those to riskier countries are smaller. To rationalize these findings, we develop a model with heterogeneous credit risk. Safe sovereign bonds are close substitutes to hedge against idiosyncratic risk, explaining large spillovers, while risky bonds are poor substitutes.

*Keywords: Convenience Yield; Spillovers; EMU; Government Debt; High-Frequency Identification; Default Risk*
*JEL Codes: E62; F36; G15; H63*

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# 1 Introduction

Low sovereign yields are key for fiscal sustainability. Many countries sell sovereign bonds at a yield below the risk-free rate plus a default risk premium. This gap is coined the *convenience yield* in reference to the many convenience services provided to investors by these relatively safe assets (e.g., collateral usage, liquidity provision, and safety, as discussed in Reis, 2022).

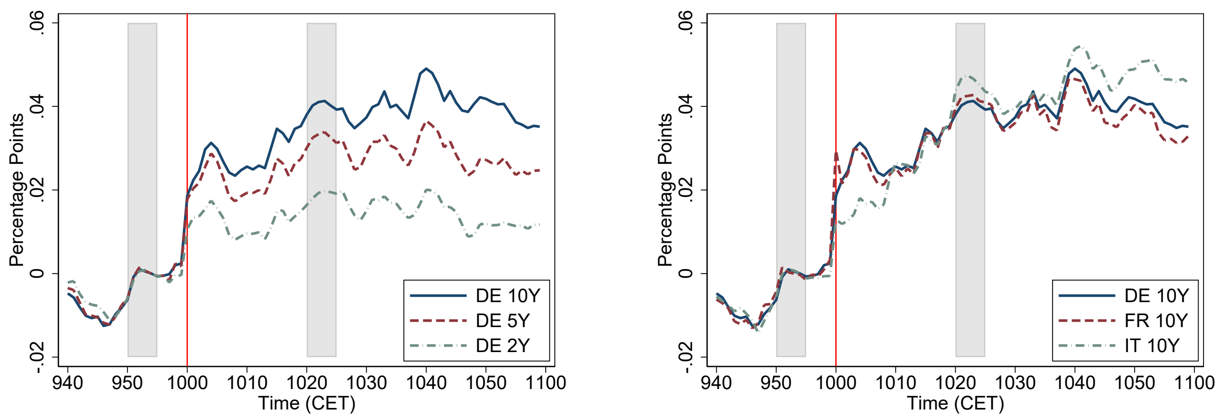
While the literature shows that the price of these convenience services declines when a country supplies more sovereign bonds (Krishnamurthy and Vissing-Jorgensen, 2012), little is known about the impact of *other countries'* bond supply. Effects of foreign safe asset issuance on the domestic convenience yield, if any, would constitute a new source of fiscal spillovers, beyond the typical spillover channels focusing on risk contagion, trade, and monetary policy.

This paper contributes to the literature by investigating convenience yield spillovers in the euro area and beyond, both in theory and in the data. To estimate these spillovers, we collect news about the supply of sovereign bonds from Germany, measure high-frequency market reactions to these events, and employ event-study and heteroskedasticity-based estimation methods. We find that spillovers to other low-risk countries' convenience yields are almost one-for-one while spillovers to riskier countries are smaller. We produce additional evidence from France confirming this pattern. To rationalize our empirical findings, we develop a stylized model in which two sovereign bonds are close substitutes to hedge against idiosyncratic income risk, leading to large spillover effects, if and only if their default risk is similarly low.

Figure 1 nicely illustrates both our identification strategy and our first main finding. On 14 December 2022, at 10:00 CET, the German debt management office (DMO) announced its issuance plan for the following calendar year. Market commentary suggests that the announced amount exceeded expectations, implying that this information led investors to revise upwards their expectations about future bond supply. Accordingly, German yields rose across maturities (left panel). The 10-year yield jumped by around 2 basis points on impact and increased in total by almost 4 basis points within 20 minutes. Even though the increase in the German yield was arguably caused by news about the supply of German debt, the French 10-year yield moved in an extremely similar way, suggesting strong spillovers and a high degree of substitutability (right panel). The Italian 10-year yield tracked the German yield less closely but also rose substantially.

Our empirical analysis leverages numerous such DMO announcements to systematically char-

Figure 1: German Debt Issuance Plan Announcement (14 December 2022)




(a) Germany (b) Spillovers

*Notes:* The red vertical line depicts the time of the announcement of the German debt issuance plan (10:00 CET). Shaded areas show the "before" and "after" time windows used to measure high-frequency changes.

acterize convenience yield spillovers. Conceptually, these spillovers arise if investors are willing to substitute the services provided by different sovereign bonds. Substitutability arguably depends on the extent of similarities between bonds. Therefore, we exploit the unique setting of the euro area where several sovereign issuers provide bonds that are denominated in the same currency, are similarly useful as hedging instruments or collateral, and whose prices are to a large extent driven by common fundamentals and policies.

In more detail, there are two key identification challenges to estimating convenience yield spillovers due to debt supply changes. That is, euro area convenience yields are affected by many common shocks, and changes in bond supply are well-anticipated by investors. Our empirical strategy that exploits the news about debt supply contained in the German DMO's debt issuance plan announcements allows us to overcome these challenges. We measure *debt supply shocks* as the change in the German 10-year yield in a 30-minute window around DMO announcements, based on the argument that these yield changes reflect revised expectations about German debt supply.

We measure convenience yields in the data as the gap between sovereign yields and the sum of euro overnight index swap (OIS) rates—a proxy for the risk-free rate—and credit default swap (CDS) rates—a proxy for the risk premium, following Jiang et al. (2020). We employ a range of state-of-the-art techniques to estimate spillovers from German debt supply shocks to other countries' convenience yields and highlight two main findings.

First, we find that convenience yield spillovers from German debt supply shocks are almost one-for-one to low-risk countries, recognized by low CDS rates, such as France, the Netherlands, Finland, Austria, and Belgium. We find spillovers close to unity also among sovereign yields at daily and intraday (30-minute window) frequency, as well as using the heteroskedasticity-based estimator of Rigobon and Sack (2004).

Second, we find that convenience yield spillovers from German debt supply shocks are substantially lower and often insignificant to riskier countries with comparably higher CDS rates, such as Italy, Spain, and Portugal. Again, this finding also emerges among sovereign yields and when using heteroskedasticity-based estimation.

We then examine whether the smaller magnitude of spillovers to riskier countries is an inherent country characteristic or varies over time. We find evidence of significant and large but not quite one-for-one spillovers from Germany to riskier countries in times when these countries are safer, as indicated by CDS rates below one. This suggests that the "safety" characteristic which determines the magnitude of convenience yield spillovers is not inherent but varies over time.

We run a battery of robustness checks to confirm the strength of our two main findings. We consider different maturities and data sources to compute convenience yields. We also consider alternative outlier treatments and different implementations of the heteroskedasticity-based estimator.

In addition, we estimate spillovers from France, where the DMO communication strategy forces us to rely on heteroskedasticity-based estimation only. Nonetheless, evidence from France confirms our results from Germany: convenience yield spillovers are almost one-to-one to other safe countries (Germany, Finland, Netherlands, Austria, and Belgium), while those to riskier countries (Italy, Spain, and Portugal) are usually smaller and insignificant.

Finally, we broaden the scope of our analysis and investigate spillovers beyond euro area sovereign debt. We find large spillovers also to bonds issued by the European Union (EU) as well as to investment-grade corporate bonds, indicating that these bonds are perceived as substitutes for bonds issued by safe euro area sovereigns. We also find significant spillovers to U.K., Danish, Swedish, and Norwegian sovereign yields, while effects on U.S., Japanese, Canadian, and Australian sovereign yields and euro area stock prices are mostly insignificant. This suggests that issuing in the same currency is not necessary for large spillovers and high substitutability, while geographic proximity and belonging to the same asset class matter.

To rationalize our main empirical findings, we build a stylized two-country three-period model of convenience yields in a currency union. We draw inspiration from the convenience yield model developed in Brunnermeier et al. (2024) and extend it by introducing a second sovereign bond issuer and default risk.

We assume that an exogenous and fixed supply of bonds is sold to households in the first period. With some probability, the economy enters a recession in the second period, in which a random subset of households experiences a strong fall in income relative to the rest. In this situation, worse-hit households sell their bonds to better-off households to mitigate their situation. In the third period, if a recession has occurred, the foreign country defaults on its bonds with a positive probability. Finally, bondholders get reimbursed from countries that have not defaulted.

Sovereign bonds carry a convenience yield because they can be re-traded at favorable prices in recessions and thereby allow households to partially insure themselves against idiosyncratic income risk. For each country, the convenience yield is defined as the bond price in period 1 relative to the price of a contract that delivers the same payoff in period 3 but that cannot be re-traded in period 2 in recessions. As noted in Reis (2022), the term convenience yield is a catch-all term capturing several convenience services provided by sovereign bonds. Hence, in the model, we focus on one specific dimension of the convenience yield, the service flow from re-trading in recessions described in Brunnermeier et al. (2024). In the empirical analysis, we use a model-free measurement of the convenience yield (Jiang et al., 2020) which is not restricted to this specific convenience service and therefore has a more general scope.

The stylized model allows us to characterize the interplay between convenience yields, sovereign bond supply, and default risk. We derive analytical results in a special case. We also parameterized the model based on data and the related literature to provide numerical results. The parametrized model confirms our analytical results and delivers numerical results that are quantitatively consistent with our empirical findings.

First, the model replicates the stylized empirical fact that a country earns a lower convenience yield if its probability of default is higher. The reason is that risky bonds trade at a lower price in recessions and are therefore less valuable as insurance against a low income realization. Quantitatively, the model matches the 24 basis point difference in convenience yields between safer and riskier euro area countries.

Second, the model predicts that convenience yields in *both* countries decrease when the supply of bonds from the safe (home) country increases. When more bonds are available, households are better insured against income risk and are less willing to pay for additional convenience services (insurance). This result implies the presence of a spillover effect because an increase in home bonds also affects the convenience yield in the *other* country.

Third, the model allows us to investigate how the magnitude of the spillover effect varies with default risk in the receiving (foreign) country. Spillovers are one-for-one when the receiving country is as safe as the origin country. In this case, both bonds are perfect substitutes. Conversely, spillovers to riskier countries are lower and decline with default risk. The parametrized model yields a spillover coefficient of 2/3 for such countries, in line with our empirical findings.

Overall, our findings have important policy implications for debt sustainability. For safe countries to secure low sovereign yields and fiscal sustainability, it matters how much safe debt is issued *in total*, and it matters less *which* country issues debt (e.g., whether debt is issued by France or Germany). This gives rise to an externality: the cost for one country to issue more debt (lower convenience yield and higher interest rates) accrues both to the issuing country and to other similarly safe countries. Therefore, our results underscore the importance of coordinated fiscal rules which can help contain this negative externality (spillover) which is present even in the absence of default risk.

The rest of this paper is structured as follows. Section 2 summarizes the related literature and highlights our contributions. Section 3 discusses the estimation strategy and the data used throughout the analysis while Section 4 presents our main empirical findings. Section 5 outlines our model of convenience yields in a monetary union as well as the main model results. Section 6 concludes.

# 2 Related Literature

First and foremost, this paper relates to the literature investigating the determinants of convenience yields of sovereign debt. Krishnamurthy and Vissing-Jorgensen (2012) show that the convenience yield in U.S. Treasuries falls when their supply increases. Jiang et al. (2020) present evidence for this negative relationship between convenience yields and bond supply for euro area countries. We contribute to this literature by documenting that convenience yields not only decline with countries' own bond supply but also with the bond supply of issuers with similar characteristics. Further determinants of convenience yields include risk-free interest rates (Nagel, 2016), safety (e.g., Mian et al. 2022), liquidity (e.g., Reis 2022), and the international monetary system more generally (Farhi and Maggiori, 2018).

Second, the model presented in this paper relates to the theoretical literature providing micro-foundations for convenience yields. We build on Brunnermeier et al. (2024) who rationalize convenience yields with the insurance value of sovereign bonds—they can be sold at a relatively high price during recessions. Our contribution is to extend the insights from their single-country model to a framework with two issuers of sovereign bonds, one of them carrying default risk. This allows us to rationalize two key features of the evidence: convenience yield levels are heterogeneous and spillovers depend on default risk differentials. Convenience yields in a framework with several issuers, but without explicit micro-foundation or default risk, have been studied, e.g., in Alpanda and Kabaca (2020).

Third, our empirical strategy relates to the literature using high-frequency identification to obtain fiscal shocks. Ray et al. (2024) identify U.S. Treasury demand shocks from auction results, while Phillot (2024) and Gomez Cram et al. (2024) identify U.S. Treasury supply shocks from auction announcements and communication of the Congressional Budget Office, respectively. Lengyel (2022) identifies supply shocks for the U.K. and Lengyel and Giuliodori (2021) identify demand shocks for euro area debt from auction results. To the best of our knowledge, this paper is the first to identify debt supply shocks for several euro area countries, using debt issuance plan announcements.

Finally, our work relates to the literature on fiscal spillovers in currency unions and in the euro area in particular. Euro area sovereign yields display a strong co-movement, in particular during crises, as documented by Caporale and Girardi (2013), Antonakakis and Vergos (2013), and Umar et al. (2021). Burriel et al. (2024) estimate the role of fundamentals, while Ehrmann and Fratzscher (2017) discuss fragmentation and the role of the unconventional monetary policy. Focusing on a particular component of sovereign yields, Galariotis et al. (2016) analyze spillovers among default risk premia, using CDS rates. We focus on another component of euro area sovereign yields, namely convenience yields. Further, the study of spillovers in the literature has focused on risk contagion or flight-to-safety behavior originating from changes in risk and risk perception. We study another source of sovereign yield spillovers that operates through bond supply and the global demand for the convenience services associated with sovereign bonds.

Perhaps most closely related is the work of Nenova (2024), who estimates bond demand elasticities using data on holdings by mutual funds and simple yields. In contrast, we rely on market data, which encompasses all investors, focus on convenience yields, and study bond substitutability in response to precisely-identified country-specific changes in debt supply. Nonetheless, our results agree along many (e.g., strong substitutability among core euro area bonds), but not all (e.g., substitutability of German sovereign bonds with corporate and supranational bonds) dimensions with the findings of Nenova (2024).

# 3 Empirical Strategy

We now outline our empirical methodology for estimating the spillover effects of changes in the debt supply of an individual country. Section 3.1 explains the challenges to identifying spillovers and our strategy to overcome these challenges using high-frequency identification and communication of debt management offices (DMOs). Section 3.2 summarizes our data and discusses the advantageous setting of the euro area. Section 3.3 outlines the estimation methods that we employ to estimate spillovers and assesses our high-frequency-identified debt supply shocks.

## 3.1 Identification

There are two main challenges to identifying the spillover effects of changes in the supply of debt of individual countries to convenience yields of other countries. First, convenience yields—and sovereign yields more generally—are not only exposed to changes in country-specific debt supply but also to a variety of other forces. Therefore, a high correlation among sovereign (convenience) yields, especially among euro area countries with low sovereign risk premia as documented by Jiang et al. (2020), does not provide decisive evidence of spillover effects, as it may also reflect the impact of common drivers. Common changes in debt supply or demand (e.g., the ECB's asset purchases) affect all convenience yields simultaneously, thereby creating a positive correlation. Conversely, changes in investors' risk perception or risk aversion can induce them to reallocate their portfolios between bonds of safer and riskier countries, generating a negative correlation. Second, changes in the supply of sovereign debt are usually anticipated well in advance. With forward-looking financial markets, the effects of debt supply changes are therefore priced in by the time the debt issuance takes place.

Our approach to overcoming these two challenges is inspired by the literature identifying the effects of monetary policy using central bank communication (e.g., Kuttner 2001). We make use of communication events of DMOs that release *news* about the country-specific supply of sovereign debt. Inspecting the co-movement of convenience yields in a tight window around the release of news about country-specific debt supply allows us to cut through confounding shocks. Moreover, utilizing news resolves the foresight issue, because the communication events release information that is not perfectly anticipated by investors.

**Measuring News about Debt Supply from DMO Communication.** Our primary source of news about the country-specific supply of sovereign debt is official communication of the *Federal Republic of Germany - Finance Agency* (German DMO), which is responsible for the German federal government's debt management, borrowing, and cash management. In additional analyses, we also make use of communication of the French DMO, but relegate the discussion of the institutional details to Appendix A.4.

The German DMO publishes its annual debt issuance plan for the subsequent calendar year in December and provides quarterly updates during the year in March, June, and September. The date and exact time of these publications are communicated in advance and therefore salient to financial markets. The headline results are typically disseminated within seconds.[1] Figure 1 exemplifies that the issuance plan publications indeed contain information that is quickly incorporated into yields. On this date, yields at various maturities jumped within the first minute of the publication. This institutional setup provides an ideal setting for a high-frequency event-study analysis.

The quantities announced by the DMO are not directly informative about the *news* contained in the announcement, because we do not know what quantities investors were expecting to be announced and, therefore, to what extent the announced quantities differed from expectations. To measure the *surprise component* of a given announcement, we compute the change in the German sovereign yield in a narrow 30-minute window around the announcement, which usually takes place at 10:00 CET. That is, we calculate the change in the yield from before (median yield between 09:50 CET and 09:55 CET) to after (median yield between 10:20 CET and 10:25 CET) the announcement. We use the change in the yield of the 10-year benchmark bond as our baseline measure of the surprise because bonds with a longer residual maturity provide a better signal-to-noise ratio.[2]

[1] For example, on 14 December 2022, the date depicted in Figure 1, Bloomberg released the message "*GERMANY TO ISSUE RECORD EU539 BILLION IN FEDERAL DEBT NEXT YEAR*" at the same minute as the announcement (10:00 CET).

[2] News about debt supply induce larger 30-minute changes in the 10-year yield than in the 5-year or 2-year yield, as exemplified by Figure 1. In addition, risk-free interest rates—another driver of sovereign

In our estimation sample, these 30-minute surprises, henceforth referred to as *debt supply shocks*, have a standard deviation of 1.1 basis points and are strong and significant predictors of daily changes in German 10-year (convenience) yields, as discussed in more detail in Section 3.3. To further support our claim that the debt supply shocks indeed measure news about debt supply, we document in Figure A.1 in the Appendix that for the issuance plan revisions (in March, June, September) there is a positive correlation with quantity revisions.

## 3.2 Data and Measurement

For our main analyses, we rely on daily financial data from Bloomberg and Refinitiv on sovereign bond yields, euro-denominated credit default swap (CDS) rates, and Overnight Index Swap (OIS) rates at various maturities. Because data on CDS rates only becomes available in 2009, our main sample runs from 2009 until 2023. The dataset covers 9 major euro area sovereign bond issuers (Germany, Netherlands, Finland, France, Austria, Belgium, Italy, Spain, and Portugal). For additional analyses, we also use bond yields of other sovereign, supranational, and corporate issuers as well as stock price indices. For the four biggest euro area countries, we also have intraday (minute-by-minute) data on 2-year, 5-year, and 10-year sovereign bond yields from Bloomberg.

Our analysis focuses on the euro area, which provides a unique setting for studying spillovers from country-specific debt issuance. Spillovers plausibly depend on various issuer and bond characteristics, such as currency, safety, sovereign issuer status, and geographic area. The euro area provides an ideal setting for identifying spillovers across countries because several issuers offer bonds that are very similar along these dimensions—including currency—allowing us to approximate an upper bound for spillovers. Even more importantly, within the euro area and Europe, some issuers differ along single dimensions, enabling us to disentangle the role of these characteristics.

**Convenience Yields.** To measure convenience yields in sovereign bonds, we follow Jiang et al. (2020) and Gnewuch (2022) and decompose bond yields as:

$$Y_t^i = R_t + \delta_t^i - CY_t^i \tag{1}$$

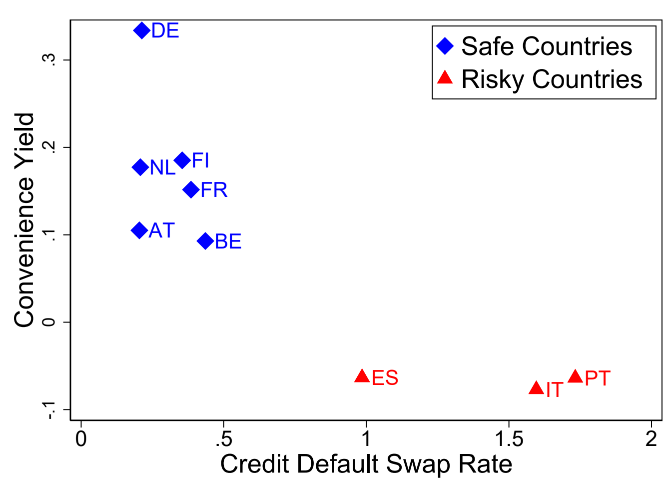
yields—are less volatile at longer horizons than at shorter horizons. In line with this, 30-minute changes around German DMO announcements explain a higher share of the variance of daily yield changes when using 10-year yields as compared to 5-year or 2-year yields.

where $Y_t^i$ denotes the bond yield for country $i$ at time $t$, $R_t$ represents the risk-free rate, measured using the maturity-matched OIS rate, $\delta_t^i$ captures the default risk premium, measured using the maturity-matched CDS rate, and $CY_t^i$ is the convenience yield. An increase in the convenience yield indicates an increase in the premium paid by investors for the convenience services of the bond and hence a larger discount on the yield for the issuer.

**Descriptive Evidence.** Convenience yields vary substantially across countries. Figure 2 plots median convenience yields and median CDS rates at the 10-year maturity for the nine countries in our main sample. There is a clear negative relationship, i.e., riskier countries, as reflected in a higher CDS rate, have lower convenience yields. The theoretical model presented in Section 5, in which convenience yields reflect the resale value in recessions, rationalizes this correlation. In the following, we refer to the group of countries with a median CDS rate above 50 basis points as "risky" countries. This group includes Italy, Spain, and Portugal. The group of countries with an average CDS rate below 50 basis points is referred to as "safe" or "low-risk" countries.

Table A.1 in the Appendix presents more detailed summary statistics of convenience yields, yields, and CDS rates, while Figures OA.1 - OA.3 in the Online Appendix show the time series of those variables.

FIGURE 2: Convenience Yields and CDS Rates in the Euro Area




*Notes:* This figure plots median 10-year convenience yields and median 10-year CDS rates for each country in the main data set. Sample period: 2009-2023.

**Estimation Sample.** Between 2007 and 2023, 68 announcements of the German DMO took place (4 per year over this 17-year period). To cleanly isolate the effects of country-specific debt supply shocks, we drop dates that coincided with major but unrelated European events including ECB Governing Council Meeting days (5 dates), have missing CDS data (11 dates), have inconsistent CDS data between Bloomberg and Refinitiv (5 dates), or took place within one day of an announcement by the French DMO (3 dates). More details on the estimation sample are relegated to Appendix A.2.

Our resulting baseline sample for estimating spillovers covers 44 announcements of the German DMO between 2009 and 2023. We use this baseline sample throughout our analysis in order to facilitate comparisons across methods and results. For some methods and estimations, we are able to use additional observations and we present robustness checks in the Appendix on larger samples, when possible. For example, when estimating yield spillovers, we do not need CDS rates and we consider a larger sample which reintroduces observations that were excluded because of missing or inconsistent CDS data.

## 3.3 Estimation Methods

To estimate the spillover effects of changes in country-specific debt supply, we use our debt supply shocks in combination with OLS, IV, and heteroskedasticity-based estimation techniques. The first approach focuses on changes within a 30-minute window. The two latter methods are applied to daily data and take into account that convenience yield changes on DMO dates may not only reflect news about debt supply but also idiosyncratic and common noise.

Throughout, we focus on estimating the *spillover* effect of changes in domestic debt supply on a foreign (convenience) yield, i.e., the foreign effect *relative* to the domestic effect. As we do not directly observe the change in expected debt supply, we cannot estimate the effect of a change in domestic debt (in billions) on the domestic yield. Implicitly, we normalize the domestic debt supply shock to have an effect of 1 basis point on the domestic yield. Importantly, this does not interfere with our estimation of the (convenience) yield spillover effect in response to a change in domestic debt supply.

**Method 1: High-Frequency Spillovers using OLS.** With a precisely timed announcement and high-frequency data, a common assumption is that noise in a narrow window around the announcement is negligible (Gürkaynak et al., 2004; Swanson, 2021). Under this assumption, the high-frequency spillover effect of a debt supply shock can be estimated with a simple OLS regression of the announcement window change in the outcome variable, namely the foreign yield, on the change in the domestic yield triggered by the news about debt supply.

