Working Paper Series | 63 | 2024

Dangerous liaisons? Debt supply and convenience yield spillovers in the euro area

This paper documents spillover effects of sovereign debt issuance among euro area countries' convenience yields, establishing a new source of fiscal spillovers in the euro area.

Cristian Arcidiacono
University of Bern

Matthieu Bellon
European Stability Mechanism

Matthias Gnewuch
European Stability Mechanism

European Stability Mechanism

Dangerous liaisons? Debt supply and convenience yield spillovers in the euro area

Cristian Arcidiacono [1] University of Bern

Matthieu Bellon [2] European Stability Mechanism

Matthias Gnewuch [3] European Stability Mechanism

Abstract

Many advanced economies sell sovereign bonds at a yield below the risk-free rate plus a default risk premium, benefiting from strong demand for safe assets. The literature shows that this "convenience yield" premium diminishes with bond supply but has focused on individual economies in isolation. In this paper, we investigate how a country's convenience yield is affected by changes in another country's supply of sovereign bonds. We collect debt issuance announcements and exploit high-frequency market reactions as well as heteroskedasticity around these events to quantify spillover effects. We find robust evidence that an increase in German debt reduces convenience yields across the euro area. Spillovers to low-risk countries are nearly one-for-one while those to riskier countries are weaker. Additional evidence from France confirms this pattern. We develop a model with multiple sovereigns and heterogeneous credit risk that rationalises our findings. Distinct but equally safe bonds are close substitutes to hedge against idiosyncratic income risk in recessions, explaining large spillovers, while risky bonds are poor substitutes. Our findings highlight a new source of fiscal spillovers among sovereign yields of low-risk countries.

Keywords: Convenience yield; spillovers; EMU; government debt; high-frequency identification; heteroskedasticity

JEL codes: E62; F36; G15; H63

[1] cristian.arcidiacono@unibe.ch
[2] m.bellon@esm.europa.eu
[3] m.gnewuch@esm.europa.eu

ISSN 2443-5503
ISBN 978-92-95223-59-2
doi: 10.2852/ 3884512
EU catalog number: DW-01-24-004-EN-N

Dangerous liaisons? Debt supply and convenience yield spillovers in the euro area*

Cristian Arcidiacono† Matthieu Bellon‡ Matthias Gnewuch§

October 23, 2024

Abstract

Many advanced economies sell sovereign bonds at a yield below the risk-free rate plus a default risk premium, benefiting from strong demand for safe assets. The literature shows that this "convenience yield" premium diminishes with bond supply but has focused on individual economies in isolation. In this paper, we investigate how a country's convenience yield is affected by changes in *another* country's supply of sovereign bonds. We collect debt issuance announcements and exploit high-frequency market reactions as well as heteroskedasticity around these events to quantify spillover effects. We find robust evidence that an increase in German debt reduces convenience yields across the euro area. Spillovers to low-risk countries are nearly one-for-one while those to riskier countries are weaker. Additional evidence from France confirms this pattern. We develop a model with multiple sovereigns and heterogeneous credit risk that rationalises our findings. Distinct but equally safe bonds are close substitutes to hedge against idiosyncratic income risk in recessions, explaining large spillovers, while risky bonds are poor substitutes. Our findings highlight a new source of fiscal spillovers among sovereign yields of low-risk countries.

Keywords: Convenience Yield; Spillovers; EMU; Government Debt; High-frequency Identification; Heteroskedasticity

JEL Codes: E62; F36; G15; H63

---

*We are deeply indebted to Ricardo Reis, Giovanni Callegari, and Yerbolat Rakhmetov for their support all along. We thank Pilar Castrillo, Yasin Mimir, Gergely Hudecz, Konstantinos Theodoridis, Alessandro Missale, Cédric Tille and various seminar participants for helpful comments and discussions. The paper received the Best Paper Award at the 2024 Annual Conference of the European Capital Markets Institute (ECMI). Financial support from ECMI is gratefully acknowledged. The views expressed herein are those of the authors and should not be attributed to any of the institutions with which they are affiliated.

†University of Bern, cristian.arcidiacono@unibe.ch.

‡European Stability Mechanism, m.bellon@esm.europa.eu.

§European Stability Mechanism, m.gnewuch@esm.europa.eu.

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 referred to as the *convenience yield* in reference to the many convenience services provided to investors by these relatively safe assets (e.g., collateral usage, liquidity provision, safety, discussed in Reis (2022)).

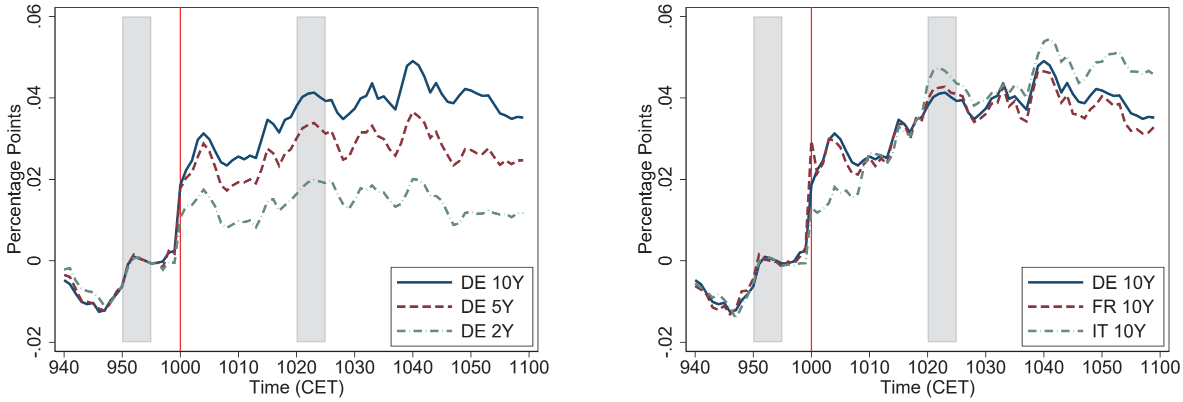
While the literature shows that the price of these convenience services declines when a country supplies more sovereign bonds (Krishnamurthy and Vissing-Jorgensen, 2012), little is known about the impact of *other countries'* bond supply. If foreign debt issuance has domestic effects on the convenience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