**Method 2: Daily Spillovers using IV.** When estimating spillovers at a daily frequency, we have to acknowledge the possible presence of common and country-specific noise. Common noise, such as news about monetary policy, would bias spillover effects estimated with simple OLS regressions, because common shocks, by definition, correlate with yield changes in the domestic country as well as in the foreign country.

However, when a high-frequency instrument, such as the debt supply shocks, is available, we can estimate spillovers at the daily frequency, as long as we maintain the assumption that there is no common noise during the 30-minute window around the announcement. To do so, we use an IV approach and regress the daily change in the outcome variable on the daily change in the domestic (convenience) yield, which is instrumented with the 30-minute window change in the domestic yield (the "debt supply shock").

This method necessitates the debt supply shock to be a strong instrument for the daily change in the (convenience) yield. We assess the first stage of these IV regressions in Table A.3. With an F-stat of 12.6, the debt supply shock is a strong instrument for the daily change in the convenience yield. Quantitatively, an increase in the yield within the 30-minute window of 1 basis point is associated with a decline in the convenience yield on that day of 0.92 basis points ($t = -3.55$). This shows that the 30-minute yield changes indeed largely reflect movements in the convenience yield and not in the other components of the sovereign yield (risk-free rate, default risk premium). Moreover, it shows that the news about debt supply is incorporated into prices within 30 minutes. The debt supply shock is also a significant predictor of the daily change in yields, although with a lower F-stat (4.8). This is consistent with the notion that yields are exposed to more additional forces than convenience yields and are therefore more noisy reflections of changes in debt supply.

**Method 3: Daily Spillovers using Heteroskedasticity-based Estimation.** As a robustness check or when there is no high-frequency instrument available—as in the case of the French DMO announcements—we use the heteroskedasticity-based estimator of Rigobon (2003) and Rigobon and Sack (2004) (henceforth, the RS estimator).

The RS estimator exploits knowledge about the timing of news about debt supply to consistently estimate spillovers. In our context, we assume that there are more news about debt supply (higher variance of convenience yield changes) on DMO announcement dates than on a set of well-chosen other days. Following Rigobon and Sack (2004), we use the business days preceding the announcement dates for this purpose. This estimator imposes the least restrictive assumptions with respect to background noise and common shocks, as it only requires them to have the same variance across the two sets of dates. In contrast, the previous methods assumed that all yield changes in a 30-minute window around the announcements reflect debt supply shocks, thereby assuming that there is no background noise in this window. We show in Table A.2 that the necessary restriction—higher variance of convenience yield changes on DMO dates—is satisfied for both German and French DMO announcements. A more detailed discussion of the methodology and its implementation through an instrumental variable approach are relegated to Section C.2 in the Online Appendix.

# 4 Empirical Findings

In this section, we estimate the spillover effects of changes in the supply of sovereign debt of an individual country. We obtain two main findings across a range of estimation techniques (event-study OLS and IV using intraday data, RS estimation using daily data). First, (convenience) yield spillovers among safe euro area countries are large, usually close to unity. Second, (convenience) yield spillovers from safe to risky countries are on average much smaller and also much less precisely estimated, possibly reflecting that effects vary over time and across countries. We document these findings for shocks originating in Germany (Sections 4.1 and 4.2). We then corroborate them by estimating spillovers from France, in which case we have fewer observations and where fewer estimation techniques apply (Section 4.3). Finally, we estimate spillover effects from Germany to a range of assets beyond the market for euro-area sovereign debt (Section 4.4).

## 4.1 Event-Study OLS Estimations using Intraday Data

We begin by estimating intraday yield spillovers (Method 1), thereby formalizing the anecdotal evidence presented in Figure 1. The advantage of using intraday data (30-minute windows) is that it minimizes the amount of contemporaneous noise and confounding shocks. The downside is that intraday data is available only for a subset of countries and variables, such that we cannot measure convenience yields.

Table 1 shows the estimated spillover effects and thus our two main findings. First, spillovers to the other safe country (France) are large, highly statistically significant, and close to 1. A 10 basis point increase in the German yield leads to an 8.8 basis point increase in the French yield. Second, spillovers to risky countries (Italy, Spain) are smaller in magnitude and less precisely estimated, though still significant. In the Appendix, we show that these findings remain unchanged if the full sample of German DMO dates is used (Table A.4), or a sample for which high-frequency data for all three countries is available (Table A.5).

Table 1: Intraday Yield Spillovers from Germany (Method 1: OLS)

| | *Safe Countries* | *Risky Countries* | |
|---|---|---|---|
| | (1)<br>$\Delta Y_{FR}$ | (2)<br>$\Delta Y_{IT}$ | (3)<br>$\Delta Y_{ES}$ |
| $\Delta Y_{DE}$ | 0.88*** | 0.62*** | 0.51** |
| | (0.10) | (0.21) | (0.24) |
| Constant | 0.00 | 0.00 | 0.00 |
| | (0.00) | (0.00) | (0.00) |
| Observations | 44 | 43 | 39 |
| $R^2$ | 0.80 | 0.20 | 0.20 |

*Notes:* Each column displays coefficients from a separate regression: $\Delta Y_{Destination,t} = \beta_0 + \beta_1 \times \Delta Y_{DE,t} + \epsilon_t$, where changes are 30-minute changes around German DMO announcements. Standard errors are reported in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

## 4.2 Event-Study IV Estimations using Intraday Data

An important limitation of the intraday analysis is that many outcome variables of interest are not available, including convenience yields and yields of smaller euro area countries. Therefore, we turn to a slightly lower (i.e., daily) frequency, which also allows us to examine whether the documented intraday spillovers persist through the end of business days. We deal with the larger amount of noise and contemporaneous shocks at the daily frequency by using the high-frequency-identified debt supply shocks in IV regressions (Method 2).

Table 2 shows our estimated convenience yield spillovers at the daily frequency. The spillover estimates again stress our two main findings. First, convenience yield spillovers are close to unity and highly statistically significant to safe countries (France, the Netherlands, Austria, Belgium, and Finland). Second, spillovers to riskier countries (Italy, Spain, and Portugal) are on average smaller in magnitude, statistically insignificant, and imprecisely estimated. This evidence also shows that the spillovers estimated in 30-minute windows persist at the daily frequency.

In addition to our main findings, we assess whether the smaller spillover effect to risky countries is an inherent country characteristic or a time-varying feature. We find that spillovers to risky countries become larger, statistically significant, and more precisely estimated once we effectively exclude periods with particularly high CDS rates above 1 by including an interaction term with the lagged CDS rate (column 11). This suggests that spillovers from safe countries can vary over time with a destination country's default risk and are not an inherent characteristic.

Spillovers being less precisely estimated for risky countries is in line with the model presented in Section 5. The model predicts spillovers between two safe countries to be close to 1 and independent of other forces. However, when countries differ in their riskiness, the spillover effect falls below 1 and also becomes dependent on further, potentially time-varying factors, such as the levels of debt supply. Hence, the imprecisely estimated spillover effect from safe to risky countries may reflect that this effect varies over time and across countries.

Table 2: Daily Convenience Yield Spillovers from Germany (Method 2: IV)

| | *Safe Countries* | | | | | | *Risky Countries* | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | (1) $\Delta CY_{FR}$ | (2) $\Delta CY_{NL}$ | (3) $\Delta CY_{FI}$ | (4) $\Delta CY_{AT}$ | (5) $\Delta CY_{BE}$ | (6) Pool | (7) $\Delta CY_{IT}$ | (8) $\Delta CY_{ES}$ | (9) $\Delta CY_{PT}$ | (10) Pool | (11) Pool |
| $\Delta CY_{DE}$ | 0.92*** | 0.97*** | 1.19*** | 0.67*** | 1.14** | | 0.79 | -0.43 | 1.62 | | |
| | (0.23) | (0.25) | (0.21) | (0.24) | (0.56) | | (0.85) | (0.90) | (1.05) | | |
| $\Delta CY_{DE}$ | | | | | | 0.98*** | | | | 0.66 | 0.89*** |
| | | | | | | (0.22) | | | | (0.65) | (0.25) |
| $\Delta CY_{DE}$ $\times \mathbb{1}\{CDS_t > 1\}$ | | | | | | | | | | | -0.48 |
| | | | | | | | | | | | (1.19) |
| Constant | -0.00 | 0.00 | -0.00 | -0.00 | -0.00 | -0.00 | -0.01 | -0.01 | -0.01 | -0.01 | -0.01 |
| | (0.00) | (0.01) | (0.00) | (0.00) | (0.01) | (0.00) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) |
| Observations | 44 | 44 | 44 | 44 | 44 | 220 | 44 | 44 | 44 | 132 | 132 |

*Notes:* Each column displays coefficients from a separate regression: $\Delta CY_{Destination,t} = \beta_0 + \beta_1 \times \Delta CY_{DE,t} + \epsilon_t$, for columns (1)-(5) and (7)-(9); $\Delta CY_{Destination,t} = \beta_0 + \beta_1 \times \Delta CY_{DE,t} + \beta_2 \Delta CY_{DE,t} \times \mathbb{1}\{CDS_t > 1\} + \epsilon_t$, for columns (6) and (10)-(11); where the daily change in the German convenience yield is instrumented with the 30-minute yield change and $\mathbb{1}\{CDS_t > 1\}$ is an indicator variable that take value 1 if the CDS rate is above 1 and 0 otherwise. Standard errors are reported in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Comparing the co-movement of convenience yields *conditional* on debt supply shocks, as documented in Table 2, with their *unconditional* co-movement (Table A.2 in the Appendix) highlights the relevance of debt supply shocks and the importance of our identification strategy. Column 4 of Table A.2 shows that the correlations between changes in the German convenience yield and in other countries' convenience yields on days without salient debt supply shocks are low and largely insignificant. In contrast, we estimate a sizeable and statistically significant conditional co-movement in response to debt supply shocks.

**Robustness Checks.** We provide a battery of robustness checks to confirm the strength of our two main findings.

First, we confirm that the findings presented in Table 2 remain unchanged when we use a less restrictive sample (Table A.7), CDS data from Refinitiv instead of from Bloomberg (Table A.8), or bonds and swaps with a maturity of 5 years instead of 10 years (Table A.9).

Second, our theory is centered on convenience yields rather than on simple yields, motivating our focus on convenience yields. Studying convenience yields removes any effects that changes in country-specific debt supply may have on risk-free rates and default risk premia from our analysis. Nonetheless, we show in Tables A.6 and OA.1 that our two main findings remain unchanged when we estimate spillovers using simple yields.

Third, we estimate spillover effects using the RS estimator (Method 3). This estimator only exploits the higher variance of convenience yields, caused by debt supply shocks, in comparison to a set of dates without such shocks. Therefore, the RS estimator imposes the least restrictive assumptions with respect to background noise but also disregards the available information on the intraday timing of announcements. The estimates using the RS estimator, though somewhat less precise than those using intraday data, confirm our two main findings in our main sample (Table OA.2) as well as in alternative implementations (Table OA.3 uses a smaller sample with a stricter exclusion rule for outliers and Tables OA.4-OA.5 show findings with alternative implementations using different instrument variables). We also implement two statistical tests to support the relevance of the Rigobon-Sack approach. Whenever applicable, the Hansen J-Test strongly supports the validity of the instrument variables used in the procedure. The Stock and Yogo test of weak IV often suggests that the instruments are somewhat weak. However, they are assessed as strong in the case of France in the restricted sample in Table OA.3 and significant coefficient estimates are highly consistent across alternative implementations.

### 4.3 Spillover Effects from Debt Supply Shocks in Other Countries

To investigate whether our two main findings are specific to debt supply shocks originating in Germany, we now turn our attention to France. The communication of the French DMO only allows us to estimate spillovers at the daily frequency, because announcements do not take place at a specific and pre-announced time of the day.[3] We can therefore estimate spillover effects from France to other countries only using the RS estimator. Fortunately, the analysis of German debt supply shocks shows that the RS estimator performs reasonably well in comparison to the other approaches, despite neglecting the available intraday information.

Table 3 presents spillover estimates from France to other euro area countries. The findings are strikingly similar to those for Germany. First, we find a spillover effect from France to Germany which is very close to unity and highly significant. Spillovers to other safe countries (Netherlands, Finland, Austria, and Belgium) are also close to unity. Second, spillovers to Italy and Spain are smaller and not or only barely significant. They are extremely imprecisely estimated for Portugal and insignificant.

TABLE 3: Daily Convenience Yield Spillovers from France (Method 3: Rigobon-Sack Estimator)

| | *Safe Countries* | | | | | *Risky Countries* | | |
|---|---|---|---|---|---|---|---|---|
| | (1) $\Delta CY_{DE}$ | (2) $\Delta CY_{NL}$ | (3) $\Delta CY_{FI}$ | (4) $\Delta CY_{AT}$ | (5) $\Delta CY_{BE}$ | (6) $\Delta CY_{IT}$ | (7) $\Delta CY_{ES}$ | (8) $\Delta CY_{PT}$ |
| $\Delta CY_{FR}$ | 1.26*** | 0.85** | 0.77* | 0.91*** | 0.95*** | -0.19 | 0.73 | 1.66 |
| | (0.39) | (0.35) | (0.43) | (0.27) | (0.31) | (0.54) | (0.64) | (4.14) |
| Constant | 0.00 | 0.00 | -0.00 | -0.00 | -0.00 | 0.00 | 0.00 | 0.02 |
| | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.01) | (0.00) | (0.02) |
| N | 44 | 44 | 44 | 44 | 44 | 44 | 44 | 44 |
| Weak IV | 4.57 | 5.13 | 3.93 | 3.95 | 4.85 | 3.97 | 3.99 | 7.61 |
| Overid. | 0.24 | 0.76 | 0.48 | 0.46 | 0.74 | 0.83 | 0.79 | 0.24 |

*Notes: Each column displays coefficients from a separate regression:* $\Delta CY_{Destination,t} = \beta_0 + \beta_1 \times \Delta CY_{FR,t} + \epsilon_t$*, where we employ the RS estimator described in Section 3.3. Each column corresponds to a different destination country. For every column, we use the two-step GMM estimator and the two instrument variables based on the change in the variance-covariance matrix of the origin and destrination country yields. Robust standard errors are reported in parentheses and stars indicate significance levels: ** $p < 0.10$*, *** $p < 0.05$*, **** $p < 0.01$*. The before last row shows the Stock-Yogo weak IV statistics while the associated threshold for the 25% maximal IV size is estimated at 7.25. The last row reports the p-value of the Hansen J overidentification test where the null hypothesis is that the instruments are valid.*

We perform a large number of robustness checks that confirm these findings for shocks orig-

[3] We have also explored the communication of the Italian DMO. However, their communication is even less suitable for our analysis, because debt issuance announcements take place when markets are closed.

inating in France. As in the case of spillovers from Germany, we consider estimates based on a smaller sample with a stricter exclusion rule for outliers (Table A.10) and alternative implementations of the heteroskedasticity-based estimator (Tables A.11-A.12) in the Appendix.

### 4.4 Spillover Effects Beyond Euro Area Sovereign Bonds

The first main finding documented in the previous subsections establishes that changes in the supply of one safe euro area country's sovereign debt have large spillover effects on convenience yields and yields of sovereign bonds of other safe euro area countries. These large effects are plausible in view of the fact that these are all very similar assets that share many characteristics (sovereign issuer, safety, currency, geographic area, asset class). The existence of multiple sovereign issuers providing very similar safe assets makes the euro area a particularly useful setting to study spillovers.

The second main finding establishes that safety matters for spillovers among euro area sovereign bonds. To investigate which other characteristics matter, we now investigate spillover effects of debt supply changes to other assets that are also relatively safe and therefore potential substitutes for euro area sovereign bonds but differ with respect to other characteristics.

First, we look at supranational bonds issued by the European Union as well as investment-grade corporate bonds, to assess spillovers to bonds that are also safe and euro-denominated but are not issued by a sovereign. Second, we study spillovers to German, French, and European stocks, which are also euro-denominated, but an entirely different asset class. Third, we study spillovers to yields of non-euro sovereign issuers in Europe and outside of Europe that are considered safe to investigate the role of the currency and the geographic area.

**Spillovers to EU Bonds & Euro Area Corporate Bonds.** Using daily data, we find sizeable and significant spillovers from German debt supply shocks to EU bond yields, demonstrating that these bonds are close substitutes. Spillovers to euro area investment-grade corporate bonds are also highly significant and close to unity (Table 4).[4] This supports

[4] For the results in Table 4, we use the Bank of America Merrill Lynch EMU Corporates Non-Financial AAA, AA, A, and BBB indices retrieved from Refinitiv Eikon as well as yields on EU bonds from Bloomberg.

the idea that highly-rated corporate bonds are also close substitutes for highly-rated government bonds, despite lacking the sovereign-issuer status.

Table 4: Daily Spillovers from Germany to Other Euro Area Assets (Method 2: IV)

| | *Supranat. Bonds* | *Corporate Bonds* | | | | *Stock Indices* | | |
|---|---|---|---|---|---|---|---|---|
| | (1) $\Delta Y_{EU}$ | (2) ΔAAA | (3) ΔAA | (4) ΔA | (5) ΔBBB | (6) ΔDAX | (7) ΔCAC40 | (8) ΔStoxx50 |
| $\Delta Y_{DE}$ | 0.80*** | 0.91*** | 1.05*** | 1.07*** | 1.11*** | 0.03 | 0.03 | 0.02 |
| | (0.12) | (0.18) | (0.17) | (0.21) | (0.28) | (0.06) | (0.07) | (0.07) |
| Constant | 0.00 | 0.00 | 0.00 | 0.01* | 0.01* | -0.00 | -0.00 | -0.00 |
| | (0.00) | (0.00) | (0.00) | (0.00) | (0.01) | (0.00) | (0.00) | (0.00) |
| Observations | 38 | 44 | 44 | 44 | 44 | 44 | 44 | 44 |

*Notes:* Each column displays coefficients from a separate regression: $\Delta Y_{EU,t} = \beta_0 + \beta_1 \times \Delta Y_{DE,t} + \epsilon_t$ for column (1); $\Delta \textit{Corporate Yield Index}_t = \beta_0 + \beta_1 \times \Delta Y_{DE,t} + \epsilon_t$ for columns (2) - (5); $\Delta log(\textit{Stock Index}_t) = \beta_0 + \beta_1 \times \Delta Y_{DE,t} + \epsilon_t$ for columns (6) - (8), where the daily change in the German yield is instrumented with the 30-minute change. Standard errors are reported in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

**Spillovers to European Stock Prices.** In contrast, we find positive but insignificant spillover effects to the major German (DAX), French (CAC 40), and European (Stoxx 50) stock price indices, demonstrating that stocks are not close substitutes for euro-area sovereign bonds. We interpret the increase in stock prices despite higher interest rates as suggestive evidence of a higher capacity and appetite to bear risks by investors, resulting from the reduced cost and higher supply of bonds which serve as a hedge against risk.

**Spillovers to Non-Euro-Area Sovereign Bonds.** Table 5 shows that there are also large and significant spillovers to sovereign bond yields of non-euro European sovereigns (the United Kingdom, Denmark, Sweden, and Norway) with the exception of Switzerland. This suggests that issuing in the same currency is not the decisive characteristic for large spillovers. In contrast, we find much smaller and insignificant spillovers to non-European sovereigns whose bonds are perceived as safe-haven-assets (United States, Japan, Canada, Australia). This suggests that geographical proximity does matter for spillovers.

# 5 A Model of Convenience Yields in a Monetary Union

We build a stylized model of convenience yields to rationalize our empirical findings. We describe the model (Section 5.1), provide intuition and analytical results under restrictive

Table 5: Daily Spillovers from Germany Beyond Euro Area Sovereign Bonds (Method 2: IV)

| | *European Countries* | | | | | *Non-European Countries* | | | |
|---|---|---|---|---|---|---|---|---|---|
| | (1) $\Delta Y_{GB}$ | (2) $\Delta Y_{DK}$ | (3) $\Delta Y_{SE}$ | (4) $\Delta Y_{NO}$ | (5) $\Delta Y_{CH}$ | (6) $\Delta Y_{US}$ | (7) $\Delta Y_{JP}$ | (8) $\Delta Y_{CA}$ | (9) $\Delta Y_{AU}$ |
| $\Delta Y_{DE}$ | 1.03*** | 1.05*** | 1.32** | 1.35** | 0.39 | 0.46 | 0.08 | 0.32 | 0.41 |
| | (0.28) | (0.12) | (0.56) | (0.53) | (0.26) | (0.37) | (0.09) | (0.33) | (0.55) |
| Constant | 0.00 | 0.00 | 0.01 | 0.01 | -0.00 | -0.01 | -0.00* | -0.01 | -0.01 |
| | (0.00) | (0.00) | (0.01) | (0.01) | (0.00) | (0.01) | (0.00) | (0.00) | (0.01) |
| Observations | 44 | 44 | 44 | 44 | 44 | 44 | 44 | 44 | 44 |

*Notes:* Each column displays coefficients from a separate regression: $\Delta Y_{Destination,t} = \beta_0 + \beta_1 \times \Delta Y_{DE,t} + \epsilon$, where the daily change in the German yield is instrumented with the 30-minute change. Standard errors are reported in parentheses. $^{*}$ $p < 0.10$, $^{**}$ $p < 0.05$, $^{***}$ $p < 0.01$.

assumptions (Section 5.2), and show that a parametrized version of the unrestricted model delivers results that are quantitatively consistent with our empirical findings (Section 5.3). We relegate technical details to Appendix B.

## 5.1 Model Setup

Time is discrete and there are three periods $t = \{1, 2, 3\}$. The model comprises a continuum of households that purchase sovereign bonds to smooth consumption over time and to insure themselves against idiosyncratic income risk that arises in recessions. As in Brunnermeier et al. (2024), sovereign bonds are considered "safe assets" because their secondary markets never dry up, and they continue to be traded (at favorable prices) even in recessions unlike other assets. As a result of their unique insurance properties, sovereign bonds carry a convenience yield premium. We assume that sovereign bonds are supplied inelastically by two countries $H$ ("Home") and $F$ ("Foreign") in a common currency.[5]

**Households.** Households in the two countries are identical and therefore we do not distinguish between households living in $H$ and $F$. Households maximize expected lifetime utility generated by consumption. They receive an exogenous income $w_{t,i}$ ("wage") in each period. The only source of household heterogeneity is income in period 2, which can be low

[5] We consider countries that form a monetary union and therefore have a fixed exchange rate. Extending the model to countries that do not share the same currency requires introducing endogenous exchange rate fluctuations as in Alpanda and Kabaca (2020).

("type A") or high ("type B") when a recession occurs. Households do not know their type in period 1, but they know the probability of receiving either level of income. To smooth consumption, households buy bonds in period 1 from the sovereign issuers $(b_1^H, b_1^F)$, re-trade them in period 2 among each other ($db_{2,i}^H, db_{2,i}^F$ for each type $i = A, B$, with $db > 0$ when bonds are sold and $db < 0$ when bonds are bought on the secondary market), and are paid back in period 3, unless a sovereign defaults.

**Uncertainty.** There are three sources of uncertainty. First, in period 2, a recession ($R = 1$) occurs with probability $P_R > 0$. Second, if and only if a recession occurs in period 2, country $F$ will default at the end of period 2 with positive probability $P(D^F = 1|R = 1) = P_D$ and $P_D > 0$. If there is no recession, there is no default risk $P(D^F = 1|R = 0) = 0$. Country $H$ does not default in either state, $P(D^H = 1) = 0$. Third, if and only if a recession occurs in period 2, household income is $w_{2,A}$ with probability $P_A$ and $w_{2,B}$ with probability $1-P_A$ and $w_{2,A} < w_{2,B}$. Otherwise, income in period 2 is identical for all households and equal to $w_{2,O}$. Figure 3 illustrates the sequence in which decisions are taken and uncertainties are resolved.

**Household Optimization.** We describe the households' optimization recursively. Households enter period 2 with bonds purchased in period 1 $(b_1^H, b_1^F)$, which they can re-trade $(db_{2,i}^H, db_{2,i}^F)$. Households of type $i = A$ or $B$ solve

$$V_{2,i}(b_1^H, b_1^F) = \max_{\{db_{2,i}^H, db_{2,i}^F\}} u(c_{2,i}) + \beta E_2 \left[u(c_{3,i}(D^F))\right] \tag{2}$$

$$s.t. \quad c_{2,i} = w_{2,i} + p_2^H db_{2,i}^H + p_2^F db_{2,i}^F \tag{3}$$

$$c_{3,i}(D^F) = w_3 + (b_1^H - db_{2,i}^H) + (b_1^F - db_{2,i}^F)(1 - D^F) \tag{4}$$

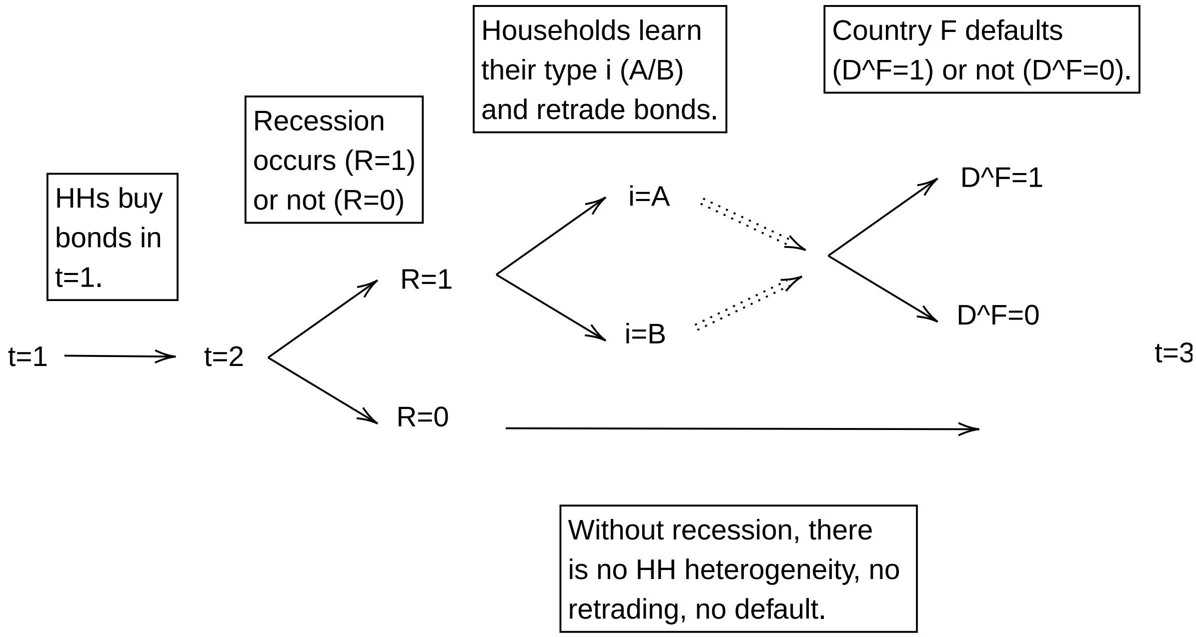
$$b_1^H - db_{2,i}^H \geq 0 \qquad \text{(no-short-selling constraint on H-bond)} \tag{5}$$

$$b_1^F - db_{2,i}^F \geq 0 \qquad \text{(no-short-selling constraint on F-bond)} \tag{6}$$

where the per-period utility function $u$ has standard properties regarding continuity and derivatives $\left(u(.) > 0,\ \lim_{c \to 0} u'(c) = +\infty,\ u''(.) \leq 0\right)$, and where $E_2$ is the expectation operator based on information available in period 2. In period 2, there is re-trading of bonds only among households, so net household demand must be 0 ($P_A db_{2,A}^c + (1 - P_A) db_{2,B}^c = 0$ for $c = H, F$). Re-trading only happens in a recession, as in the absence of a recession, households remain homogeneous. $D^F$ is an indicator variable that takes the value 1 if country $F$ defaults (which also only happens when a recession occurs).[6] At this point in time, the only

[6] If there is a default, the default is complete and all bond value is lost for the household.

Figure 3: Model Timing




uncertainty remaining is whether country $F$ will default in period 3 or not.

We assume that bond supply is low enough to constrain households' decisions in recessions.[7] In recessions, type-A households experience a steeper decline in income and want to re-sell their bonds to compensate for the income loss. The assumption on bond supply restricts our attention to the equilibria where there is a shortage of safe assets, meaning that, in recessions, type-A households would be willing to re-sell even more bonds at the going prices than what they hold. In other words, we consider corner solutions where the no-short-selling constraints on both bonds are binding for type-A households.

As a result, households are not able to fully insure themselves against idiosyncratic income risk with sovereign bonds. Markets are incomplete as we assume that there are no other

[7] Technically, we assume that the domestic and foreign bonds issued in period 1 $(B_1^H, B_1^F)$ are such that $B_1^H < \hat{b}_1^H$ and $B_1^F < \widehat{b}_2^F\left(B_1^H\right)$ and where the value $\hat{b}_1^H$ and the function $\widehat{b}_2^F\left(B_1^H\right)$ are derived as a function of model parameters in Appendix section B.3 .

financial instruments that can provide insurance against such risk. Therefore, the valuation of sovereign bonds also depends on households' valuation of additional insurance. Both sovereign bonds carry a convenience yield premium above the yields that would be determined by the bonds' repayment profile.

Technically, when the no-short-selling constraints are binding, there is a range of prices that clear the market. The price at which the type-B households are willing to buy all available bonds exceeds the price at which the type-A households are willing to sell all their bonds, and the equilibrium prices $(p_2^H, p_2^F)$ can be anywhere in between. To resolve this indeterminacy, we assume that the prices are such that type-B households are indifferent between buying one more or one fewer marginal unit of either bonds.[8]

Now turning our attention to period 1, households solve

$$V_1 = \max_{\{b_1^H, b_1^F\}} u(c_1) + \beta E_1 \left[ V_{2,i}(b_1^H, b_1^F) \right] \tag{7}$$

$$s.t. \qquad c_1 = w_1 - p_1^H b_1^H - p_1^F b_1^F \tag{8}$$

where $p_1^H$ and $p_1^F$ are the equilibrium bond prices in period 1, respectively, and where $E_1$ is the expectation operator based on information in period 1. Households need to form expectations because of aggregate uncertainty ($R$, $D^F$) as well as idiosyncratic uncertainty ($i = A$ or $B$). Since households learn their "type" only at the start of period 2, they make identical decisions in period 1 $(b_1^H, b_1^F)$. Demand from all households must equal the exogenous supply of bonds $(B_1^H, B_1^F)$, respectively.

**Convenience Yields.** Sovereign bonds are convenient because they can be sold in a recession. We assume that other financial instruments are illiquid in recessions and that the convenience yield is the premium paid by investors for having the option of re-trading sovereign bonds in recessions. We measure the convenience yield of country $c$ as the (log) difference between the price of a bond $(p_1^c)$ and the price of a contract $(\tilde{p}_1^c)$ that has the same payment profile as the corresponding bond (full reimbursement in period 3 if there is

[8]Our results would continue to hold qualitatively if we instead assume that the prices are at a fixed distance between the two ends of the price ranges, as long as the prices are strictly larger than the prices that make type-A households indifferent.

no default) but cannot be sold in period 2:

$$CY_1^c = \log\left(\frac{p_1^c}{\tilde{p}_1^c}\right) \tag{9}$$

This convenience yield definition is analytically more tractable than the definition used later in empirical analysis $\left(\frac{1}{\tilde{p}_1^c} - \frac{1}{p_1^c}\right)$, yet approximately equivalent, as derived in Appendix B.9.

## 5.2 Analytical Results

We solve for all variables analytically in the Appendix B in the general case. The convenience yields of home and foreign can be expressed as

$$CY_1^H = \log\left(\frac{(1-P_R)u'(c_{3,O}) + P_R(1-P_A)E_2\left[u'(c_{3,B})\right]\left[1 + \frac{P_A}{1-P_A}\overbrace{\frac{u'(c_{2,A})}{u'(c_{2,B})}}^{\text{benefit}^H}\right]}{(1-P_R)u'(c_{3,O}) + P_R(1-P_A)E_2\left[u'(c_{3,B})\right]\left[1 + \frac{P_A}{1-P_A}\underbrace{\frac{E_2\left[u'(c_{3,A})\right]}{E_2\left[u'(c_{3,B})\right]}}_{\text{cost}^H}\right]}\right) \tag{10}$$

$$CY_1^F = \log\left(\frac{(1-P_R)u'(c_{3,O}) + P_R(1-P_A)E_2\left[u'(c_{3,B})\right]\left[1 + \overbrace{\frac{P_A}{1-P_A}\frac{u'(c_{2,A})}{u'(c_{2,B})}}^{\text{benefit}^F}\right](1-P_D)}{(1-P_R)u'(c_{3,O}) + P_R(1-P_A)E_2\left[u'(c_{3,B})\right]\left[1 + \underbrace{\frac{P_A}{1-P_A}\frac{u'(c_{3,A(D^F=0)})}{u'(c_{3,B(D^F=0)})}}_{\text{cost}^F}\right](1-P_D)}\right) \tag{11}$$

with $c_{2,A} = w_{2,A} + p_2^H B_1^H + p_2^F B_1^F$ and $c_{2,B} = w_{2,B} - \frac{P_A}{(1-P_A)}(p_2^H B_1^H + p_2^F B_1^F)$ in period 2, and with $c_{3,O} = w_3 + B_1^H + B_1^F$, $c_{3,A} = w_3$ and $c_{3,B}(D^F) = w_3 + \frac{(B_1^H + B_1^F D^F)}{(1-P_A)}$ in period 3.

These equations illustrate that convenience yields are positive as long as there is a non-zero recession probability ($P_R > 0$), default is not systematic ($P_D < 1$), and the *benefit* of selling bonds in a recession exceeds the *cost* of doing so.

The *benefit* reflects that sovereign bonds enable households to transfer resources from the poor (type-A) income realization to the rich (type-B) income realization in recessions. The *benefit* increases with the consumption difference between types, captured by the weighted ratio of type-A over type-B marginal utilities in recessions.

However, insurance has a *cost*, which is that type-A households miss out on the payoff of bonds in period 3 as it goes entirely to type-B households. This *cost* is reflected by the weighted ratio of type-A over type-B marginal utilities in period 3.

Our assumption that bond supply is rationed implies that households cannot perfectly insure against idiosyncratic income risk. In turn, this implies that the *benefit* exceeds the *cost* of insurance and both convenience yields are positive (unless $P_D = 1$, in which case $CY_1^F = 0$).

In the special case in which a recession happens with certainty ($P_R = 1$), we derive three main results (proofs are relegated to the Appendix B). While less realistic, this special case preserves the essential mechanisms and considerably simplifies expressions. Subsection 5.3 confirms numerically that our analytical results remain valid when $P_R \leq 1$.

### 5.2.1 Higher Default Risk Erodes the Convenience Yield

**Analytical Results (A).** In the case when $P_R = 1$, we derive that

(i) $CY_1^F < CY_1^H$ if $0 < P_D$ while $CY_1^F = CY_1^H$ if $P_D = 0$,

(ii) $\frac{\partial\left(CY_1^H - CY_1^F\right)}{\partial P_D} \geq 0$ for $0 \leq P_D \leq 1$.

In words, Analytical Result (A.i) states that the home convenience yield is larger than the foreign convenience yield when there is positive default risk. In the limit case of no default risk, the two convenience yields are identical. Analytical Result (A.ii) states that the difference in convenience yields between the safe (home) and the risky (foreign) country increases with the probability of default of the risky foreign bond.[9]

Intuitively, convenience yields reflect the net benefits of being able to sell a bond if income is low (type A) in a recession. Bonds that trade at a higher price in a recession are therefore more valuable as insurance and earn a larger convenience yield. Default risk drives down the price of the foreign bond in a recession because it reduces the expected return of the foreign bond. In consequence, risky foreign bonds earn a smaller convenience yield than

[9]As in Kaldorf and Röttger (2023), countries with higher default risk earn a lower convenience yield. However, the mechanism that generates this relationship in our model is different. In Kaldorf and Röttger (2023), the "convenience" of bonds declines with default risk, because default risk leads to larger haircuts, making the bonds less useful as collateral.

home bonds.

Our first analytical results is consistent with the data featured in Figure 2. Indeed, the figure shows that riskier countries (those with a higher default probability and higher CDS rates) have a lower convenience yield compared with safer countries.

### 5.2.2 Higher Bond Supply Erodes Convenience Yields

Our paper focuses on the movements of convenience yields across countries in response to an increase in the supply of home bonds. In the model, these correspond to the derivatives of convenience yields with respect to $B_1^H$. For completeness, we also examine the case of a change in the supply of foreign bonds.

**Analytical Results (B).** In the case when $P_R = 1$, we have that

(i) $\frac{\partial CY_1^F}{\partial B_1^H} \leq 0$, $\frac{\partial CY_1^H}{\partial B_1^H} \leq 0$,

(ii) $\frac{\partial CY_1^F}{\partial B_1^F} \leq 0$, and $\frac{\partial CY_1^H}{\partial B_1^F} \leq 0$

if $\frac{B_1^H + B_1^F}{(1-P_A)w_3 + (B_1^H + B_1^F)} \frac{c_{3,B}(0)u''(c_{3,B}(0))}{u'(c_{3,B}(0))} > -1$ and $\frac{B_1^H}{(1-P_A)w_3 + B_1^H} \frac{c_{3,B}(1)u''(c_{3,B}(1))}{u'(c_{3,B}(1))} > -1$.

We use condensed notations for period 3 consumption in the above results. In period 3 following a recession, type-B households hold all the bonds because they bought everything from type-A households in period 2. Therefore, $c_{3,B}(1) = w_3 + \frac{B_1^H}{1-P_A}$ is a type-B household's consumption in period 3 when the foreign bond defaults and $c_{3,B}(0) = w_3 + \frac{B_1^H + B_1^F}{1-P_A}$ is its consumption in period 3 without default.

In words, Analytical Result (B.i) shows that *both* home and foreign convenience yields decrease when the supply of home bonds increases. Analytical Result (B.ii) shows the same response for an increase in the supply of foreign bonds.

Intuitively, our second analytical results reflect the logic of supply and demand. The convenience yield reflects the value of the insurance services provided by a sovereign bond in recessions. The supply of the insurance services is determined by bond issuance in period 1 $(B_1^H, B_1^F)$ because insurance is achieved by re-selling bonds in period 2 and the total amount available for insurance purpose in a recession (akin to insurance payouts) is $p_2^H B_1^H + p_2^F B_1^F$. The results provide sufficient conditions for standard supply-demand logic to apply, ensuring that an increase in bond supply increases the amount available for insurance, i.e., the increase in supply is not offset by declines in bond prices.[10] In turn, greater insurance facilitated by more home bonds (or more foreign bonds) reduces the appetite for more insurance and reduces both convenience yields.

The conditions have an intuitive interpretation themselves: they require that type-B households' coefficients of relative risk aversion $\left(-\frac{c.u''(c)}{u'(c)}\right)$ are not too high in period 3 in both the default and no-default states, or that the share of bond payoffs in type-B households' income is not too high. The empirical literature suggests that coefficients of relative risk aversion are between 1 and 10, and most likely around 3, while the share of sovereign bond income in total income is unlikely to exceed 10% for most households.[11] Therefore, there is evidence suggesting the conditions are met.

#### 5.2.3 Convenience Yield Spillovers Decrease with Default Risk Differential

We now compare the magnitude of convenience yields responses to a change in bond supply across countries by studying $\frac{\partial CY_1^F}{\partial B_1^H} / \frac{\partial CY_1^H}{\partial B_1^H}$. In other words, this ratio captures spillovers in convenience yields arising from a home bond supply change.

**Analytical Results (C).** In the case when $P_R = 1$, we have that

(i) $\frac{\partial CY_1^F}{\partial B_1^H} / \frac{\partial CY_1^H}{\partial B_1^H} \to 1$ when $P_D \to 0$,

(ii) $\frac{\partial CY_1^F}{\partial B_1^H} = 0$ when $P_D = 1$,

(iii) $\frac{\partial \frac{\partial CY_1^F}{\partial B_1^H} / \frac{\partial CY_1^H}{\partial B_1^H}}{\partial P_D} \leq 0$ and the $\frac{\partial CY_1^F}{\partial B_1^H} / \frac{\partial CY_1^H}{\partial B_1^H}$ declines monotonically from 1 to 0 as $P_D$ increases from 0 to 1 if the utility function is characterized by strong prudence ($u'''$ is positive and large enough).

The extreme cases considered in Analytical Results (C.i) and (C.ii) are straightforward. When the foreign country is as safe as the home country (Analytical Result C.i), the two bonds offer identical payoffs, their convenience yields are the same, they move one-to-one

[10] We show in the Appendix that if the conditions are not met, for example when risk aversion is very high, bond prices in recessions can become extremely sensitive to the availability of bonds, and an increase in home bonds can trigger a drop in prices that brings down the total value of re-tradable bonds (the value being the price times the quantity).

[11] Among others, Attanasio and Weber (1995) estimate the coefficient of relative risk aversion around 2 using data from the Consumer Expenditure Survey while Chetty (2006) estimates coefficients between 1 and 3 using labor supply data.

with any shock, and the spillover from a home bond supply change is one. When the foreign bond defaults with certainty in a recession (Analytical Result C.ii), the foreign convenience yield is constant and equal to zero, because the price of the foreign bond in a recession is 0. Thus, there is no spillover to the foreign convenience yield.

To get intuition about spillover magnitudes in between the extreme cases as considered in Analytical Result (C.iii), analytical derivations are helpful to realize that all the difference in the magnitude of the convenience yields' response comes from the *cost* component.

An increase in the probability of default makes type-B households poorer in period 3 in expectation. When the utility function is characterized by strong prudence, being poorer leads to an increase in type-B households' risk aversion in period 3. As a result the valuation of the *cost* component of the home convenience yield becomes more sensitive to variations in home bonds: an increase in home bonds provides much more insurance against *default* risks, the *cost* component of the home convenience yield increases much more with home bonds, and the home convenience yield decreases much more. In contrast, the *cost* component of the foreign convenience yield is unaffected by default risks. To sum up, when $P_D$ is larger, the home convenience yield responds more to a home bond supply change than the foreign convenience yield and spillovers from the home country are smaller.

Examination of equations 10-11 reveals another role for default risk in the general case when $P_R < 1$. When the probability of default gets closer to one, it shrinks the foreign convenience yield to insignificance. In the foreign country, it dampens all the mechanisms discussed in the special case of $P_R = 1$. As a result, the response of the foreign convenience yield to home bond supply changes are smaller compared to the response of the home convenience yield in absolute terms. The shrinking of the foreign convenience yield and its variations is therefore an additional force lowering spillovers to the foreign country.

## 5.3 Numerical Results

Next, we use our model to provide numerical results, which serve two purposes. First, these results illustrate that our analytical results hold away from the special case ($P_R = 1$) that was used in some derivations. Second, the results show that, with reasonable parameter values, the model—despite its simplicity—generates convenience yield differentials between safe and risky countries and spillover coefficients to safe and risky countries which are in line with the data (cf. Figure 2 and Table 2).

**Parametrization.** To provide numerical results, we parametrize the model. We discuss here only the key parameters and relegate other parametrization considerations to Appendix B.10. Table B.1 lists all parameter values.

Since the convenience yield reflects an insurance value (i.e., the value attached to being able to re-sell the bonds in a recession), its level for a default risk-free country ($H$) is mainly determined by the coefficient of relative risk aversion, the probability of a recession, income risk (in a recession), and the supply of debt. The coefficient of relative risk aversion is set to $\sigma = 5.5$, a value in the middle of the range of values reported in the empirical literature (1 to 10). We set the probability of a recession (within a 10-year period) to $P_R = 0.5$, as during the first 20 years since the inception of the euro area, there has been one major crisis (the euro crisis) during which default risk became a serious issue. Income dispersion (income of rich relative to poor households) rises in a recession by around 50%, towards the upper end of the range of estimates provided for the Great Recession by Heathcote et al. (2020). Debt issuance by countries is set to 20% of country-specific GDP, approximating the annual gross debt issuance by euro area countries.

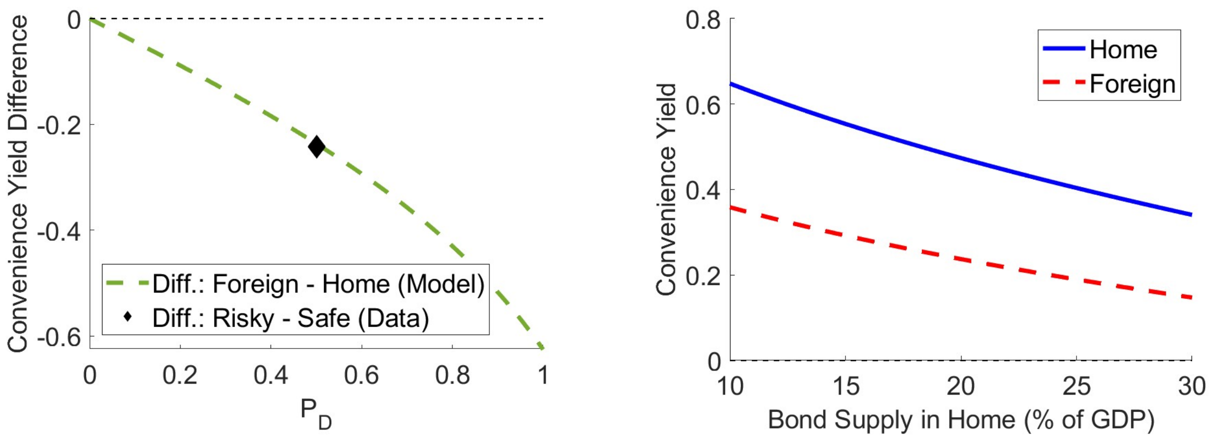
Given the risk-free country's convenience yield level, the convenience yield differential for the (potentially) risky country ($F$) as well as the spillover coefficient mainly depend on the probability of default in a recession. Based on average cumulative default probabilities of around 25% (over a 10-year period) implied by CDS rates for risky countries in our dataset (Italy, Spain, Portugal), we set $P_D^{Risky} = 0.5$, such that the ex-ante default probability is $P_R \times P_D = 0.25$. For safe countries, we set $P_D^{Safe} = 0$.

### 5.3.1 Higher Default Risk Erodes the Convenience Yield

The left panel of Figure 4 illustrates the difference in convenience yields between the foreign and the home country over a range of default probabilities $P_D$ (for the foreign country). It confirms that the foreign convenience yield is systematically lower than the home convenience yield, except when there is no default risk and both convenience yields are identical (Analytical Results A). Figure B.1 in the Appendix illustrates the convenience yield levels for both countries underlying the difference shown in the left panel of Figure 4.

Quantitatively, the model aligns well with the empirical evidence. Using data on CDS-implied cumulative default risk probabilities in the context of our model, risky countries have a default probability in a recession of 50%. As depicted in the left panel of Figure 4 with a black diamond, their median convenience yield in the data is 24 basis points lower than that of safe countries (cf. Figure 2 or Table A.1, where we average the safe and risky countries' median values). As shown with the dashed green line, the parametrized model predicts the same convenience yield difference between countries when $P_D = 0.5$.

FIGURE 4: Convenience Yields Decline with Default Risk and Bond Supply




(A) The Role of Default Risk

(B) The Role of Bond Supply (at *Home*)

### 5.3.2 Higher Bond Supply Erodes Convenience Yields

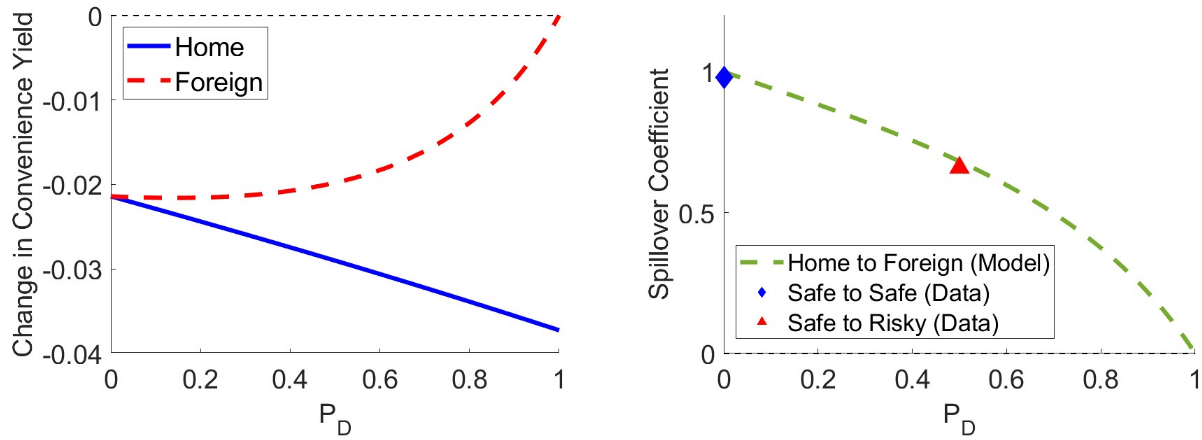
The right panel of Figure 4 plots the convenience yield levels of home and foreign over a range of values for the supply of home bonds (holding foreign bond supply fixed). It confirms that both convenience yields decline if home issues more bonds (Analytical Results B.i).

### 5.3.3 Convenience Yield Spillovers Decrease with Default Risk Differential

The left panel of Figure 5 illustrates how both countries' convenience yields change when the supply of home bonds increases by 10%, as a function of the default probability of foreign bonds. The changes in both convenience yields are negative, in line with the notion that higher bond supply erodes the convenience yield. However, the magnitude of the decline in the foreign convenience yield relative to the decline in the home convenience yield—the spillover coefficient as depicted in the right panel of Figure 5—depends very much on the default probability. When there is no default risk, bonds are perfect substitutes and hence the spillover coefficient is 1. As default risk increases, the spillover effect weakens monotonically. In the limit case where default risk (conditional on a recession) is 1, the foreign bond carries no convenience yield and there is no spillover effect. This confirms Analytical Results C.

Quantitatively, the model predicts a spillover coefficient from home to a "safe" foreign country ($P_D = P_D^{Safe} = 0$) of 1, very close to the empirical estimate of 0.98 (Table 2), which is depicted in the right panel of Figure 5 with a blue diamond. Moreover, the model predicts a spillover coefficient from home to a "risky" foreign country ($P_D = P_D^{Risky} = 0.5$) of 0.68, again close to the empirical estimate of 0.66, as depicted with a red triangle.

FIGURE 5: Spillovers in Convenience Yields from Bond Supply Shocks at *Home*




(A) Change in Convenience Yields ($\Delta CY_F$, $\Delta CY_H$) (B) Spillover Coefficient ($\Delta CY_F/\Delta CY_H$)

# 6 Conclusion

We examine empirically the relationships between convenience yields of different countries. To do so, we identify debt supply shocks in Germany, using publications of debt issuance plans by the German DMO alongside minute and daily data on bond (convenience) yields. We employ several estimation techniques, ranging from high-frequency event-study methods in the spirit of Gürkaynak et al. (2004) to the heteroskedasticity-based estimator of Rigobon (2003). We find spillovers from Germany to be almost one-to-one when the receiving countries are low-risk, while the spillovers to riskier countries are lower and mostly insignificant. We confirm the two main findings by estimating spillovers originating from France.

To rationalize our findings, we build and parametrize a convenience yield model close to Brunnermeier et al. (2024) and extend it along two key dimensions—by introducing multiple sovereigns and incorporating default risk. The model predicts (i) a higher convenience yield when a country's probability of default is lower, (ii) a decrease in countries' convenience yields when the supply of bonds increases in one safe country, and (iii) a spillover effect that declines with the default risk of the receiving country. The parametrized version of the model replicates the magnitude of the uncovered spillovers.

Our paper contributes to the academic literature as well as to policy debates by showing the existence of a new form of fiscal spillover effects operating through the global demand for the convenience services associated with sovereign bonds. These spillover effects are unlikely to be fully internalized by sovereign issuers, reinforcing the case for coordinated policies. Our results highlight the importance of considering cross-border effects in fiscal planning and the potential financial stability benefits of harmonized debt management strategies within the euro area.

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# A Empirical Appendix

## A.1 Summary Statistics & Descriptive Evidence

Table A.1 presents summary statistics of convenience yields, yields, and CDS rates, as illustrated in Figure 2.

Table A.1: Summary Statistics

| Country | Convenience Yield | | | Yield | | | CDS | | |
|---|---|---|---|---|---|---|---|---|---|
| | Mean | Median | SD | Mean | Median | SD | Mean | Median | SD |
| Germany | 0.37 | 0.33 | 0.26 | 1.16 | 0.88 | 1.21 | 0.30 | 0.21 | 0.24 |
| Netherlands | 0.19 | 0.18 | 0.24 | 1.39 | 1.09 | 1.30 | 0.34 | 0.21 | 0.31 |
| Finland | 0.19 | 0.19 | 0.20 | 1.43 | 1.05 | 1.30 | 0.38 | 0.35 | 0.21 |
| France | 0.15 | 0.15 | 0.23 | 1.61 | 1.28 | 1.29 | 0.53 | 0.39 | 0.36 |
| Austria | 0.09 | 0.11 | 0.22 | 1.54 | 1.19 | 1.38 | 0.39 | 0.20 | 0.38 |
| Belgium | 0.08 | 0.09 | 0.24 | 1.76 | 1.27 | 1.48 | 0.61 | 0.44 | 0.57 |
| Italy | -0.08 | -0.08 | 0.36 | 3.03 | 2.90 | 1.55 | 1.74 | 1.60 | 0.75 |
| Spain | -0.18 | -0.06 | 0.44 | 2.68 | 2.12 | 1.81 | 1.29 | 0.99 | 0.91 |
| Portugal | -0.32 | -0.06 | 0.74 | 3.81 | 3.15 | 3.09 | 2.32 | 1.73 | 2.06 |

*Note*: This table reports the mean, median, and standard deviation (SD) for convenience yields, yields, and CDS rates for the period 2009-2023. All values are reported in percentage points and for the 10-year maturity. The data is at daily frequency.

Table A.2 presents key descriptive statistics on changes in convenience yields for the set of DMO announcement dates and the set of the preceding dates. Comparing statistics across these two sets of dates provides suggestive evidence about the relevance of the DMO announcements. The top panel focuses on Germany and the bottom one on France. The first two columns report standard deviations of daily changes in convenience yields, on the days preceding the announcements and on the announcement dates respectively. They are almost systematically and significantly higher in the second column that focuses on the announcement dates (p-values of testing the difference are reported in the third column). This supports the view that DMO announcements generate shocks that move the convenience yields more than on normal days.

The right panel in Table A.2 shows that the co-movements of changes in convenience yields across countries tend to differ between announcement dates and the preceding days. Correlations are notably higher and more significant on announcement dates (columns 6-7 versus columns 4-5). Together with the higher standard deviations, this evidence supports the relevance of the announcements and the use of the RS estimator based on heteroskedasticity as done in Section 4.3.

Table A.2: Variances and correlations on announcement ($T$) and non-announcement ($T-1$) dates

| | CY change, std. dev. by dates | | | Corr. with source shock by dates | | | |
|---|---|---|---|---|---|---|---|
| | (1) $sd_{T-1}$ | (2) $sd_T$ | (3) $sd_{T-1} = sd_T$ p-value | (4) $\beta_{T-1}$ | (5) $\beta_{T-1} = 0$ p-value | (6) $\beta_T$ | (7) $\beta_T = 0$ p-value |
| **Germany** | | | | | | | |
| $\Delta CY_{DE}$ | 0.018 | 0.024 | 0.067 | 1.000 | . | 1.000 | . |
| $\Delta CY_{NL}$ | 0.015 | 0.022 | 0.011 | 0.375 | 0.000 | 0.700 | 0.000 |
| $\Delta CY_{FI}$ | 0.032 | 0.053 | 0.001 | 0.883 | 0.000 | 1.577 | 0.022 |
| $\Delta CY_{FR}$ | 0.021 | 0.027 | 0.091 | 0.694 | 0.002 | 0.918 | 0.000 |
| $\Delta CY_{AT}$ | 0.016 | 0.024 | 0.009 | 0.436 | 0.006 | 0.613 | 0.000 |
| $\Delta CY_{BE}$ | 0.031 | 0.041 | 0.069 | 0.378 | 0.372 | 0.498 | 0.040 |
| $\Delta CY_{IT}$ | 0.054 | 0.054 | 0.972 | 0.248 | 0.422 | 0.333 | 0.367 |
| $\Delta CY_{ES}$ | 0.043 | 0.049 | 0.384 | 0.688 | 0.004 | 0.526 | 0.192 |
| $\Delta CY_{PT}$ | 0.054 | 0.093 | 0.001 | 0.599 | 0.148 | 0.544 | 0.294 |
| Observations | 44 | 44 | . | 44 | . | 44 | . |
| **France** | | | | | | | |
| $\Delta CY_{FR}$ | 0.016 | 0.024 | 0.054 | 1.000 | . | 1.000 | . |
| $\Delta CY_{DE}$ | 0.011 | 0.028 | 0.000 | 0.403 | 0.037 | 0.730 | 0.005 |
| $\Delta CY_{NL}$ | 0.014 | 0.022 | 0.047 | 0.384 | 0.181 | 0.740 | 0.008 |
| $\Delta CY_{FI}$ | 0.020 | 0.029 | 0.099 | 0.694 | 0.010 | 0.676 | 0.012 |
| $\Delta CY_{AT}$ | 0.017 | 0.024 | 0.102 | 0.754 | 0.003 | 0.791 | 0.000 |
| $\Delta CY_{BE}$ | 0.018 | 0.024 | 0.154 | 0.395 | 0.151 | 0.735 | 0.000 |
| $\Delta CY_{IT}$ | 0.041 | 0.045 | 0.711 | 0.139 | 0.814 | -0.028 | 0.904 |
| $\Delta CY_{ES}$ | 0.033 | 0.035 | 0.822 | 0.478 | 0.442 | 0.685 | 0.021 |
| $\Delta CY_{PT}$ | 0.233 | 0.088 | 0.000 | 7.769 | 0.155 | 1.310 | 0.100 |
| Observations | 22 | 22 | . | 22 | . | 22 | . |

*Notes:* The top panel focuses on spillovers from Germany following issuance plan announcements by the German DMO, while the second panel focuses on spillovers from France. The first and second columns report the standard deviations of daily changes in 10-year convenience yields at announcement dates (column 2) and on the days before announcement dates (column 1). Column (3) reports the upper one-sided p-value of the test on the equality of standard deviations. Columns (4) and (6) report the coefficient estimate of equation $\Delta CY_{receiving} = \alpha + \beta \Delta CY_{source} + \varepsilon$ respectively on announcement dates ($T$) and the preceding business day ($T-1$) where the receiving country is indicated by the row title. Columns (5) and (7) report the p-value of a significance test with robust standard errors.

## A.2 Estimation Sample

We obtain the dates of issuance plan publications from the website of the German DMO (www.deutsche-finanzagentur.de). Between 2007 and 2023, 68 announcements took place, i.e., 4 per year over this 17-year period. To arrive at our baseline estimation sample, we perform a number of sample selection steps:

1. We exclude 5 dates that coincided with major but unrelated European events: 27 September 2011 (Parliament was dissolved in Spain and Chancellor Merkel hosted the Greek Prime Minister for a key meeting); 25 June 2012 (Spain's request for support from the European Stability Mechanism); 17 December 2014 (ECB governing council meeting day); 22 March 2016 (Brussels terrorist attack); 28 September 2022 (heightened volatility caused by the sabotage of the Nordstream pipeline on 26 September).

2. We need to exclude the first 10 dates (before September 2009) and 24 March 2011 because of missing CDS data.

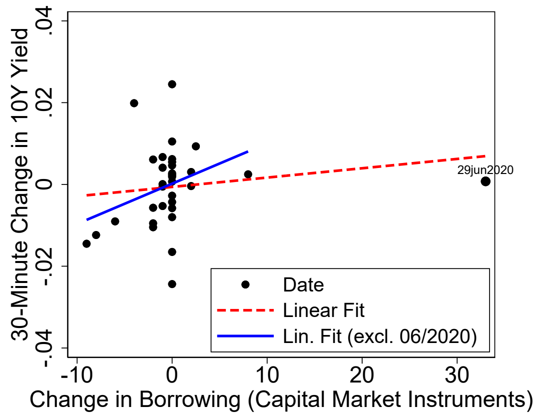
3. Because CDS contracts are not as liquid as sovereign bonds or OIS contracts, we exclude 5 dates on which changes in CDS rates provided by Bloomberg and Refinitiv are inconsistent. Specifically, we calculate the Euclidean distance between CDS changes $d_t^i = \sqrt{(\Delta\delta_t^{i,Bloomberg})^2 - (\Delta\delta_t^{i,Eikon})^2}$ and exclude episodes $t$ when $\left|d_t^i - \frac{1}{T}\sum_t^T d_t^i\right| > 2\sqrt{\frac{1}{T}\sum_t^T \left(d_t^i - \frac{1}{T}\sum_t^T d_t^i\right)^2}$ for some $i$. In other words, we exclude episodes when the distance between the change in the CDS across sources relative to the average distance exceeds two standard deviations.

4. We exclude 3 dates because the both the French and German DMOs made an announcement within the same 2-day window.

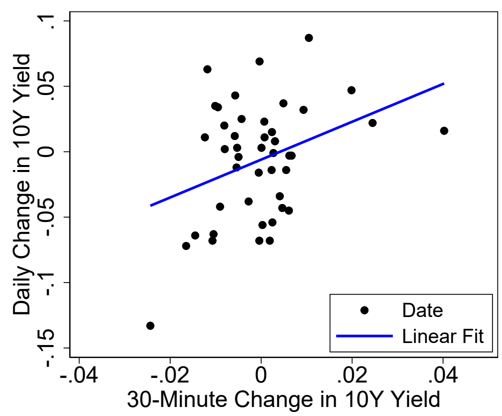
The resulting baseline sample covers 44 announcements of the German DMO between 2009 and 2023. Applying the same steps to the French DMO announcements leaves us with 22 observations for France. As shown in Figure OA.4 in the Online Appendix, announcement dates in the baseline sample are evenly spread across the full estimation period.

## A.3 German Debt Supply Shocks

Figure A.1: German Finance Agency Announcements




(A) Quantity Revisions & HF Yield Changes




(B) HF & Daily Yield Changes

*Notes:* Yield changes are expressed in percentage points. Quantity changes are in billion euros. Note that these quantity revisions are only available for the March, June, and September updates of issuance plans, but not the initial publications in December. Further, note that quantity revisions are at best rough measures of "surprises", because any information released over three months will already have moved expectations. The June 2020 publication nicely illustrates this point. A huge increase in the issuance of bonds (by more than €30bn) barely caused a market reaction, since markets were already anticipating a large increase due to the fiscal measures announced in the wake of the COVID-19 crisis.

Table A.3: Decomposition of Effect of Instrument on German Convenience Yield

| | (1) $\Delta Y_{DE}$ | (2) $\Delta OIS$ | (3) $\Delta CDS_{DE}$ | (4) $\Delta CY_{DE}$ |
|---|---|---|---|---|
| $\Delta Y_{DE}$ | 1.45** | 0.74 | -0.22** | -0.93*** |
| | (0.66) | (0.66) | (0.10) | (0.26) |
| Constant | -0.01 | -0.01 | 0.00 | 0.00 |
| | (0.01) | (0.01) | (0.00) | (0.00) |
| Observations | 44 | 44 | 44 | 44 |
| $R^2$ | 0.13 | 0.06 | 0.06 | 0.18 |
| F | 4.79 | 1.29 | 5.49 | 12.59 |

*Notes:* Each column displays coefficients from a separate regression: $\Delta X_t = \beta_0 + \beta_1 \times \Delta Y_{DE,t} + \epsilon_t$, where left-hand side variables are daily changes and the right-hand side variable is the 30-minute change around the German DMO announcement. Standard errors are reported in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

## A.4 French Debt Supply Shocks

The *Agence France Trésor* (henceforth, the French Treasury) manages the French state's cash requirements with the objectives of allowing the state to meet its financial commitments at all times, whatever the circumstances. It communicates about its issuance plan and future total financing requirements for the upcoming year at least twice a year.

First, the French Treasury publishes a press release announcing a tentative plan, typically in September (and never later than the first Tuesday of October). This release coincides with the first presentation by the finance ministry of the budget law proposal (*Projet de Loi de Finances*) to the public, starting with a presentation in the council of ministers (*conseil des ministres*). Second, the French Treasury publishes another press release announcing its final issuance plan when the budget process is concluding, typically in December. In some years, it announces revisions to that plan, and these announcements are typically linked to the presentation of a budget law amendment proposal.

Overall, each of these press releases provides official information to the public about the supply of French debt. Further, these are the only communication events about the annual total amount of issuance of the French Treasury.

The institutional setting in France does not allow us to exploit minute-by-minute variations in yields as in the German case but nonetheless allows us to use estimators that rely on changes in the magnitude of shocks across announcement and no-announcement dates. Because the French Treasury announcements are made in connection with progress in the budget process, they are subject to the uncertainty of that process. It is not possible to anticipate when the finance ministry will be able to publish the budget law proposal or when the parliamentary debates of the budget law will conclude. Both events are tied to negotiations that are not easily predictable in terms of content and timing. Therefore, the French Treasury does not pre-commit to publish these press releases at a specific date and time. However, the unpredictability of the negotiation outcome means that the press releases have the potential to carry unexpected news, causing substantial yield variations on that day.

## A.5 Robustness Checks

### A.5.1 Method 1: Event-Study OLS Estimations using Intraday Data

TABLE A.4: Intraday Yield Spillovers from Germany (Method 1: OLS) – Full Sample

| | *Safe Countries* | *Risky Countries* | |
|---|---|---|---|
| | (1) | (2) | (3) |
| | $\Delta Y_{FR}$ | $\Delta Y_{IT}$ | $\Delta Y_{ES}$ |
| $\Delta Y_{DE}$ | 0.88*** | 0.54*** | 0.50** |
| | (0.06) | (0.19) | (0.20) |
| Constant | 0.00 | 0.00 | 0.00 |
| | (0.00) | (0.00) | (0.00) |
| Observations | 68 | 66 | 53 |
| $R^2$ | 0.83 | 0.14 | 0.17 |

*Notes:* Each column displays coefficients from a separate regression: $\Delta Y_{Destination,t} = \beta_0 + \beta_1 \times \Delta Y_{DE,t} + \epsilon_t$, where changes are 30-minute changes around German DMO announcements. Standard errors are reported in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

TABLE A.5: Intraday Yield Spillovers from Germany (Method 1: OLS) – Homogeneous Sample

| | *Safe Countries* | *Risky Countries* | |
|---|---|---|---|
| | (1) | (2) | (3) |
| | $\Delta Y_{FR}$ | $\Delta Y_{IT}$ | $\Delta Y_{ES}$ |
| $\Delta Y_{DE}$ | 0.87*** | 0.60** | 0.53** |
| | (0.11) | (0.23) | (0.24) |
| Constant | 0.00 | 0.00 | 0.00 |
| | (0.00) | (0.00) | (0.00) |
| Observations | 38 | 38 | 38 |
| $R^2$ | 0.80 | 0.18 | 0.22 |

*Notes:* Each column displays coefficients from a separate regression: $\Delta Y_{Destination,t} = \beta_0 + \beta_1 \times \Delta Y_{DE,t} + \epsilon_t$, where changes are 30-minute changes around German DMO announcements. Standard errors are reported in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

### A.5.2 Method 2: Event-Study IV Estimations using Intraday Data

Table A.6: Daily Yield Spillovers from Germany (Method 2: IV)

| | *Safe Countries* | | | | | | *Risky Countries* | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | (1) $\Delta Y_{FR}$ | (2) $\Delta Y_{NL}$ | (3) $\Delta Y_{FI}$ | (4) $\Delta Y_{AT}$ | (5) $\Delta Y_{BE}$ | (6) Pool | (7) $\Delta Y_{IT}$ | (8) $\Delta Y_{ES}$ | (9) $\Delta Y_{PT}$ | (10) Pool | (11) Pool |
| $\Delta Y_{DE}$ | 0.99*** | 0.98*** | 1.09*** | 1.03*** | 1.18*** | | 0.53 | 0.56 | 0.88 | | |
| | (0.12) | (0.07) | (0.09) | (0.11) | (0.29) | | (0.47) | (0.37) | (0.65) | | |
| $\Delta Y_{DE}$ | | | | | | 1.05*** | | | | 0.66 | 0.80*** |
| | | | | | | (0.12) | | | | (0.43) | (0.24) |
| $\Delta Y_{DE} \times \mathbb{1}\{CDS_t > 1\}$ | | | | | | | | | | | -0.26 |
| | | | | | | | | | | | (0.68) |
| Constant | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 0.01* | 0.01 | 0.02 | 0.01 | 0.01 |
| | (0.00) | (0.00) | (0.00) | (0.00) | (0.01) | (0.00) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) |
| Observations | 44 | 44 | 44 | 44 | 44 | 220 | 44 | 44 | 44 | 132 | 132 |

*Notes:* Each column displays coefficients from a separate regression: $\Delta Y_{Destination,t} = \beta_0 + \beta_1 \times \Delta Y_{DE,t} + \epsilon_t$, for columns (1)-(5) and (7)-(9); $\Delta Y_{Destination,t} = \beta_0 + \beta_1 \times \Delta Y_{DE,t} + \beta_2 \Delta Y_{DE,t} \times \mathbb{1}\{CDS_t > 1\} + \epsilon_t$, for columns (6) and (10)-(11); where the daily change in the German convenience yield is instrumented with the 30-minute yield change and $\mathbb{1}\{CDS_t > 1\}$ is an indicator variable that take value 1 if the CDS rate is above 1 and 0 otherwise. Standard errors are reported in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table A.7: Daily Convenience Yield Spillovers from Germany (Method 2: IV) – Larger Sample

| | *Safe Countries* | | | | | | *Risky Countries* | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | (1) $\Delta CY_{FR}$ | (2) $\Delta CY_{NL}$ | (3) $\Delta CY_{FI}$ | (4) $\Delta CY_{AT}$ | (5) $\Delta CY_{BE}$ | (6) Pool | (7) $\Delta CY_{IT}$ | (8) $\Delta CY_{ES}$ | (9) $\Delta CY_{PT}$ | (10) Pool | (11) Pool |
| $\Delta CY_{DE}$ | 0.90*** | 0.97*** | 1.21*** | 0.78*** | 1.05* | | 0.61 | -0.80 | 1.97* | | |
| | (0.23) | (0.24) | (0.21) | (0.22) | (0.54) | | (0.88) | (1.08) | (1.12) | | |
| $\Delta CY_{DE}$ | | | | | | 0.98*** | | | | 0.59 | 0.92*** |
| | | | | | | (0.21) | | | | (0.65) | (0.23) |
| $\Delta CY_{DE}$ | | | | | | | | | | | -0.67 |
| $\times \mathbb{1}\{CDS_t > 1\}$ | | | | | | | | | | | (1.18) |
| Constant | -0.00 | 0.00 | -0.00 | -0.00 | -0.00 | -0.00 | -0.01 | -0.01 | -0.01 | -0.01* | -0.01 |
| | (0.00) | (0.01) | (0.00) | (0.00) | (0.01) | (0.00) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) |
| Observations | 47 | 47 | 47 | 47 | 47 | 235 | 47 | 47 | 47 | 141 | 141 |

*Notes:* Each column displays coefficients from a separate regression: $\Delta CY_{Destination,t} = \beta_0 + \beta_1 \times \Delta CY_{DE,t} + \epsilon_t$, for columns (1)-(5) and (7)-(9); $\Delta CY_{Destination,t} = \beta_0 + \beta_1 \times \Delta CY_{DE,t} + \beta_2 \Delta CY_{DE,t} \times \mathbb{1}\{CDS_t > 1\} + \epsilon_t$, for columns (6) and (10)-(11); where the daily change in the German convenience yield is instrumented with the 30-minute yield change and $\mathbb{1}\{CDS_t > 1\}$ is an indicator variable that take value 1 if the CDS rate is above 1 and 0 otherwise. Standard errors are reported in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table A.8: Daily Convenience Yield Spillovers from Germany (Method 2: IV) – EIKON CDS Data

| | *Safe Countries* | | | | | | *Risky Countries* | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | (1) $\Delta CY_{FR}$ | (2) $\Delta CY_{NL}$ | (3) $\Delta CY_{FI}$ | (4) $\Delta CY_{AT}$ | (5) $\Delta CY_{BE}$ | (6) Pool | (7) $\Delta CY_{IT}$ | (8) $\Delta CY_{ES}$ | (9) $\Delta CY_{PT}$ | (10) Pool | (11) Pool |
| $\Delta CY_{DE}$ | 0.94*** (0.25) | 1.16** (0.43) | 1.01*** (0.19) | 1.22*** (0.27) | 1.14 (0.68) | | 0.51 (0.80) | -0.03 (1.00) | 1.27 (0.92) | | |
| $\Delta CY_{DE}$ | | | | | | 1.10*** (0.28) | | | | 0.59 (0.74) | 1.05*** (0.24) |
| $\Delta CY_{DE}$ $\times \mathbb{1}\{CDS_t > 1\}$ | | | | | | | | | | | -1.12 (1.55) |
| Constant | -0.00 (0.00) | 0.00 (0.00) | -0.00** (0.00) | -0.00 (0.00) | -0.00 (0.01) | -0.00 (0.00) | -0.01 (0.01) | -0.01 (0.01) | -0.02 (0.01) | -0.01 (0.01) | -0.01 (0.01) |
| Observations | 39 | 31 | 25 | 24 | 38 | 157 | 39 | 39 | 39 | 117 | 117 |

*Notes:* Each column displays coefficients from a separate regression: $\Delta CY_{Destination,t} = \beta_0 + \beta_1 \times \Delta CY_{DE,t} + \epsilon_t$, for columns (1)-(5) and (7)-(9); $\Delta CY_{Destination,t} = \beta_0 + \beta_1 \times \Delta CY_{DE,t} + \beta_2 \Delta CY_{DE,t} \times \mathbb{1}\{CDS_t > 1\} + \epsilon_t$, for columns (6) and (10)-(11); where the daily change in the German convenience yield is instrumented with the 30-minute yield change and $\mathbb{1}\{CDS_t > 1\}$ is an indicator variable that take value 1 if the CDS rate is above 1 and 0 otherwise. Standard errors are reported in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table A.9: Daily Convenience Yield Spillovers from Germany (Method 2: IV) – 5-Year Maturity

| | *Safe Countries* | | | | | | *Risky Countries* | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | (1) $\Delta CY_{FR}$ | (2) $\Delta CY_{NL}$ | (3) $\Delta CY_{FI}$ | (4) $\Delta CY_{AT}$ | (5) $\Delta CY_{BE}$ | (6) Pool | (7) $\Delta CY_{IT}$ | (8) $\Delta CY_{ES}$ | (9) $\Delta CY_{PT}$ | (10) Pool | (11) Pool |
| $\Delta CY_{DE}$ | 1.07*** (0.20) | 1.06*** (0.18) | 1.06*** (0.33) | 0.60** (0.27) | 0.84 (0.52) | | 0.77 (0.80) | 0.17 (0.78) | 0.81 (0.84) | | |
| $\Delta CY_{DE}$ | | | | | | 0.92*** (0.18) | | | | 0.58 (0.66) | 1.00** (0.44) |
| $\Delta CY_{DE}$ $\times \mathbb{1}\{CDS_t > 1\}$ | | | | | | | | | | | -0.84 (1.08) |
| Constant | 0.00 (0.00) | 0.00 (0.00) | -0.00 (0.00) | -0.00 (0.00) | 0.00 (0.00) | 0.00 (0.00) | -0.00 (0.01) | 0.00 (0.01) | -0.00 (0.01) | -0.00 (0.01) | -0.00 (0.01) |
| Observations | 41 | 41 | 41 | 41 | 41 | 205 | 41 | 41 | 41 | 123 | 123 |

*Notes:* Each column displays coefficients from a separate regression for the 5-year maturity: $\Delta CY_{Destination,t} = \beta_0 + \beta_1 \times \Delta CY_{DE,t} + \epsilon_t$, for columns (1)-(5) and (7)-(9); $\Delta CY_{Destination,t} = \beta_0 + \beta_1 \times \Delta CY_{DE,t} + \beta_2 \Delta CY_{DE,t} \times \mathbb{1}\{CDS_t > 1\} + \epsilon_t$, for columns (6) and (10)-(11); where the daily change in the German convenience yield is instrumented with the 30-minute yield change and $\mathbb{1}\{CDS_t > 1\}$ is an indicator variable that take value 1 if the CDS rate is above 1 and 0 otherwise. Standard errors are reported in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

### A.5.3 Method 3: Rigobon-Sack Estimator

TABLE A.10: Daily Convenience Yield Spillovers from France (Method 3: Rigobon-Sack Estimator) – $1^{st}$ Alternative Implementation (Sample)

| | *Safe Countries* | | | | | *Risky Countries* | | |
|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| | $\Delta CY_{DE}$ | $\Delta CY_{NL}$ | $\Delta CY_{FI}$ | $\Delta CY_{AT}$ | $\Delta CY_{BE}$ | $\Delta CY_{IT}$ | $\Delta CY_{ES}$ | $\Delta CY_{PT}$ |
| $\Delta CY_{FR}$ | 1.13*** | 0.92** | 0.89*** | 0.96*** | 1.00*** | -0.41 | 0.48 | 0.88 |
| | (0.31) | (0.41) | (0.29) | (0.23) | (0.29) | (0.56) | (0.43) | (1.04) |
| Constant | 0.00 | 0.00 | -0.00 | -0.00 | -0.00 | 0.00 | 0.00 | 0.01 |
| | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.01) | (0.00) | (0.01) |
| N | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 |
| Weak IV | 5.204 | 4.953 | 5.567 | 5.121 | 5.991 | 5.325 | 5.223 | 6.286 |
| Overid. | 0.193 | 0.391 | 0.339 | 0.359 | 0.989 | 0.712 | 0.950 | 0.363 |

*Notes: This table reports coefficient estimates of equation $\Delta CY_{Destination,t} = \beta_0 + \beta_1 \times \Delta CY_{FR,t} + \epsilon_t$ where we employ the RS estimator described in Section 3.3. This table is similar to Table 3, except that results are obtained on a smaller sample that additionally excludes observations with potential outliers for yield variations in the destination countries. For every column, we use the two instrument variables based on the change in the variance-covariance matrix of the origin and destination country yields. Again, we use the two-step GMM estimator. Each column corresponds to a different destination country. Robust standard errors are reported in parentheses and stars indicate significance levels: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. The before last row shows the Stock-Yogo weak ID statistics while the associated threshold for the 25% maximal IV size is estimated at 7.25. The last row reports the p-value of the Hansen J overidentification test where the null hypothesis is that the instruments are valid.*

TABLE A.11: Daily Convenience Yield Spillovers from France (Method 3: Rigobon-Sack Estimator) – $2^{nd}$ Alternative Implementation (Different Instruments)

| | *Safe Countries* | | | | | *Risky Countries* | | |
|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| | $\Delta CY_{DE}$ | $\Delta CY_{NL}$ | $\Delta CY_{FI}$ | $\Delta CY_{AT}$ | $\Delta CY_{BE}$ | $\Delta CY_{IT}$ | $\Delta CY_{ES}$ | $\Delta CY_{PT}$ |
| $\Delta CY_{FR}$ | 0.71*** | 0.52*** | 0.90*** | 0.58*** | 0.72*** | -0.27 | 0.46 | 1.77 |
| | (0.20) | (0.20) | (0.23) | (0.20) | (0.17) | (0.34) | (0.33) | (2.19) |
| Constant | 0.00 | 0.00 | -0.00* | 0.00 | -0.00 | 0.00 | 0.00 | 0.00 |
| | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.01) | (0.00) | (0.01) |
| N | 44 | 44 | 44 | 44 | 44 | 44 | 44 | 44 |
| Weak IV | 1.868 | 1.868 | 1.868 | 1.868 | 1.868 | 1.868 | 1.868 | 1.868 |
| Overid. | 0.705 | 0.526 | 0.368 | 0.212 | 0.560 | 0.177 | 0.366 | 0.732 |

*Notes: This table reports coefficient estimates of equation $\Delta CY_{Destination,t} = \beta_0 + \beta_1 \times \Delta CY_{FR,t} + \epsilon_t$ where we employ the RS estimator described in Section 3.3. This table is similar to Table 3, except that results are obtained with different instruments. For every column, we use the instrument variables based on the change in the variance-covariance matrix of the origin country and the 8 destination country yields. Again, we use the two-step GMM estimator. Each column corresponds to a different destination country. Robust standard errors are reported in parentheses and stars indicate significance levels: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. The before last row shows the Stock-Yogo weak ID statistics while the associated threshold for the 25% maximal IV size is estimated at 11.7. The last row reports the p-value of the Hansen J overidentification test where the null hypothesis is that the instruments are valid.*

TABLE A.12: Daily Convenience Yield Spillovers from France (Method 3: Rigobon-Sack Estimator) – $3^{rd}$ Alternative Implementation (Different Instruments)

| | *Safe Countries* | | | | | *Risky Countries* | | |
|---|---|---|---|---|---|---|---|---|
| | (1) $\Delta CY_{DE}$ | (2) $\Delta CY_{NL}$ | (3) $\Delta CY_{FI}$ | (4) $\Delta CY_{AT}$ | (5) $\Delta CY_{BE}$ | (6) $\Delta CY_{IT}$ | (7) $\Delta CY_{ES}$ | (8) $\Delta CY_{PT}$ |
| $\Delta CY_{FR}$ | 0.94** | 0.96* | 0.64 | 0.83*** | 1.03** | -0.20 | 0.75 | -2.81 |
| | (0.37) | (0.52) | (0.47) | (0.29) | (0.43) | (0.54) | (0.64) | (5.40) |
| Constant | 0.00 | 0.00 | -0.00 | -0.00 | -0.00 | 0.00 | 0.00 | 0.01 |
| | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.01) | (0.01) | (0.02) |
| N | 44 | 44 | 44 | 44 | 44 | 44 | 44 | 44 |
| Weak IV | 8.044 | 8.044 | 8.044 | 8.044 | 8.044 | 8.044 | 8.044 | 8.044 |

*Notes: This table reports coefficient estimates of equation $\Delta CY_{Destination,t} = \beta_0 + \beta_1 \times \Delta CY_{FR,t} + \epsilon_t$ where we employ the RS estimator described in Section 3.3. This table is similar to Table 3, except that results are obtained with different instruments. For every column, we use the instrument variable constructed only with French yield variations (i.e. based on the change in the first column of variance-covariance matrix of origin and destination country yields). Again, we use the two-step GMM estimator. Each column corresponds to a different destination country. Robust standard errors are reported in parentheses and stars indicate significance levels: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. The last row shows the Stock-Yogo weak ID statistics while the associated threshold for the 25% maximal IV size is estimated at 5.53.*

# B Theory Appendix

This appendix section solves the model step by step.

## B.1 Period 2 Without a Recession

In this case, all households receive the same income now and in the third and final period. Therefore, there is no reason to re-trade bonds and consumption is the same for all and equal to income:

$$\begin{aligned} db^H_{2,O} &= db^F_{2,O} = 0 \\ c_{2,O} &= w_{2,O} \end{aligned}$$

## B.2 Period 2 With a Recession

In this case, households can be of type $i$ =A or B and solve:

$$
\begin{aligned}
&V_{2,i}(b_1^H, b_1^F) = \\
&\quad \max_{\{c_{2,i}, db_{2,i}^H, db_{2,i}^F\}} u(c_{2,i}) + \beta \left[P_D u(w_3 + b_1^H - db_{2,i}^H) + (1 - P_D) u(w_3 + b_1^H - db_{2,i}^H + b_1^F - db_{2,i}^F)\right] \\
&\quad s.t. \quad c_{2,i} = w_{2,i} - p_2^H db_{2,i}^H - p_2^F db_{2,i}^F \\
&\quad \qquad b_1^H - db_{2,i}^H \geq 0 \qquad \text{(no-short-selling constraint on H-bond)} \\
&\quad \qquad b_1^F - db_{2,i}^F \geq 0 \qquad \text{(no-short-selling constraint on F-bond)}
\end{aligned}
$$

The three first order conditions for the choice variables are

$$
\begin{aligned}
u'(c_{2,i}) - \lambda_{2,i} &= 0 \\
\beta \left[P_D u'(w_3 + b_1^H - db_{2,i}^H) + (1 - P_D) u'(w_3 + b_1^H - db_{2,i}^H + b_1^F - db_{2,i}^F)\right] - \lambda_{2,i} p_2^H + \mu_{2,i}^H &= 0 \\
\beta (1 - P_D) u'(w_3 + b_1^H - db_{2,i}^H + b_1^F - db_{2,i}^F) - \lambda_{2,i} p_2^F + \mu_{2,i}^F &= 0
\end{aligned}
$$

where $\mu_{2,i}^H$, $\mu_{2,i}^F \geq 0$ are the Lagrange multipliers associated with the no-short-selling constraint. We also have:

$$
\begin{aligned}
0 &= \lambda_{2,i} \left(c_{2,i} - w_{2,i} - p_2^H db_{2,i}^H - p_2^F db_{2,i}^F\right) \\
0 &= \mu_{2,i}^H \left(b_1^H + db_{2,i}^H\right) \\
0 &= \mu_{2,i}^F \left(b_1^F + db_{2,i}^F\right)
\end{aligned}
$$

Market clearing implies that al the bonds sold by one type of households are bought by the other type. Therefore, we have that $P_A db_{2,A}^H = -(1 - P_A) db_{2,B}^H$ and $P_A db_{2,A}^F = -(1 + P_A) db_{2,B}^F$. Note that type-A households' income declines more strongly, which means that their willingness to smooth consumption by selling bonds is stronger.

## B.3 Bond Prices in a Recession

We presently consider the point at which bond prices are such that type-A households do not want to sell any more bonds, or equivalently, when the short-selling constraint is not strictly binding. Let us denote such prices $p_{2,A}^H$ and $p_{2,A}^F$. For these prices, the associated

Lagrange multipliers are null ( $\mu_{2,A}^H = \mu_{2,A}^F = 0$). Furthermore, type-A households' first order conditions simplify to

$$\begin{aligned} u'(w_{2,A} + p_2^H db_{2,A}^H + p_2^F db_{2,A}^F) &= \lambda_{2,A} \\ \beta u'(w_3) &= \lambda_{2,A} p_2^H \\ \beta(1-P_D)u'(w_3) &= \lambda_{2,A} p_2^F \end{aligned}$$

and we obtain

$$p_{2,A}^H = \frac{\beta u'(w_3)}{u'(w_{2,A} + p_{2,A}^H[^F])} \quad (12)$$

$$db_{2,A}^H + (1-P_D) db_{2,A} p_{2,A}^F = p_{2,A}^H (1-P_D) \quad (13)$$

where $p_{2,A}^H$ is implicitly defined by equation 12 for given values of $\left(db_{2,A}^H, db_{2,A}^F\right)$.

Alternatively, we consider the point at which bond prices are such that type-B households do not want to buy any more bonds. Let us denote such prices $p_{2,B}^H$ and $p_{2,B}^F$. Again, the Lagrange multipliers associated with the short-selling constraints are null ($\mu_{2,B}^H = \mu_{2,B}^F = 0$). Furthermore, type-B households' first order conditions simplify to

$$\begin{aligned} u'\left(w_{2,B} - \frac{P_A}{(1-P_A)}(p_2^H db_{2,A}^H + p_2^F db_{2,A}^F)\right) &= \lambda_{2,B} \\ \beta\left[P_D u'\left(w_3 + \left(1 + \frac{P_A}{(1-P_A)}\right) db_{2,A}^H\right) + (1-P_D)u'\left(w_3 + \left(1 + \frac{P_A}{(1-P_A)}\right)(db_{2,A}^H + db_{2,A}^F)\right)\right] &= \lambda_{2,B} p_2^H \\ \beta(1-P_D)u'\left(w_3 + \left(1 + \frac{P_A}{(1-P_A)}\right)(db_{2,A}^H + db_{2,A}^F)\right) &= \lambda_{2,B} p_2^F \end{aligned}$$

and we obtain

$$p_{2,B}^H = \frac{\beta\left[P_D u'\left(w_3 + \frac{1}{(1-P_A)} db_{2,A}^H\right) + (1-P_D)u'\left(w_3 + \frac{1}{(1-P_A)}(db_{2,A}^H + db_{2,A}^F)\right)\right]}{u'\left(w_{2,B} - \frac{P_A}{(1-P_A)}(p_{2,B}^H db_{2,A}^H + p_{2,B}^F db_{2,A}^F)\right)} \quad (14)$$

$$\begin{aligned} p_{2,B}^F &= p_{2,B}^H \frac{(1-P_D)u'\left(w_3 + \frac{1}{(1-P_A)}(db_{2,A}^H + db_{2,A}^F)\right)}{P_D u'\left(w_3 + \frac{1}{(1-P_A)} db_{2,A}^H\right) + (1-P_D)u'\left(w_3 + \frac{1}{(1-P_A)}(db_{2,A}^H + db_{2,A}^F)\right)} \\ &= \frac{\beta(1-P_D)u'\left(w_3 + \frac{1}{(1-P_A)}(db_{2,A}^H + db_{2,A}^F)\right)}{u'\left(w_{2,B} - \frac{P_A}{(1-P_A)}(p_{2,B}^H db_{2,A}^H + p_{2,B}^F db_{2,A}^F)\right)} \quad (15) \end{aligned}$$

where $p_{2,B}^H$ is implicitly defined by equation 14 for given values of $\left(db_{2,B}^H, db_{2,B}^F\right)$. After substituting $p_{2,B}^F$ for $p_{2,B}^H$ using 15, we observe that the right-hand side of equation 14 is strictly positive and decreasing in $p^H_{2,B}$, while the left-hand side increases linearly from 0 to infinity. Therefore, this equation has a unique solution. Consequently, equation 14 also determines a unique price $p^F_{2,B}$. The foreign- to home-price ratio is hence equal to the type-B households' marginal utility in the state with default over their marginal utility in the state without default.

For reasons that will be clear later, let's introduce $e_2(db^H_{2,A}, db^F_{2,A}) = p^H_{2,B}db^H_{2,A} + p^F_{2,B}db^F_{2,A}$ which reflects the value traded by type-A households in a recession using type-B household's valuation. Re-arranging the above expressions, we get

$$\frac{1}{\beta}e_2(db^H_{2,A}, db^F_{2,A})u'\left(w_{2,B} - \frac{P_A}{(1-P_A)}e_2(db^H_{2,A}, db^F_{2,A})\right) = \left[P_D u'\left(w_3 + \frac{db^H_{2,A}}{(1-P_A)}\right) + (1-P_D)u'\left(w_3 + \frac{db^H_{2,A} + db^F_{2,A}}{(1-P_A)}\right)\right]db^H_{2,A} + (1-P_D)u'\left(w_3 + \frac{db^H_{2,A} + db^F_{2,A}}{(1-P_A)}\right)db^F_{2,A} \quad (16)$$

The left-hand side is increasing in $e$. The derivatives of the right-hand side with respect to respectively $db^H_{2,A}$ and $db^F_{2,A}$ are

$$P_D u'(c_{3,B}(1))\left[\frac{\frac{db^H_{2,A}}{(1-P_A)}}{w_3 + \frac{db^H_{2,A}}{(1-P_A)}}\frac{c_{3,B}(1)u''(c_{3,B}(1))}{u'(c_{3,B}(1))} + 1\right] + (1-P_D)u'(c_{3,B}(0))\left[\frac{\frac{(db^H_{2,A}+db^F_{2,A})}{(1-P_A)}}{w_3 + \frac{(db^H_{2,A}+db^F_{2,A})}{(1-P_A)}}\frac{c_{3,B}(0)u''(c_{3,B}(0))}{u'(c_{3,B}(0))} + 1\right]$$

and

$$(1-P_D)u'(c_{3,B}(0))\left[\frac{\frac{(db^H_{2,A}+db^F_{2,A})}{(1-P_A)}}{w_3 + \frac{(db^H_{2,A}+db^F_{2,A})}{(1-P_A)}}\frac{c_{3,B}(0)u''(c_{3,B}(0))}{u'(c_{3,B}(0))} + 1\right]$$

with $c_{3,B}(1) = w_3 + \frac{1}{(1-P_A)}db^H_{2,A}$ and $c_{3,B}(0) = w_3 + \frac{1}{(1-P_A)}(db^H_{2,A} + db^F_{2,A})$. As a result we have that $\frac{\partial e_2(db^H_{2,A}, db^F_{2,A})}{\partial db^H_{2,A}} > 0$ and $\frac{\partial e_2(db^H_{2,A}, db^F_{2,A})}{\partial db^F_{2,A}} > 0$ if $\frac{(db^H_{2,A}+db^F_{2,A})}{(1-P_A)w_3+(db^H_{2,A}+db^F_{2,A})}\frac{c_{3,B}(0)u''(c_{3,B}(0))}{u'(c_{3,B}(0))} > -1$ and $\frac{db^H_{2,A}}{(1-P_A)w_3+db^H_{2,A}}\frac{c_{3,B}(1)u''(c_{3,B}(1))}{u'(c_{3,B}(1))} > -1$. Note that this condition is satisfied if the coefficients of relative aversion ($-\frac{c_{3,B}(0)u''(c_{3,B}(0))}{u'(c_{3,B}(0))}$ and $-\frac{c_{3,B}(1)u''(c_{3,B}(1))}{u'(c_{3,B}(1))}$) are low enough, and if the ratio of bond repayments to total type-B income in period 3 is low enough. This is likely the case, as the literature typically estimates the coefficient of relative aversion between 1 and 10, and because bond repayments are unlikely to exceed 10% of income.

Up to this point, bond prices $p^H_2$ and $p^F_2$ are undetermined because their determination depends on whether bond availability is binding (corner solutions) or not (interior solutions).

In the main text, we focus on the case where both bonds are rationed and the two no-short-selling conditions are binding. We show in the online appendix sections C.3.1 and C.3.2 that this is the case when when $B_1^H < \hat{b}_1^H$ and $B_1^F < \widehat{b}_2^F\left(B_1^H\right)$ and where the value $\hat{b}_1^H$ and the function $\widehat{b}_2^F\left(B_1^H\right)$ are defined in subsections C.3.1 and C.3.2 respectively. In a recession, worse-hit type-A households would like to be able to sell more foreign and home bonds to better improve their consumption levels and smooth their lifetime consumption. However, they could not buy more bonds in period 1 because these were in limited supply. When the recession hits, they sell all the bonds they have and we then have that $db_{2,A}^H = b_1^H$ and $db_{2,A}^F = b_1^F$.

Prices are undetermined. On one hand, type-A households are constrained from selling more bonds (the no-short-selling constraints hold with equality) and any set of prices $p_2^H \geq p_{2,A}^H$ and $p_2^F \geq p_{2,A}^F$ would be consistent with this corner equilibrium. On the other hand, type-B households are willing to buy bonds as long as $p_2^H \leq p_{2,B}^H$ and $p_2^F \leq p_{2,B}^F$. Therefore, there is a range of possible equilibrium prices. We assume that $p_2^H = p_{2,B}^H$ and $p_2^F = p_{2,B}^F$.[12]

Having solved for re-traded quantities and prices, we solve for consumption:

$$
\begin{aligned}
c_{2,A} &= w_{2,A} + p_2^H b_1^H + p_2^F b_1^F \\
c_{2,B} &= w_{2,B} - \frac{P_A}{(1-P_A)}(p_2^H b_1^H + p_2^F b_1^F)
\end{aligned}
$$

## B.4 Period 1

After unpacking some notations, households solve

$$
\begin{aligned}
\max_{\{b_1^H, b_1^F\}} u(c_1) \quad &+\beta(1-P_R)\left[u(w_{2,O}) + \beta u(w_3 + b_1^H + b_1^F)\right] \\
&+ \beta P_R\left[p_A V_{2,A}(b_1^H, b_1^F) + (1-P_A)V_{2,B}(b_1^H, b_1^F)\right] \\
s.t. \qquad\qquad & c_1 = w_1 - p_1^H b_1^H - p_1^F b_1^F
\end{aligned}
$$

[12] We checked with numerical solutions that our results remain valid for prices $p_2^H = ap_{2,A}^H + (1-a)p_{2,B}^H$ and $p_2^F = ap_{2,A}^F + (1-a)p_{2,B}^F$ as long as $0 < a \leq 1$.

with

$$
\begin{aligned}
V_{2,A}(b_1^H, b_1^F) &= u(w_{2,A} + p_2^H b_1^H + p_2^F b_1^F) + \beta u(w_3), \\
V_{2,B}(b_1^H, b_1^F) &= u\left(w_{2,B} - \frac{P_A}{1-P_A}(p_2^H db_{2,B}^H + p_2^F db_{2,B}^F)\right) \\
&\quad + \beta\left[P_D u\left(w_3 + b_1^H + \frac{P_A db_{2,B}^H}{1-P_A}\right) + (1-P_D)u\left(w_3 + b_1^H + b_1^F + \frac{P_A(db_{2,B}^H + db_{2,B}^F)}{1-P_A}\right)\right]
\end{aligned}
$$

Importantly, we have that $\frac{\partial db_{2,B}^H}{\partial b_1^H} = 0$ and $\frac{\partial db_{2,B}^F}{\partial b_1^F} = 0$ in the above definition of $V_{2,B}(b_1^H, b_1^F)$ because every household is small and does not anticipate that buying more bonds in period 1 would relax the aggregate supply constraint in period 2. Conversely, $\frac{\partial db_{2,A}^H}{\partial b_1^H} < 0$ and $\frac{\partial db_{2,A}^F}{\partial b_1^F} < 0$ because households internalize that they can re-sell in period 2 any additional unit of bonds bought in period 1.

The first order condition with respect to $b_1^H$ is

$$
\begin{aligned}
p_1^H u'(c_1) &= \beta^2(1-P_R)u'(w_3 + b_1^H + b_1^F) + \beta P_R P_A \frac{\partial V_{2,A}(b_1^H, b_1^F)}{\partial b_1^H} + \beta P_R(1-P_A)\frac{\partial V_{2,B}(b_1^H, b_1^F)}{\partial b_1^H} \\
\text{with} \quad & \frac{\partial V_{2,A}(b_1^H, b_1^F)}{\partial b_1^H} = p_2^H u'(w_{2,A} + p_2^H b_1^H + p_2^F b_1^F) \\
& \frac{\partial V_{2,B}(b_1^H, b_1^F)}{\partial b_1^H} = \beta\left[P_D u'\left(w_3 + \frac{b_1^H}{1-P_A}\right) + (1-P_D)u'\left(w_3 + \frac{b_1^H + b_1^F}{1-P_A}\right)\right]
\end{aligned}
$$

and we have a similar one for $b_1^F$

$$
\begin{aligned}
p_1^F u'(c_1) &= \beta^2(1-P_R)u'(w_3 + b_1^H + b_1^F) + \beta P_R P_A p_2^F u'(w_{2,A} + p_2^H b_1^H + p_2^F b_1^F) \\
&\quad + \beta^2 P_R(1-P_A)(1-P_D)u'\left(w_3 + \tfrac{b_1^H + b_1^F}{1-P_A}\right)
\end{aligned}
$$

## B.5 Convenience Yields and Non Re-Tradable Bond Prices

We introduce non-re-tradable bonds $\tilde{b}_1^H$ and $\tilde{b}_1^F$. The budget constraints in periods 1 and 3 in the households' optimization constraints now include additional terms reflecting the buying and selling of these new bonds:

$$
\begin{aligned}
c_1 &= w_1 - p_1^H b_1^H - p_1^F b_1^F - \tilde{p}_1^H \tilde{b}_1^H - \tilde{p}_1^F \tilde{b}_1^F && \text{(Period 1)} \\
c_{3,A} &= w_3 + \tilde{b}_1^H + \tilde{b}_1^F D^F && \text{(Period 3 after a recession)} \\
c_{3,B} &= w_3 + b_1^H + db_{2,B}^H + \tilde{b}_1^H + (b_1^F + db_{2,B}^F + \tilde{b}_1^F) D^F && \text{(Period 3 after a recession)} \\
c_{3,O} &= w_3 + b_1^H + b_1^F + \tilde{b}_1^H + \tilde{b}_1^F && \text{(Period 3 without recession)}
\end{aligned}
$$

Assuming that the new bonds' supply is zero, the new first order conditions associated with $\tilde{b}_1^H$ and $\tilde{b}_1^F$ are

$$
\begin{aligned}
\tilde{p}_1^H u'(c_1) &= \beta^2 (1-P_R) u'(w_3 + b_1^H + b_1^F) \\
&\quad + \beta^2 P_R P_A \left[ P_D u'(w_3) + (1-P_D) u'(w_3) \right] \\
&\quad + \beta^2 P_R (1-P_A) \left[ P_D u'(c_{3,B}(1)) + (1-P_D) u'(c_{3,B}(0)) \right] \\
\tilde{p}_1^F u'(c_1) &= \beta^2 (1-P_R) u'(w_3 + b_1^H + b_1^F) + \beta^2 P_R (1-P_D) \left[ P_A u'(w_3) + (1-P_A) u'(c_{3,B}(0)) \right]
\end{aligned}
$$

with $c_{3,B}(1) = w_3 + \frac{1}{(1-P_A)} b_1^H$ and $c_{3,B}(0) = w_3 + \frac{1}{(1-P_A)} (b_1^H + b_1^F)$.

From now on, we use the market clearing condition to introduce the exogenous supply of bonds ($b_1^H = B_1^H$ and $b_1^F = B_1^F$). Having solved for all prices, we can solve for convenience yields using the definition $CY_1^c = p_1^c / \tilde{p}_1^c$ (equation 9). Hence, the convenience yields associated with the home and foreign bonds are:

$$
\begin{aligned}
CY_1^H &= log \left( \frac{\frac{(1-P_R)}{P_R} u'(c_{3,O}) + P_A \frac{p_2^H}{\beta} u'(w_{2,A} + p_2^H B_1^H + p_2^F B_1^F) + (1-P_A) \left[ P_D u'(c_{3,B}(1)) + (1-P_D) u'(c_{3,B}(0)) \right]}{\frac{(1-P_R)}{P_R} u'(c_{3,O}) + P_A u'(w_3) + (1-P_A) \left[ P_D u'(c_{3,B}(1)) + (1-P_D) u'(c_{3,B}(0)) \right]} \right) \\
CY_1^F &= log \left( \frac{(1-P_R) u'(w_3 + B_1^H + B_1^F) + \frac{1}{\beta} P_R P_A p_2^F u'(w_{2,A} + p_2^H B_1^H + p_2^F B_1^F) + P_R (1-P_A)(1-P_D) u'(c_{3,B}(0))}{(1-P_R) u'(w_3 + B_1^H + B_1^F) + P_R P_A (1-P_D) u'(w_3) + P_R (1-P_A)(1-P_D) u'(c_{3,B}(0))} \right)
\end{aligned}
$$

with $c_{3,O} = w_3 + B_1^H + B_1^F$. Interestingly, we observe with the help of equation 12 that setting $p_2^H = p_{2,A}^H$ implies that $CY_1^H = CY_1^F = 0$. We also observe that $\frac{\partial CY_1^H}{\partial w_{2,A}} > 0$ and $\frac{\partial CY_1^F}{\partial w_{2,A}} > 0$ as $w_{2,A}$ only appears once in the numerator and prices are independent of $w_{2,A}$.

Using equations 14 and 15 that determine period 2 prices, the above equations can be rearranged into:

$$CY_1^H = \log\left(\frac{(1-P_R)u'(c_{3,O})+P_R(1-P_A)E_2\left[u'(c_{3,B})\right]\left[1+\frac{P_A}{1-P_A}\frac{u'(w_{2,A}+p_2^H B_1^H+p_2^F B_1^F)}{u'\left(w_{2,B}-\frac{P_A}{(1-P_A)}(p_2^H B_1^H+p_2^F B_1^F)\right)}\right]}{(1-P_R)u'(c_{3,O})+P_R(1-P_A)E_2\left[u'(c_{3,B})\right]\left[1+\frac{P_A}{1-P_A}\frac{u'(w_3)}{E_2[u'(c_{3,B})]}\right]}\right) \tag{17}$$

$$CY_1^F = \log\left(\frac{(1-P_R)u'(c_{3,O})+P_R(1-P_A)(1-P_D)u'(c_{3,B}(0))\left[1+\frac{P_A}{1-P_A}\frac{u'(w_{2,A}+p_2^H B_1^H+p_2^F B_1^F)}{u'\left(w_{2,B}-\frac{P_A}{(1-P_A)}(p_2^H B_1^H+p_2^F B_1^F)\right)}\right]}{(1-P_R)u'(c_{3,O})+P_R(1-P_A)(1-P_D)u'(c_{3,B}(0))\left[1+\frac{P_A}{1-P_A}\frac{u'(w_3)}{u'(c_{3,B}(0))}\right]}\right)$$

with $c_{3,O} = w_3 + B_1^H + B_1^F$, $c_{3,B}(1) = w_3 + \frac{B_1^H}{1-P_A}$, $c_{3,B}(0) = w_3 + \frac{B_1^H+B_1^F}{1-P_A}$ and $E_2\left[u'(c_{3,B})\right] = P_D u'(c_{3,B}(1)) + (1-P_D)u'(c_{3,B}(0))$. In both expressions, note that the term in squared brackets in the numerator corresponds to the gap between the marginal utility of type-A and type-B households in period 2. Households are able to insure themselves (partially) and to reduce this gap by re-trading their bonds (increasing transfers $p_2^H B_1^H + p_2^F B_1^F$ from poor type-A households to rich type-B households). The term in squared brackets in the denominator corresponds to the gap between the marginal utility of type-A and type-B households in period 3 and captures the costs for type-A of having sold all bonds and insuring themselves in the period 2 recession. This makes clear that the value of the convenience yields are based on the benefits from insurance (the term in square brackets in the numerator) relative to the its costs (the term in square brackets in the denominator).

When $P_R = 1$, the equations simplify further and the convenience yields are equal to

$$CY_1^H = \log\left(\frac{1+\frac{P_A}{1-P_A}\frac{u'(c_{2,A})}{u'(c_{2,B})}}{1+\frac{P_A}{1-P_A}\frac{E_2\left[u'(c_{3,A})\right]}{E_2\left[u'(c_{3,B})\right]}}\right) \tag{18}$$

$$CY_1^F = \log\left(\frac{1+\frac{P_A}{1-P_A}\frac{u'(c_{2,A})}{u'(c_{2,B})}}{1+\frac{P_A}{1-P_A}\frac{u'(w_3)}{u'(c_{3,B}(0))}}\right) \tag{19}$$

with $c_{2,A} = w_{2,A} + p_2^H B_1^H + p_2^F B_1^F$, $c_{2,B} = w_{2,B} - \frac{P_A}{(1-P_A)}(p_2^H B_1^H + p_2^F B_1^F)$, $E_2\left[u'(c_{3,A})\right] = u'(w_3)$ and $E_2\left[u'(c_{3,B})\right] = P_D u'\left(w_3 + \frac{B_1^H}{1-P_A}\right) + (1-P_D)u'\left(w_3 + \frac{B_1^H+B_1^F}{1-P_A}\right)$.

## B.6 Proof of First Results when $P_R = 1$

We are interested in the difference between the country convenience yields.

$$CY_1^F - CY_1^H \quad = \quad \log\left(\frac{1+\frac{P_A}{1-P_A}\frac{E_2\left[u'(c_{3,A})\right]}{E_2\left[u'(c_{3,B})\right]}}{1+\frac{P_A}{1-P_A}\frac{u'(w_3)}{u'\left(w_3+\frac{B_1^H+B_1^F}{1-P_A}\right)}}\right) \tag{20}$$

It's straightforward to see that $CY_1^F - CY_1^H \leq 0$ because $u'\left(w_3+\frac{B_1^H+B_1^F}{1-P_A}\right) \leq P_D u'\left(w_3+\frac{B_1^H}{1-P_A}\right) + (1-P_D)u'\left(w_3+\frac{B_1^H+B_1^F}{1-P_A}\right) \leq u'(w_3)$, and $\frac{u'(w_3)}{u'\left(w_3+\frac{B_1^H+B_1^F}{1-P_A}\right)} \geq \frac{E_2\left[u'(c_{3,A})\right]}{E_2\left[u'(c_{3,B})\right]}$ from the concavity of the utility function. This proves our first result that the convenience yield is higher in the 'safe' country.

Turning our attention to the variations of the convenience yield difference with respect to the probability of default in the foreign country

$$\begin{aligned}
\frac{\partial\left(CY_1^F - CY_1^H\right)}{\partial P_D} &= \frac{\partial}{\partial P_D}\log\left(1+\frac{P_A}{1-P_A}\frac{E_2\left[u'(c_{3,A})\right]}{E_2\left[u'(c_{3,B})\right]}\right) \\
&= -\frac{\frac{P_A}{1-P_A}\frac{E_2\left[u'(c_{3,A})\right]\left(u'(c_{3,B}(1))-u'(c_{3,B}(0))\right)}{\left(E_2\left[u'(c_{3,B})\right]\right)^2}}{1+\frac{P_A}{1-P_A}\frac{E_2\left[u'(c_{3,A})\right]}{E_2\left[u'(c_{3,B})\right]}} = \frac{\frac{u'(c_{3,B}(0))-u'(c_{3,B}(1))}{E_2\left[u'(c_{3,B})\right]}}{\frac{1-P_A}{P_A}\frac{E_2\left[u'(c_{3,B})\right]}{E_2\left[u'(c_{3,A})\right]}+1}
\end{aligned}$$

with $c_{3,B}(1) = w_3 + \frac{B_1^H}{1-P_A}$ and $c_{3,B}(0) = w_3 + \frac{B_1^H+B_1^F}{1-P_A}$. Furthermore, $\frac{\partial\left(CY_1^F - CY_1^H\right)}{\partial P_D} < 0$, again because the utility function is concave and $u'\left(w_3+\frac{B_1^H+B_1^F}{1-P_A}\right) - u'\left(w_3+\frac{B_1^H}{1-P_A}\right) < 0$. This complements our first result by showing that the gap between the country convenience yield of the foreign relative to the 'safe' country decreases with the probability of default. In other words in the euro area, this predicts that country convenience yields relative to Germany decrease with the country credit default rates.

## B.7 Proof of Second Results when $P_R = 1$

Next, we examine how the two convenience yields move in response to a shock to the supply of home bonds. Technically, we examine $\frac{\partial CY_1^F}{\partial B_1^H}$ and $\frac{\partial CY_1^H}{\partial B_1^H}$.

$$\frac{\partial CY_1^H}{\partial B_1^H} = \frac{\frac{P_A}{1-P_A}\frac{\partial\left(\frac{u'(c_{2,A})}{u'(c_{2,B})}\right)}{\partial B_1^H}}{1+\frac{P_A}{1-P_A}\frac{u'(c_{2,A})}{u'(c_{2,B})}} + 2\frac{\frac{P_A}{1-P_A}\frac{E_2\left[u'(c_{3,A})\right]\left(P_D u''(c_{3,B}(1))+(1-P_D)u''(c_{3,B}(0))\right)}{\left(E_2\left[u'(c_{3,B})\right]\right)^2}}{1+\frac{P_A}{1-P_A}\frac{E_2\left[u'(c_{3,A})\right]}{E_2\left[u'(c_{3,B})\right]}} \tag{21}$$

$$\frac{\partial CY_1^F}{\partial B_1^H} = \frac{\frac{P_A}{1-P_A}\frac{\partial\left(\frac{u'(c_{2,A})}{u'(c_{2,B})}\right)}{\partial B_1^H}}{1+\frac{P_A}{1-P_A}\frac{u'(c_{2,A})}{u'(c_{2,B})}} + 2\frac{\frac{P_A}{1-P_A}\frac{u'(w_3)u''(c_{3,B}(0))}{\left(u'(c_{3,B}(0))\right)^2}}{1+\frac{P_A}{1-P_A}\frac{u'(w_3)}{u'(c_{3,B}(0))}} \tag{22}$$

with $c_{2,A} = w_{2,A} + p_2^H B_1^H + p_2^F B_1^F$, $c_{2,B} = w_{2,B} - \frac{P_A}{1-P_A}(p_2^H B_1^H + p_2^F B_1^F)$, $E_2\left[u'(c_{3,A})\right] = u'(w_3)$, $c_{3,B}(1) = w_3 + \frac{B_1^H}{1-P_A}$, $c_{3,B}(0) = w_3 + \frac{B_1^H+B_1^F}{1-P_A}$ and $E_2\left[u'(c_{3,B})\right] = P_D u'(c_{3,B}(1)) + (1-P_D)u'(c_{3,B}(0))$. In both equations, the second fraction is negative because $u' > 0$ and the utility function is concave ($u'' < 0$). Those terms relate to the marginal cost of additional insurance as measured by the period 3 consumption gap between type-A and type-B households. They convey the fact that more home bonds increases this gap, as type-B households are able to sell even more bonds and consume even more.

In both equations 21 and 22, the first fraction is the same and can be developed using $e_2(B_1^H, B_2^F) = p_2^H B_1^H + p_2^F B_2^F$ to become

$$\frac{\frac{P_A}{1-P_A}\frac{\partial\left(\frac{u'(c_{2,A})}{u'(c_{2,B})}\right)}{\partial B_1^H}}{1+\frac{P_A}{1-P_A}\frac{u'(c_{2,A})}{u'(c_{2,B})}} = \frac{\frac{P_A}{1-P_A}\frac{\partial\left(\frac{u'(w_{2,A}+e_2(B_1^H,B_2^F))}{u'\left(w_{2,B}-\frac{P_A}{1-P_A}e_2(B_1^H,B_2^F)\right)}\right)}{\partial e_2(B_1^H,B_2^F)}\frac{\partial e_2(B_1^H,B_2^F)}{\partial B_1^H}}{1+\frac{P_A}{1-P_A}\frac{u'(c_{2,A})}{u'(c_{2,B})}}$$

$$= \frac{\frac{u''(w_{2,A}+e_2(B_1^H,B_2^F))u'\left(w_{2,B}-\frac{P_A e_2(B_1^H,B_2^F)}{1-P_A}\right)+u'(w_{2,A}+e_2(B_1^H,B_2^F))\frac{P_A}{1-P_A}u''\left(w_{2,B}-\frac{P_A e_2(B_1^H,B_2^F)}{1-P_A}\right)}{\left(u'(w_{2,B}-\frac{P_A e_2(B_1^H,B_2^F)}{1-P_A})\right)^2}\frac{\partial e_2(B_1^H,B_2^F)}{\partial B_1^H}}{\frac{1-P_A}{P_A}+\frac{u'(c_{2,A})}{u'(c_{2,B})}}$$

which is negative when $\frac{(B_1^H+B_1^F)}{(1-P_A)w_3+(B_1^H+B_1^F)}\frac{c_{3,B}(0)u''(c_{3,B}(0))}{u'(c_{3,B}(0))} > -1$ and $\frac{B_1^H}{(1-P_A)w_3+b_1^H}\frac{c_{3,B}(1)u''(c_{3,B}(1))}{u'(c_{3,B}(1))} > -1$, because $\frac{\partial e_2(B_1^H,B_2^F)}{\partial B_1^H} > 0$ under that condition (see equation 16 and the subsequent discussion in the subsection on bond prices in recessions). This captures the fact that more home bonds allows for greater insurance and thereby reduces the appetite for even more insurance.

This proves our second result, that the two convenience yields decline when the supply of home bonds increases. This is both because the marginal benefits of insurance decline and because the marginal costs of insurance increase. In other words, $\frac{\partial CY_1^F}{\partial B_1^H} < 0$ and $\frac{\partial CY_1^H}{\partial B_1^H} < 0$ because all of their components are negative.

We also examine how the two convenience yields move in response to a shock to the supply of foreign bonds. Technically, we examine $\frac{\partial CY_1^F}{\partial B_1^F}$ and $\frac{\partial CY_1^H}{\partial B_1^F}$.

$$\frac{\partial CY_1^H}{\partial B_1^F} = \frac{\frac{P_A}{1-P_A}\frac{\partial\left(\frac{u'(c_{2,A})}{u'(c_{2,B})}\right)}{\partial B_1^F}}{1+\frac{P_A}{1-P_A}\frac{u'(c_{2,A})}{u'(c_{2,B})}} + 2\frac{\frac{P_A}{1-P_A}\frac{E_2\left[u'(c_{3,A})\right](1-P_D)u''(c_{3,B}(0))}{\left(E_2\left[u'(c_{3,B})\right]\right)^2}}{1+\frac{P_A}{1-P_A}\frac{E_2\left[u'(c_{3,A})\right]}{E_2\left[u'(c_{3,B})\right]}} \tag{23}$$

$$\frac{\partial CY_1^F}{\partial B_1^F} = \frac{\frac{P_A}{1-P_A}\frac{\partial\left(\frac{u'(c_{2,A})}{u'(c_{2,B})}\right)}{\partial B_1^F}}{1+\frac{P_A}{1-P_A}\frac{u'(c_{2,A})}{u'(c_{2,B})}} + 2\frac{\frac{P_A}{1-P_A}\frac{u'(w_3)u''(c_{3,B}(0))}{\left(u'(c_{3,B}(0))\right)^2}}{1+\frac{P_A}{1-P_A}\frac{u'(w_3)}{u'(c_{3,B}(0))}} \tag{24}$$

with $c_{2,A} = w_{2,A} + p_2^H B_1^H + p_2^F B_1^F$, $c_{2,B} = w_{2,B} - \frac{P_A}{1-P_A}(p_2^H B_1^H + p_2^F B_1^F)$, $E_2\left[u'(c_{3,A})\right] = u'(w_3)$, $c_{3,B}(1) = w_3 + \frac{B_1^H}{1-P_A}$, $c_{3,B}(0) = w_3 + \frac{B_1^H+B_1^F}{1-P_A}$ and $E_2\left[u'(c_{3,B})\right] = P_D u'(c_{3,B}(1)) + (1-P_D)u'(c_{3,B}(0))$. In both equations, we just proved that the first term is negative. Given the properties of the utility function, we also have that the second terms are negative. Therefore, $\frac{\partial CY_1^F}{\partial B_1^F} \leq 0$ and $\frac{\partial CY_1^H}{\partial B_1^F} \leq 0$.

## B.8 Proof of Third Results when $P_R = 1$

It is easy to show that $\frac{\partial CY_1^F}{\partial B_1^H}/\frac{\partial CY_1^H}{\partial B_1^H}$ is positive and tends to one when the probability of default $P_D$ goes to zero. Conversely, when $P_D$ goes to one, the foreign country has a constant convenience yield equal to zero. This holds irrespective of the level of home bonds, implying no spillovers and that $\frac{\partial CY_1^F}{\partial B_1^H}/\frac{\partial CY_1^H}{\partial B_1^H}$ tends to zero when the probability of default $P_D$ goes to one. Otherwise, in the general case when $0 < P_D < 1$, the two derivatives $\frac{\partial CY_1^F}{\partial B_1^H}$ and $\frac{\partial CY_1^H}{\partial B_1^H}$ are linked by a positive coefficient that varies with income dynamics and bond quantities.

To study the variations of $\frac{\partial CY_1^F}{\partial B_1^H}/\frac{\partial CY_1^H}{\partial B_1^H}$ with respect to the probability of default, we only have to focus on the second fraction of equation 21 because it is the only term that depends on $P_D$. We take its derivative

$$\frac{\partial\left(\frac{(P_D u''(c_{3,B}(1))+(1-P_D)u''(c_{3,B}(0)))}{(P_D u'(c_{3,B}(1))+(1-P_D)u'(c_{3,B}(0)))^2+\frac{P_A}{1-P_A}u'(w_3)(P_D u'(c_{3,B}(1))+(1-P_D)u'(c_{3,B}(0)))}\right)}{\partial P_D} =$$

$$\frac{(u''(c_{3,B}(1))-u''(c_{3,B}(0)))\left((E_2\left[u'(c_{3,B})\right])^2+\frac{P_A}{1-P_A}E_2\left[u'(c_{3,A})\right]E_2\left[u'(c_{3,B})\right]\right)}{\left((P_D u'(c_{3,B}(1))+(1-P_D)u'(c_{3,B}(0)))^2+\frac{P_A}{1-P_A}u'(w_3)\left(P_D u'(c_{3,B}(1))+(1-P_D)u'(c_{3,B}(0))\right)\right)^2}$$

$$-\frac{E_2\left[u''(c_{3,B})\right](u'(c_{3,B}(1))-u'(c_{3,B}(0)))\left(2E_2\left[u'(c_{3,B})\right]+\frac{P_A}{1-P_A}E_2\left[u'(c_{3,A})\right]\right)}{\left((P_D u'(c_{3,B}(1))+(1-P_D)u'(c_{3,B}(0)))^2+\frac{P_A}{1-P_A}u'(w_3)\left(P_D u'(c_{3,B}(1))+(1-P_D)u'(c_{3,B}(0))\right)\right)^2}$$

with $c_{3,B}(1)=w_3+\frac{B_1^H}{1-P_A}$ and $c_{3,B}(0)=w_3+\frac{B_1^H+B_1^F}{1-P_A}$. Because the utility function is concave, the second term, which is on the last line, is positive. If we assume that the utility function is not characterized by 'prudence' and that $u'''=0$, the first term is null and we have that $\frac{\partial^2 CY_1^H}{\partial B_1^H \partial P_D}\geq 0$. This implies $\frac{\partial \frac{\partial CY_1^F}{\partial B_1^H}/\frac{\partial CY_1^H}{\partial B_1^H}}{\partial P_D}\geq 0$.

Conversely, if we assume that the utility function is characterized by prudence ($u'''>0$), we have that the first fraction is negative. If it is negative enough to imply
$\frac{(u''(c_{3,B}(1))-u''(c_{3,B}(0)))}{-E_2[u''(c_{3,B})]}\left(1+\frac{P_A}{1-P_A}\frac{E_2\left[u'(c_{3,A})\right]}{E_2[u'(c_{3,B})]}\right)\leq\frac{-(u'(c_{3,B}(1))-u'(c_{3,B}(0)))}{E_2[u'(c_{3,B})]}\left(2+\frac{P_A}{1-P_A}\frac{E_2\left[u'(c_{3,A})\right]}{E_2[u'(c_{3,B})]}\right)$
and therefore $\frac{\partial^2 CY_1^H}{\partial B_1^H \partial P_D}\leq 0$, this implies $\frac{\partial \frac{\partial CY_1^F}{\partial B_1^H}/\frac{\partial CY_1^H}{\partial B_1^H}}{\partial P_D}\leq 0$.

Therefore, the difference in the response of the convenience yields with respect to an increase in home bonds is ambiguous and crucially depends on 'prudence'.

To build intuition about the above results, it can be helpful to examine $-\frac{P_D u''(c_{3,B}(1))+(1-P_D)u''(c_{3,B}(0))}{P_D u'(c_{3,B}(1))+(1-P_D)u'(c_{3,B}(0))}$ as variations in $\frac{\partial CY_1^F}{\partial B_1^H}/\frac{\partial CY_1^H}{\partial B_1^H}$ (the magnitude of spillovers) with $P_D$ are governed by this fraction. This fraction is closely connected to type-B households' absolute risk aversion in period 3, which is itself key to evaluating the *cost* component of convenience yields.

- When $u'''=0$, the numerator is constant.
  - A greater $P_D$ increases the denominator and absolute risk aversion in period 3 falls.
  - Investors care less about changes in the *cost* component of convenience yields.
  - $CY_1^H$ decreases less strongly in response to a marginal increase in home bonds.
  - $\frac{\partial CY_1^F}{\partial B_1^H}/\frac{\partial CY_1^H}{\partial B_1^H}$ is greater: spillovers from the home countries are larger when $P_D$ is larger.
- When $u'''>0$, variations in $P_D$ introduce another effect.
  - A greater $P_D$ increases the numerator which contributes to increasing the absolute

risk aversion in period 3.

- If this new effect dominates, investors care more about changes in the *cost* component of convenience yields.
- We get the opposite results: spillovers from the home countries are smaller when $P_D$ is larger.

## B.9 Convenience Yield Definition

In this section, we show that the definition of the convenience yield used in the data is up to an approximation equal to the definition chosen in the model. The yield-to-maturity, as used empirically, relates to the price according to $y_1 = \frac{1}{p_1} - 1$. In the data, we use the OIS rate and CDS rate to construct the "yield without convenience benefits", which in the model is $\tilde{y_1} = \frac{1}{\tilde{p_1}} - 1$. For yields close to 0, we can use $y_1 \approx log(1+y_1) = -log(p_1)$. The convenience yield measured in the data is $CY_1 = \tilde{y_1} - y_1$, but can, using the approximation, be rewritten as: $CY_1 = \log\left(\frac{p_1}{\tilde{p_1}}\right)$, which is the formulation we use in the model analysis (equation 9).

## B.10 Model Parametrization

In this Appendix, we discuss the parameters of the model that are not already explained in the main text (Section 5.3). The full list of parameters is summarized in Table B.1.

We consider that countries issue bonds with a maturity of 10 years, which implies that periods 1 and 3 are 10 years apart. We assume that one period lasts one year and for simplicity, we assume that the recession, if it takes place, takes place after 5 years. So effectively, with periods 1, 2, and 3, we model years 1, 6, and 11. Then, $\beta$ governs the risk-free rate over five years. We set $\beta = 1$ to have an annual risk-free (real) interest rate of 0% close to the value observed in the euro area since its inception. We choose the real, not the nominal, interest rate as a target because there is no inflation in our model.

For household period utility, we choose a standard Constant Relative Risk Aversion (CRRA) utility function with a CRRA coefficient set to $\sigma = 5.5$, as discussed in the main text. Household period income is normalized to 1 ($w_1 = w_2 = w_3 = 1$) in all periods except in recessions. The share of households that experience a drop in income in a recession is set to 50%, hence $P_A = 0.5$. The average drop in household income is set to 5%, as in large recessions, such as the Great Recession. However, as documented by Heathcote et al. (2020), in recessions household income can change very heterogeneously, such that income

Table B.1: Model Calibration

| Parameter | Description | Value |
|---|---|---|
| $\beta$ | Discount Factor | 1 |
| $\sigma$ | Coefficient of Relative Risk Aversion | 5.5 |
| $P_R$ | Probability of Recession | 0.5 |
| $P_D^{Safe}$ | Probability of Default in a Recession (Safe Country) | 0 |
| $P_D^{Risky}$ | Probability of Default in a Recession (Risky Country) | 0.5 |
| $P_A$ | Share of Type-A Households | 0.5 |
| $w_1, w_2, w_3$ | Household Income (Outside Recessions) | 1 |
| $w_{2,A}$ | Income in a Recession for Type-A Households | 0.75 |
| $w_{2,B}$ | Income in a Recession for Type-B Households | 1.15 |
| $B_1^H, B_1^F$ | Annual Debt Issuance (Relative to Income in H+F) | 0.1 |

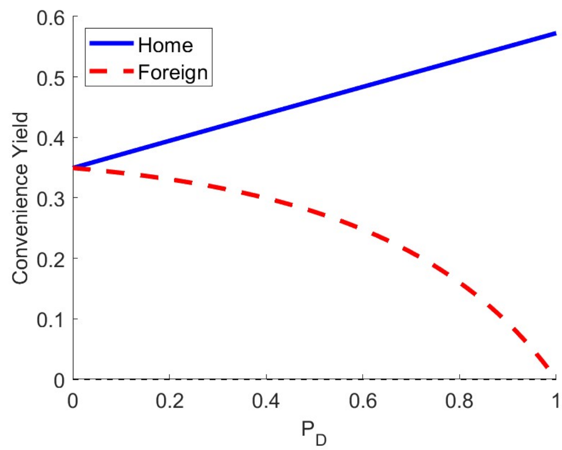
dispersion rises substantially. Therefore, we choose income for type-A households to fall by 25% ($w_{2,A} = 0.75$), while it rises by 15% for type-B households ($w_{2,B} = 1.15$). This implies an increase in income dispersion ($w_{2,B}/w_{2,A}$) of around 50%.

Annual debt issuance relative to total income (across both countries) is set to $B_1 = 0.1$, implying that each country issues 20% of debt relative to its own income (which is 0.5 when countries have identical size). This is in line with gross debt issuance by euro area sovereigns which is close to 20% of GDP annually. To have symmetric home and foreign countries when $P_D = P_D^{Safe} = 0$, we choose the same value for both countries.

## B.11 Additional Numerical Results

Figure B.1 illustrates the levels of the convenience yield for both countries over a range of default risk probabilities. It is worth pointing out that the home convenience yield rises with the foreign default probability, because the total amount of available insurance in a recession ($p_2^H b_1^H + p_2^F b_1^F$) falls, implying that the marginal value of insurance rises.

FIGURE B.1: Convenience Yield Levels over $P_D$



# Online Appendix to "Dangerous Liaisons? Debt Supply and Convenience Yield Spillovers in the Euro Area"

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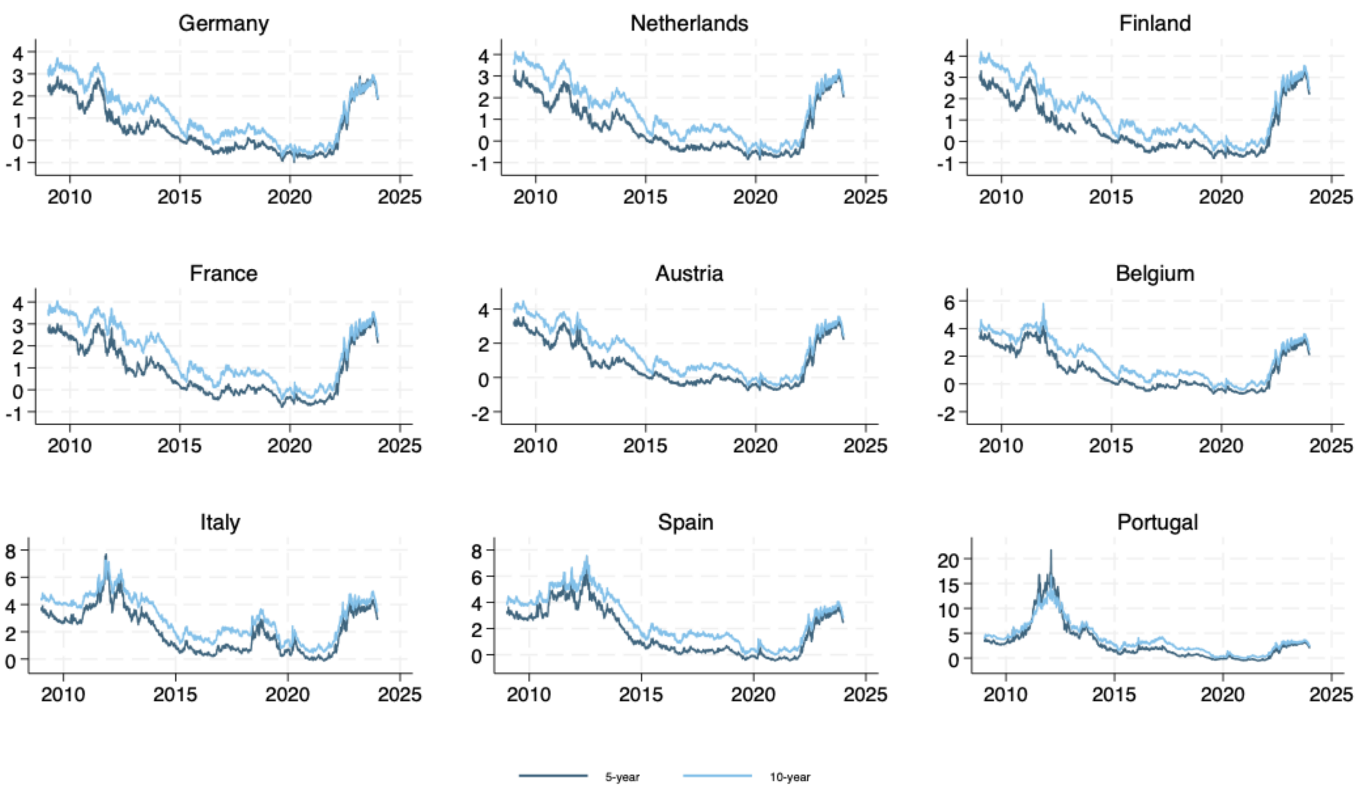
# C Online Appendix

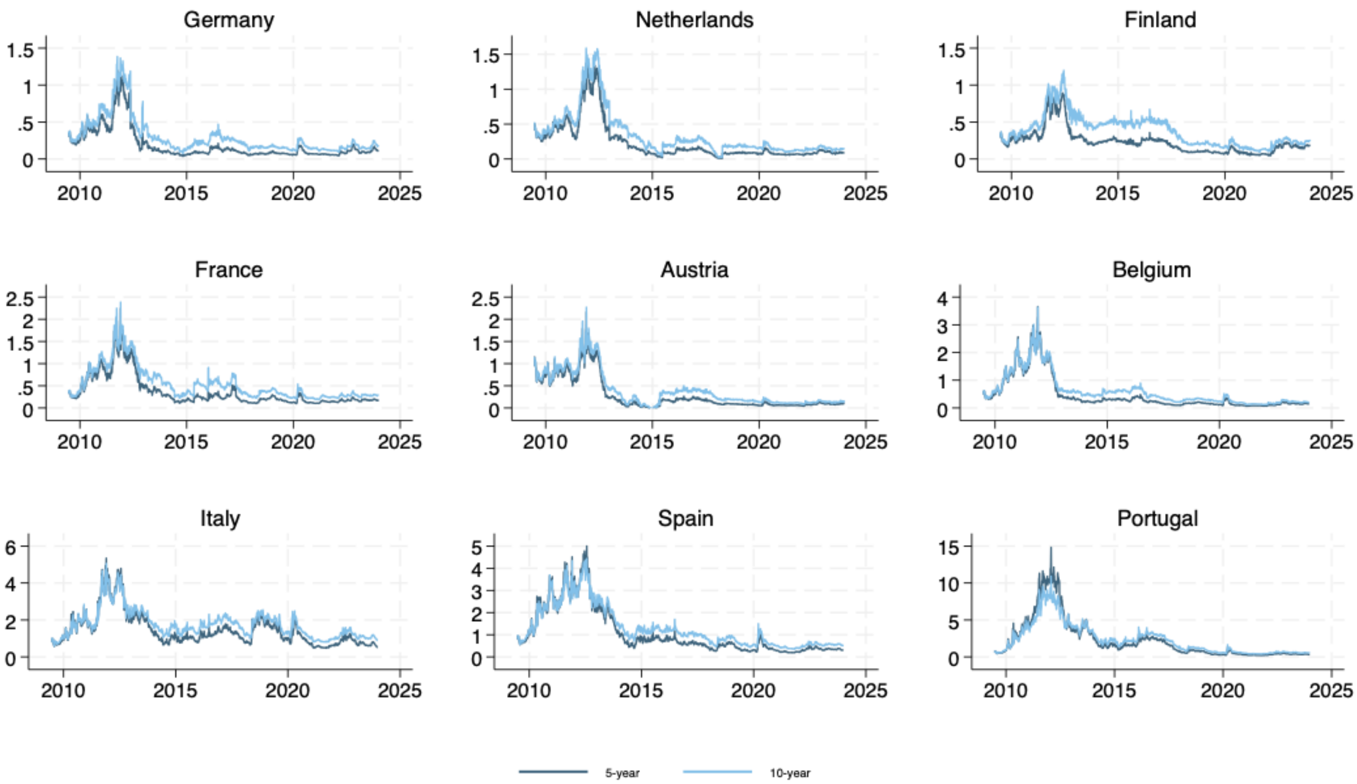
## C.1 Additional Tables & Figures

FIGURE OA.1: Time Series of Sovereign Yields



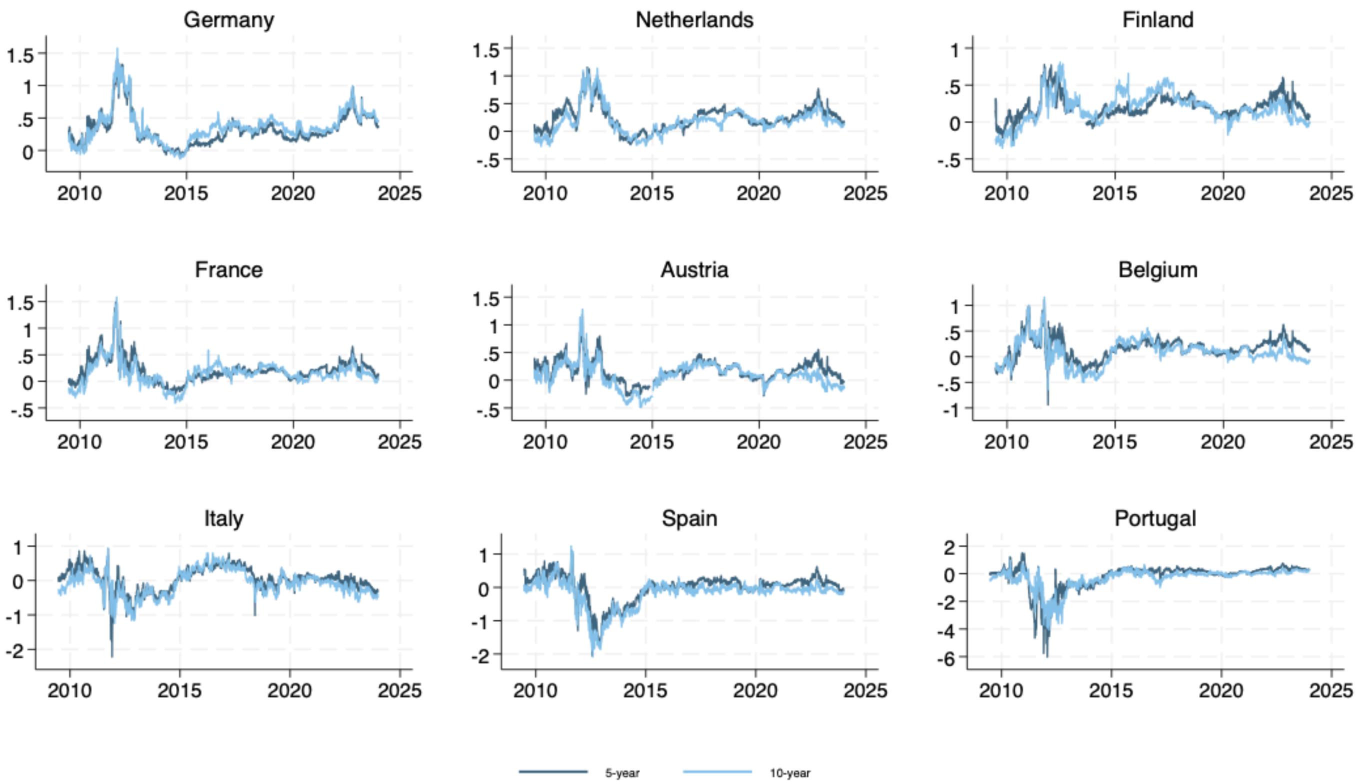

*Notes:* Sovereign yields are measured in percentage points.

Figure OA.2: Time Series of CDS Rates




*Notes:* CDS rates are measured in percentage points.

Figure OA.3: Time Series of Convenience Yields




*Notes:* Convenience yields are measured in percentage points.

Figure OA.4: Distribution of Policy Dates by Country and Year

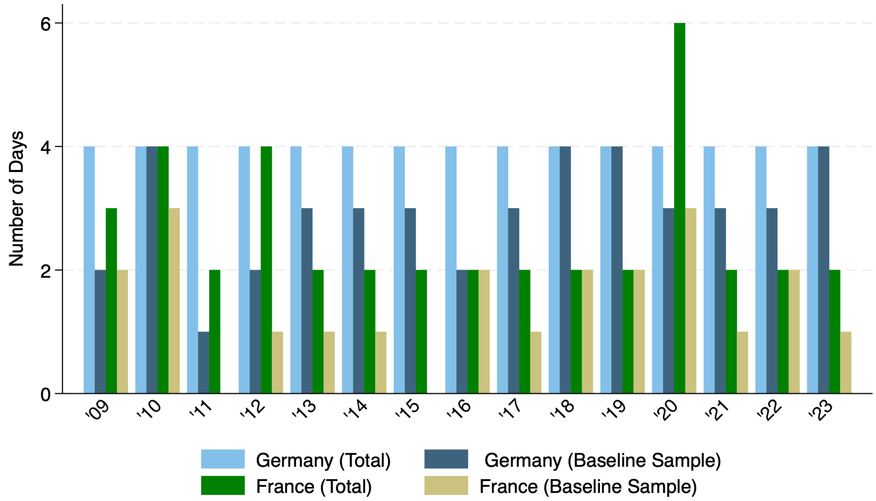



Table OA.1: Daily Yield Spillovers from Germany (Method 2: IV) – Larger Sample

| | *Safe Countries* | | | | | | *Risky Countries* | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | (1) $\Delta Y_{FR}$ | (2) $\Delta Y_{NL}$ | (3) $\Delta Y_{FI}$ | (4) $\Delta Y_{AT}$ | (5) $\Delta Y_{BE}$ | (6) Pool | (7) $\Delta Y_{IT}$ | (8) $\Delta Y_{ES}$ | (9) $\Delta Y_{PT}$ | (10) Pool | (11) Pool |
| $\Delta Y_{DE}$ | 0.89*** | 0.89*** | 1.05*** | 1.01*** | 1.01*** | | 0.21 | 0.18 | 0.80 | | |
| | (0.16) | (0.13) | (0.10) | (0.12) | (0.30) | | (0.66) | (0.62) | (0.75) | | |
| $\Delta Y_{DE}$ | | | | | | 0.97*** | | | | 0.40 | 0.85*** |
| | | | | | | (0.14) | | | | (0.58) | (0.24) |
| $\Delta Y_{DE} \times \mathbb{1}\{CDS > 1\}$ | | | | | | | | | | | -0.91 |
| | | | | | | | | | | | (1.07) |
| Constant | 0.00 | -0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 0.01 | 0.01 | 0.01 |
| | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) |
| Observations | 64 | 64 | 64 | 64 | 64 | 320 | 64 | 64 | 64 | 192 | 192 |

*Notes:* Each column displays coefficients from a separate regression: $\Delta Y_{Destination,t} = \beta_0 + \beta_1 \times \Delta Y_{DE,t} + \epsilon_t$, for columns (1)-(5) and (7)-(9); $\Delta Y_{Destination,t} = \beta_0 + \beta_1 \times \Delta Y_{DE,t} + \beta_2 \Delta Y_{DE,t} \times \mathbb{1}\{CDS > 1\} + \epsilon_t$, for columns (6) and (10)-(11); where the daily change in the German convenience yield is instrumented with the 30-minute yield change and $\mathbb{1}\{CDS > 1\}$ is an indicator variable that take value 1 if the CDS rate is above 1 and 0 otherwise. Standard errors are reported in parentheses. $^{*}$ $p < 0.10$, $^{**}$ $p < 0.05$, $^{***}$ $p < 0.01$.

Table OA.2: Daily Convenience Yield Spillovers from Germany (Method 3: Rigobon-Sack Estimator)

| | *Safe Countries* | | | | | *Risky Countries* | | |
|---|---|---|---|---|---|---|---|---|
| | (1) $\Delta CY_{FR}$ | (2) $\Delta CY_{NL}$ | (3) $\Delta CY_{FI}$ | (4) $\Delta CY_{AT}$ | (5) $\Delta CY_{BE}$ | (6) $\Delta CY_{IT}$ | (7) $\Delta CY_{ES}$ | (8) $\Delta CY_{PT}$ |
| $\Delta CY_{DE}$ | 0.93*** | 2.87* | 1.09*** | 1.33** | 0.89 | 0.54 | -0.30 | 0.08 |
| | (0.29) | (1.60) | (0.37) | (0.53) | (1.03) | (1.00) | (1.20) | (1.32) |
| Constant | -0.00* | -0.01 | -0.00 | -0.00 | -0.00 | -0.01 | 0.00 | -0.01 |
| | (0.00) | (0.01) | (0.00) | (0.00) | (0.00) | (0.01) | (0.01) | (0.01) |
| N | 88 | 88 | 88 | 88 | 88 | 88 | 88 | 88 |
| Weak IV | 6.126 | 5.261 | 4.025 | 3.750 | 3.205 | 3.172 | 3.170 | 3.126 |
| Overid. | 0.605 | 0.866 | 0.733 | 0.383 | 0.510 | 0.949 | 0.538 | 0.125 |

*Notes: Each column displays coefficients from a separate regression: $\Delta CY_{Destination,t} = \beta_0 + \beta_1 \times \Delta CY_{DE,t} + \epsilon_t$, where we employ the RS estimator described in Section 3.3. Each column corresponds to a different destination country. For every column, we use the two-step GMM estimator and the two instrument variables based on the change in the variance-covariance matrix of the origin and destination country yields. Robust standard errors are reported in parentheses and stars indicate significance levels: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. The before last row shows the Stock-Yogo weak IV statistics while the associated threshold for the 25% maximal IV size is estimated at 7.25. The last row reports the p-value of the Hansen J overidentification test where the null hypothesis is that the instruments are valid.*

Table OA.3: Daily Convenience Yield Spillovers from Germany (Method 3: Rigobon-Sack Estimator) – $1^{st}$ Alternative Implementation (Subsample)

| | *Safe Countries* | | | | | *Risky Countries* | | |
|---|---|---|---|---|---|---|---|---|
| | (1) $\Delta CY_{FR}$ | (2) $\Delta CY_{NL}$ | (3) $\Delta CY_{FI}$ | (4) $\Delta CY_{AT}$ | (5) $\Delta CY_{BE}$ | (6) $\Delta CY_{IT}$ | (7) $\Delta CY_{ES}$ | (8) $\Delta CY_{PT}$ |
| $\Delta CY_{DE}$ | 1.02*** | 1.35*** | 1.32*** | 1.64*** | 1.44 | 1.13 | 1.27 | 4.22 |
| | (0.27) | (0.39) | (0.41) | (0.63) | (1.09) | (1.39) | (1.16) | (4.14) |
| Constant | -0.00 | -0.00* | -0.00 | -0.00 | -0.00 | -0.00 | 0.00 | -0.01 |
| | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.01) | (0.00) | (0.01) |
| N | 72 | 72 | 72 | 72 | 72 | 72 | 72 | 72 |
| Weak IV | 10.537 | 3.287 | 6.885 | 3.673 | 4.122 | 2.459 | 2.446 | 2.670 |
| Overid. | 0.115 | 0.691 | 0.370 | 0.717 | 0.857 | 0.445 | 0.252 | 0.094 |

*Notes: This table reports coefficient estimates of equation $\Delta CY_{Destination,t} = \beta_0 + \beta_1 \times \Delta CY_{DE,t} + \epsilon_t$ where we employ the RS estimator described in Section 3.3. This table is similar to Table OA.2, except that results are obtained on a smaller sample that additionally excludes observations with potential outliers for yield variations in the destination countries. For every column, we use the two instrument variables based on the change in the variance-covariance matrix of variations in the origin and destination country yields. Again, we use the two-step GMM estimator. Each column corresponds to a different destination country. Robust standard errors are reported in parentheses and stars indicate significance levels: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. The before last row shows the Stock-Yogo weak ID statistics while the associated threshold for the 25% maximal IV size is estimated at 7.25. The last row reports the p-value of the Hansen J overidentification test where the null hypothesis is that the instruments are valid.*

Table OA.4: Daily Convenience Yield Spillovers from Germany (Method 3: Rigobon-Sack Estimator) – $1^{st}$ Alternative Implementation (Different Instruments)

| | *Safe Countries* | | | | | *Risky Countries* | | |
|---|---|---|---|---|---|---|---|---|
| | (1) $\Delta CY_{FR}$ | (2) $\Delta CY_{NL}$ | (3) $\Delta CY_{FI}$ | (4) $\Delta CY_{AT}$ | (5) $\Delta CY_{BE}$ | (6) $\Delta CY_{IT}$ | (7) $\Delta CY_{ES}$ | (8) $\Delta CY_{PT}$ |
| $\Delta CY_{DE}$ | 0.64** | 1.26** | 1.12*** | 0.89*** | -0.33 | -0.40 | 0.54 | -1.13 |
| | (0.25) | (0.60) | (0.15) | (0.24) | (0.41) | (0.62) | (0.76) | (1.01) |
| Constant | -0.00 | -0.00 | -0.00* | -0.00 | 0.00 | -0.00 | 0.00 | 0.00 |
| | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.01) |
| N | 88 | 88 | 88 | 88 | 88 | 88 | 88 | 88 |
| Weak IV | 1.982 | 1.982 | 1.982 | 1.982 | 1.982 | 1.982 | 1.982 | 1.982 |
| Overid. | 0.086 | 0.829 | 0.450 | 0.401 | 0.434 | 0.129 | 0.082 | 0.746 |

*Notes: This table reports coefficient estimates of equation $\Delta CY_{Destination,t} = \beta_0 + \beta_1 \times \Delta CY_{DE,t} + \epsilon_t$ where we employ the RS estimator described in Section 3.3. This table is similar to Table OA.2, except that results are obtained with different instruments. For every column, we use the instrument variables based on the change in the variance-covariance matrix of the origin country and the 8 destination country yields. Again, we use the two-step GMM estimator. Each column corresponds to a different destination country. Robust standard errors are reported in parentheses and stars indicate significance levels: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. The before last row shows the Stock-Yogo weak ID statistics while the associated threshold for the 25% maximal IV size is estimated at 11.07. The last row reports the p-value of the Hansen J overidentification test where the null hypothesis is that the instruments are valid.*

Table OA.5: Daily Convenience Yield Spillovers from Germany (Method 3: Rigobon-Sack Estimator) – $3^{rd}$ Alternative Implementation (Different Instruments)

| | *Safe Countries* | | | | | *Risky Countries* | | |
|---|---|---|---|---|---|---|---|---|
| | (1) $\Delta CY_{FR}$ | (2) $\Delta CY_{NL}$ | (3) $\Delta CY_{FI}$ | (4) $\Delta CY_{AT}$ | (5) $\Delta CY_{BE}$ | (6) $\Delta CY_{IT}$ | (7) $\Delta CY_{ES}$ | (8) $\Delta CY_{PT}$ |
| $\Delta CY_{DE}$ | 1.18 | 2.70 | 1.17** | 0.86 | 0.72 | 0.55 | -0.09 | 0.67 |
| | (0.73) | (1.81) | (0.47) | (0.53) | (0.91) | (1.02) | (1.20) | (1.28) |
| Constant | -0.00 | -0.01 | -0.00 | -0.00 | -0.00 | -0.01 | 0.00 | -0.01 |
| | (0.00) | (0.01) | (0.00) | (0.00) | (0.00) | (0.01) | (0.01) | (0.01) |
| N | 88 | 88 | 88 | 88 | 88 | 88 | 88 | 88 |
| Weak IV | 6.319 | 6.319 | 6.319 | 6.319 | 6.319 | 6.319 | 6.319 | 6.319 |

*Notes: This table reports coefficient estimates of equation $\Delta CY_{Destination,t} = \beta_0 + \beta_1 \times \Delta CY_{DE,t} + \epsilon_t$ where we employ the RS estimator described in Section 3.3. This table is similar to Table OA.2, except that results are obtained with different instruments. For every column, we use the instrument variable constructed only with German yield variations (based on the change in the first column of variance-covariance matrix of origin and destination country yields). Again, we use the two-step GMM estimator. Each column corresponds to a different destination country. Robust standard errors are reported in parentheses and stars indicate significance levels: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. The last row shows the Stock-Yogo weak ID statistics while the associated threshold for the 25% maximal IV size is estimated at 5.53.*

## C.2 Rigobon-Sack Estimator

Our dataset for the implementation of the RS estimator includes daily changes in convenience yields for each country on two categories of dates: the $E$ subset includes dates where announcements are made, whereas the $NE$ subset consists of dates prior to these and therefore without any announcements.

We outline the challenges in estimating spillovers between convenience yields among euro area countries in the main text, and the following equations offer a clear description of the endogeneity present in the system:

$$\Delta CY_t^H = \beta^{FH} \Delta CY_t^F + \delta Z_t + \epsilon_t$$

$$\Delta CY_t^F = \beta^{HF} \Delta CY_t^H + Z_t + \eta_t$$

where $\Delta CY_t^H$ is the daily change of the home country's convenience yield, $\Delta CY_t^F$ is the daily change of the foreign country's convenience yield and $Z_t$ are common background variables (noise). $\epsilon_t$ and $\eta_t$ are shocks, such as debt supply shocks, to the convenience yields of home and foreign, respectively. Our aim is to estimate the coefficient $\beta^{HF}$, i.e. the spillover effect of a change of the home country's convenience yield on the foreign country's convenience yield, following a debt supply change in the home country.

The identification through heteroskedasticity, as in Rigobon (2003) and Rigobon and Sack (2004), does not require the complete absence of both common and idiosyncratic shocks. Instead, it relies on the following assumptions:

$$\sigma_\epsilon^E > \sigma_\epsilon^{NE},$$

$$\sigma_\eta^E = \sigma_\eta^{NE},$$

$$\sigma_z^E = \sigma_z^{NE}.$$

In words, the method assumes that the variances of common shocks ($Z$) and the shock to the foreign country ($\eta$) are equal on both event and non-event days, while the variance of the shock to the home country ($\epsilon$) is higher on event days compared to non-event days. This increase in variance on event days is attributed to the impact of debt supply announcements.

With this assumption, we can estimate the parameter $\beta^{HF}$ by contrasting the covariance matrices of the change in the home country convenience yield and the change in the foreign country convenience yield on event days versus non-event days.

In practice, we can build the following instruments and implement the estimator through an instrumental variable approach:

$$w_i \equiv \{\Delta CY_t^H, t \in E\} \cup \{-\Delta CY_t^H, t \in NE\}$$
$$w_s \equiv \{\Delta CY_t^F, t \in E\} \cup \{-\Delta CY_t^F, t \in NE\}.$$

While we could use the IV estimation using just one instrument (as in Rigobon and Sack, 2004), we prefer to follow Arai (2017) for our main results and use the orthogonality of both instruments as the moment conditions for the GMM estimation, since this provides more efficient estimates[1]. The moment conditions are described as follows:

$$E[f_t(\beta^{HF})] = 0,$$

where

$$f_t(\beta^{HF}) = Q_t \cdot e_t,$$
$$Q_t = [w_{i,t}\,,\; w_{s,t}]',$$
$$e_t = \Delta CY_t^F - \beta^{HF} \Delta CY_t^H.$$

The GMM estimate of $\beta^{HF}$ can be obtained by solving the minimum distance problem:

$$\beta^{HF}_{gmm} = \text{arg min } f_T(\beta^{HF})' \; W \; f_T(\beta^{HF}),$$

where $f_T(\beta^{HF}) = \sum_{t=1}^{T} f_t(\beta^{HF})$ and $W$ is an appropriate $2 \times 2$ weighting matrix.

[1] Results are robust to this choice. See Appendix A.5.3.

## C.3 Additional Theoretical Analysis

### C.3.1 Interior Solutions

In the case of interior solutions, prices clear the secondary bond market in period 2 and there is a unique price for each bond. This means that $p^H_{2,A} = p^H_{2,B} = p^H_2$ and $p^F_{2,A} = p^F_{2,B} = p^F_2$.

Combining equations 12-15 allows to compare the relative prices for the two bonds according to each household type's valuation:

$$\begin{aligned}
\frac{p^F_{2,A}}{p^H_{2,A}} &= (1-P_D) \\
\frac{p^F_{2,B}}{p^H_{2,B}} &= (1-P_D)\frac{u'\left(w_3 + \frac{1}{(1-P_A)}(db^H_{2,A} + db^F_{2,A})\right)}{P_D u'\left(w_3 + \frac{1}{(1-P_A)}db^H_{2,A}\right) + (1-P_D)u'\left(w_3 + \frac{1}{(1-P_A)}(db^H_{2,A} + db^F_{2,A})\right)} \\
\Rightarrow \frac{p^F_{2,A}}{p^H_{2,A}} &> \frac{p^F_{2,B}}{p^H_{2,B}} \text{ if } db^F_{2,A} > 0 \text{ and } \frac{p^F_{2,A}}{p^H_{2,A}} = \frac{p^F_{2,B}}{p^H_{2,B}} \text{ if } db^F_{2,A} = 0. \qquad (25)
\end{aligned}$$

The inequality in equation 25 comes from decreasing marginal utility as $u'\left(w_3 + \frac{db^H_{2,A}}{(1-P_A)}\right) \geq u'\left(w_3 + \frac{db^H_{2,A}+db^F_{2,A}}{(1-P_A)}\right)$ which becomes a strict inequality if $db^F_{2,A} > 0$. Therefore, this means that we can only have $p^H_{2,A} = p^H_{2,B}$ and $p^F_{2,A} = p^F_{2,B}$ if $db^F_{2,A} = 0$. In other words, when there is no bond rationing, households do not re-trade the foreign bond. This happens because the services provided by home bonds strictly dominate, as the bonds allow to save without any default risk. Type-B households buy home bonds to smooth consumption between period 2 and 3, and once consumption is smoothed using home bonds, these households have no reasons to buy any foreign bonds. Knowing that foreign bonds won't be traded in period 2, households don't buy them in period 1.

In the case of interior solutions, type-A households sell an amount $db^H_{2,A} = \hat{b}^H_1$ of home bonds that is the solution of the following system of equations (based on equations 12 and 14):

$$\begin{aligned}
p^H_{2,A} &= \frac{\beta u'(w_3)}{u'(w_{2,A} + p^H_{2,A} db^H_{2,A})} \\
p^H_{2,B} &= \frac{\beta u'\left(w_3 + \frac{1}{(1-P_A)}db^H_{2,A}\right)}{u'\left(w_{2,B} - \frac{P_A}{(1-P_A)}p^H_{2,B} db^H_{2,A}\right)} \\
p^H_{2,A} &= p^H_{2,B}
\end{aligned}$$

Note that the first equation implicitly defines a function $p_{2,A}^H(db_{2,A}^H)$ (it is the supply function from type-A household) that always increases with $db_{2,A}^H$ under some condition. This results from applying the implicit function theorem, as we get that $\frac{\partial p_{2,A}^H}{\partial db_{2,A}^H}u'(w_{2,A}+p_{2,A}^H db_{2,A}^H)+p_{2,A}^H u''(w_{2,A}+p_{2,A}^H db_{2,A}^H)\left(\frac{\partial p_{2,A}^H}{\partial db_{2,A}^H}db_{2,A}^H+p_{2,A}^H\right)=0$ and then that $\frac{\partial p_{2,A}^H}{\partial db_{2,A}^H}=-\frac{(p_{2,A}^H)^2u''(w_{2,A}+p_{2,A}^H db_{2,A}^H)}{u'(w_{2,A}+p_{2,A}^H db_{2,A}^H)+p_{2,A}^H db_{2,A}^H u''(w_{2,A}+p_{2,A}^H db_{2,A}^H)}=\frac{(p_{2,A}^H)^2\frac{-u''(c_{2,A})}{u'(c_{2,A})}}{1-\frac{p_{2,A}^H db_{2,A}^H}{c_{2,A}}\frac{-c_{2,A}u''(c_{2,A})}{u'(c_{2,A})}}$ which is non-negative if and only if $1-\frac{p_{2,A}^H db_{2,A}^H}{c_{2,A}}\frac{-c_{2,A}u''(c_{2,A})}{u'(c_{2,A})}\geq 0$. In other words, the latter is true if the coefficient of relative aversion is low enough $\left(\frac{-c_{2,A}u''(c_{2,A})}{u'(c_{2,A})}\text{ is small}\right)$, and if type-A households' dis-savings in recession is small relative to type-A households' consumption.

Then, note that the second equation of the system implicitly defines a function $p_{2,B}^H(db_{2,A}^H)$. That function is the demand function from type-B households that always decreases with $db_{2,A}^H$. This results from applying the implicit function theorem, as we get that $\frac{\partial p_{2,B}^H}{\partial db_{2,A}^H}u'\left(w_{2,B}-\frac{P_A}{(1-P_A)}p_2^H db_{2,A}^H\right)-p_{2,B}^H\frac{P_A}{(1-P_A)}\left(\frac{\partial p_{2,B}^H}{\partial db_{2,A}^H}db_{2,A}^H+p_{2,B}^H\right)u''\left(w_{2,B}-\frac{P_A}{(1-P_A)}p_2^H db_{2,A}^H\right)=\frac{\beta}{(1-P_A)}u''\left(w_3+\frac{1}{(1-P_A)}db_{2,A}^H\right)$ and that $\frac{\partial p_{2,B}^H}{\partial db_{2,A}^H}=\frac{\frac{\beta}{(1-P_A)}u''\left(w_3+\frac{1}{(1-P_A)}db_{2,A}^H\right)+\frac{P_A}{(1-P_A)}(p_{2,B}^H)^2u''\left(w_{2,B}-\frac{P_A}{(1-P_A)}p_2^H db_{2,A}^H\right)}{u'\left(w_{2,B}-\frac{P_A}{(1-P_A)}p_2^H db_{2,A}^H\right)-p_{2,B}^H db_{2,A}^H\frac{P_A}{(1-P_A)}u''\left(w_{2,B}-\frac{P_A}{(1-P_A)}p_2^H db_{2,A}^H\right)}$ which is clearly non-positive. Furthermore, the $p_{2,B}^H(db_{2,A}^H)$ function goes from $\frac{\beta u'(w_3)}{u'(w_{2,B})}$ when $db_{2,A}^H=0$ down to 0 when $db_{2,A}^H$ is such that $c_{2,B}=w_3+\frac{1}{(1-P_A)}db_{2,A}^H$ reaches the satiation point where $u'(c_{2,B})=0$ (e.g., this happens when $db_{2,A}^H$ goes to infinity in CRRA utility functions).

As illustrated with Figure OA.5, the above system of equations has a unique solution $\left(\hat{p}_2^H,\hat{b}_1^H\right)$ when $1-\frac{p_{2,A}^H db_{2,A}^H}{c_{2,A}}\frac{-c_{2,A}u''(c_{2,A})}{u'(c_{2,A})}\geq 0$. This is because $p_{2,A}^H(0)=\frac{\beta u'(w_3)}{u'(w_{2,A})}<\frac{\beta u'(w_3)}{u'(w_{2,B})}=p_{2,B}^H(0)$ and then because the two implicit functions – namely type-A household's supply $p_{2,A}^H(db_{2,A}^H)$ and type-B household's demand $p_{2,B}^H(db_{2,A}^H)$ – must cross and cross only once.

To recap, the period-2 household problem has an interior solution if $1-\frac{p_{2,A}^H db_{2,A}^H}{c_{2,A}}\frac{-c_{2,A}u''(c_{2,A})}{u'(c_{2,A})}\geq 0$. In that case, type-A households sell a quantity of home bond $db_{2,A}^H=\hat{b}_1^H$ to type-B households and no foreign bonds are traded ($db_{2,A}^F=0$).

### C.3.2 Mixed Interior/Corner Solutions

Let's now consider the case where $B_1^H<\hat{b}_1^H$. In that case, type-A households' no-short-selling condition binds for the home bond and we have $db_{2,A}^H=B_1^H$ and $db_{2,B}^H=\frac{-P_A}{1-P_A}B_1^H$. On one hand, type-A households are constrained from selling more home bonds: any price

$p_2^H \geq p_{2,A}^H$ would be consistent with our corner equilibrium.

On the other hand, type-B households are willing to buy bonds as long as $p_2^H \leq p_{2,B}^H$. Therefore, there is a range of possible equilibrium prices from $p_{2,A}^H$ to $p_{2,B}^H$. We assume that $p_2^H = p_{2,B}^H$.

Turning our attention to foreign bonds, the equilibrium could also be a corner solution or an interior solution.

Let's first consider the case of the interior solution where foreign bond supply is not binding and, therefore, where $p_{2,A}^F = p_{2,B}^F$. The system of price equations 12-15 can be re-written as follows (specifically by combining equations 13 and 15 for the first line, and by making use of equation 16 for the rest):

$$\frac{u'\left(w_3 + \frac{1}{(1-P_A)}(B_1^H + db_{2,A}^F)\right)}{u'(w_3)} = \frac{u'\left(w_{2,B} - \frac{P_A}{(1-P_A)}e_2\right)}{u'(w_{2,A}+e_2)} \tag{26}$$

$$\frac{1}{\beta}e_2 u'\left(w_{2,B} - \frac{P_A}{(1-P_A)}e_2\right) = \tag{27}$$

$$\left[P_D u'\left(w_3 + \frac{B_1^H}{(1-P_A)}\right) + (1-P_D)u'\left(w_3 + \frac{B_1^H + db_{2,A}^F}{(1-P_A)}\right)\right] B_1^H + (1-P_D)u'\left(w_3 + \frac{B_1^H + db_{2,A}^F}{(1-P_A)}\right) db_{2,A}^F$$

In what follows, we will focus on values of $e_2$ that are equal or less than $\frac{(1-P_A)}{P_A}w_{2,B}$ to ensure that we never consider negative consumption for type-B households. We also require that $db_{2,A}^F \geq -B_1^H - (1-P_A)w_3$ to ensure non-negative type-A household's consumption.

Equation 26 characterizes how many foreign bonds are sold by type-A households as an implicit function $db_{26}(.)$ of $e_2$, the bond value exchanged by a type-A household. Applying the implicit function theorem, we get that $\frac{\partial db_{26}}{\partial e_2} = -(1-P_A)u'(w_3)\frac{\frac{P_A}{(1-P_A)}u''\left(w_{2,B}-\frac{P_A}{(1-P_A)}e_2\right)u'(w_{2,A}+e_2)+u'\left(w_{2,B}-\frac{P_A}{(1-P_A)}e_2\right)u''(w_{2,A}+e_2)}{(u'(w_{2,A}+e_2))^2 u''\left(w_3+\frac{1}{(1-P_A)}(B_1^H+db_{2,A}^F)\right)} \leq 0$. For $e_2 = 0$, equation 26 becomes $u'\left(w_3 + \frac{1}{(1-P_A)}(B_1^H + db_{26}(0))\right) = \frac{u'(w_{2,B})}{u'(w_{2,A})}u'(w_3)$. Because $w_{2,B} > w_{2,A}$, the corresponding bond exchange must be such that $\frac{1}{(1-P_A)}(B_1^H + db_{26}(0)) > 0$. For $e_2 = \frac{(1-P_A)}{P_A}w_{2,B}$, the right-hand side of equation 26 tends to $+\infty$ and that requires $db_{26}((1-P_A)w_{2,B}/P_A) + B_1^H$ to be equal to $-(1-P_A)w_3$.

Equation 27 also characterizes how many foreign bonds are sold by type-A households as an implicit function $db_{27}(e_2)$. We already proved that $\frac{\partial db_{27}}{\partial e_2} > 0$ (in the paragraph following equation 16) if $\frac{(db_{2,A}^H + db_{2,A}^F)}{(1-P_A)w_3 + (db_{2,A}^H + db_{2,A}^F)}\frac{c_{3,B}(0)u''(c_{3,B}(0))}{-u'(c_{3,B}(0))} < 1$ and $\frac{db_{2,A}^H}{(1-P_A)w_3 + db_{2,A}^H}\frac{c_{3,B}(1)u''(c_{3,B}(1))}{-u'(c_{3,B}(1))} < 1$. For $e_2 = 0$, equation 27 becomes

FIGURE OA.5: Existence and uniqueness of interior solutions (graphical proof).

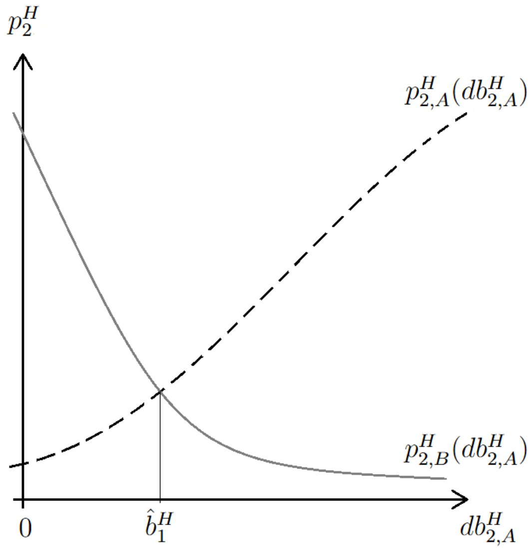
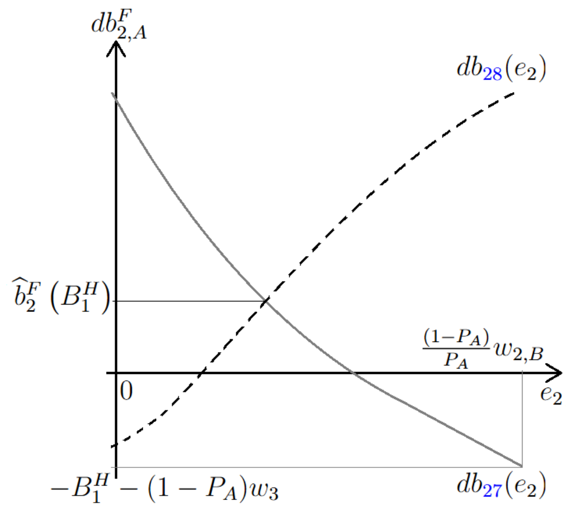



FIGURE OA.6: Existence and uniqueness of partially-corner solutions (graphical proof).




$P_D u'\left(w_3 + \frac{B_1^H}{(1-P_A)}\right) B_1^H + (1-P_D)u'\left(w_3 + \frac{B_1^H + db_{27}(0)}{(1-P_A)}\right)(B_1^H + db_{27}(0)) = 0$. This can only happen for $B_1^H + db_{27}(0) < 0$, which then implies that $B_1^H + db_{27}(0) < 0 < B_1^H + db_{26}(0)$ and $db_{27}(0) < db_{26}(0)$. For $e_2 = \frac{(1-P_A)}{P_A} w_{2,B}$, the right-hand side of equation 27 is

$P_D u'\left(w_3 + \frac{B_1^H}{(1-P_A)}\right) B_1^H + (1-P_D)u'\left(w_3 + \frac{B_1^H + db_{27}\left(\frac{(1-P_A)}{P_A}w_{2,B}\right)}{(1-P_A)}\right)\left(B_1^H + db_{27}\left(\frac{(1-P_A)}{P_A}w_{2,B}\right)\right) > 0.$

The right-hand side of equation 27 tends to $-\infty$ when evaluated at $db_{2,A}^F = db_{26}((1 - P_A)w_{2,B}/P_A)$. Because it is continuously increasing, it reaches positive values for some value $db_{27}((1-P_A)w_{2,B}/P_A) > db_{26}((1-P_A)w_{2,B}/P_A)$.

Combining the information from the previous two paragraphs, we prove graphically in Figure OA.6 that the system of equations 26-27 has a unique solution $\left(\widehat{b}_2^F\left(B_1^H\right), \widehat{e}_2\left(B_1^H\right)\right)$ for a given supply $B_1^H$ such that $B_1^H < \hat{b}_1^H$. This happens because the function $db_{26}(e_2)$ is below $db_{27}(e_2)$ at $e_2 = 0$ and continuously rises with $e_2$ to a point where it exceeds $db_{27}(e_2)$.

Going back to the original set of price equations, equation 13 allows us to solve for the foreign bond price.

$$p_2^F = p_{2,B}^F = p_{2,A}^F = \frac{\beta(1-P_D)u'(w_3)}{u'(w_{2,A} + \widehat{e}_2\left(B_1^H\right))}$$