These new spillovers arise if investors are willing to substitute the services provided by different sovereign bonds. Substitutability might be particularly relevant in monetary unions where these bonds are equally useful as hedging instruments or collateral and their prices are driven by synchronised shocks, fundamentals, and policies.

This paper contributes to the literature by investigating spillovers between convenience yields in the euro area, both in theory and in the data. We develop a stylised model to illustrate that high substitutability across bonds arises from similar credit risk and amplifies spillover effects, i.e., the response of the domestic convenience yield to a change in the foreign convenience yield stemming from a change in foreign bond supply. To estimate these spillovers, we collect news about the supply of sovereign bonds from Germany, measure high-frequency market reactions to them, and employ event-study and heteroskedasticity-based estimators. We find that spillovers to other low-risk countries' convenience yields are close to unity, indicating a high degree of substitutability, while spillovers to riskier countries are weaker.

Figure 1 nicely illustrates both our identification strategy and our main result. On 14 December 2022, at 10:00 CET, the German debt management office 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

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



(A) Germany (B) Spillovers

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

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.

In more detail, we start by presenting a stylised two-country three-period model of convenience yields in a currency union as a conceptual framework for our analysis. We draw inspiration from the convenience yield model developed in Brunnermeier et al. (2024) and extend it by introducing two sovereign bond issuers and default risk. In the first period, an exogenous and fixed supply of bonds is sold to households. With some probability, the economy enters a recession in the second period, in which a random subset of households experiences a stronger fall in income than the rest. In the third period, if a recession has taken place, the foreign country defaults on its bonds with a positive probability. In a recession, worse-hit households sell their bonds to better-off households to mitigate their situation. Bondholders get reimbursed in period 3 from countries that do not default. 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 retraded in period 2 in recessions.

Sovereign bonds carry a convenience yield because they can be retraded at favourable prices in recessions and thereby allow households to partially insure themselves against idiosyncratic income risk. 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 retrading 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 stylised model allows us to characterise the interplay between convenience yields, sovereign bond supply, and credit default risk. We solve the model analytically in a special case and provide numerical results in the more general case. We obtain three main results.

First, the model predicts that a country earns a lower convenience yield when 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 realisation. We easily verify the negative relationship between convenience yields and default risk in the data.

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. This result highlights that changes in bond supply in the home country also affect the foreign country's convenience yield, which is the spillover effect at the core of this paper.

Third, the model allows us to investigate how the magnitude of the spillover effect varies with default risk in the receiving 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 are 0 when the receiving country is certain to default in a recession. In between these extreme cases, plausible calibrations suggest that the spillovers decline with default risk. In other words, riskier countries are less affected by supply changes in the safe country bonds.

Then, we empirically examine convenience yield spillovers in the euro area resulting from changes in the supply of debt.

The two key identification challenges are that euro area convenience yields are affected by many common shocks and that changes in bond supply are well-anticipated by investors. To overcome these, we exploit the news about debt supply contained in the German Debt

Management Office's (DMO) debt issuance plan announcements. 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 changes are entirely driven by revised expectations about German debt supply.

We employ a range of state-of-the-art techniques to estimate spillovers from German bond supply shocks to other countries' convenience yields. Convenience yields are measured 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 highlight two main findings.

First, we find that daily convenience yield spillovers from German debt supply shocks are close to unity among low-risk countries, indicated 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 high-frequency, as well as using Rigobon and Sack (2004)'s heteroskedasticity-based estimator.

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

We run a battery of robustness checks to confirm the strength of our results. 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 for 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 countries. We also find significant spillovers to

UK bond yields, while effects on US bond yields, euro area stock prices, and exchange rates are mostly insignificant.

Our results 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 discusses our contributions. Section 3 presents our model of convenience yields in a monetary union and explains the main model predictions. Section 4 presents the estimation strategy and the data used throughout the analysis. Section 5 provides an overview of our empirical results and 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 US 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 rationalise 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 rationalise 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 US Treasury demand shocks from auction results, while Phillot (2024) and Gomez Cram et al. (2024) identify US Treasury supply shocks from auction announcements and communication of the Congressional Budget Office, respectively. Lengyel (2022) identifies supply shocks for the UK 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) analyse 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 behaviour 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.

3 A Model of Convenience Yields in a Monetary Union

We build a stylised model of convenience yields to guide our empirical analysis.

3.1 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 favourable prices) even in recessions unlike other assets. As a result of their unique insurance properties, sovereign bonds carry a convenience yield premium. In turn, sovereign bonds are supplied inelastically by two countries H ("Home") and F ("Foreign") in a common currency.[1]

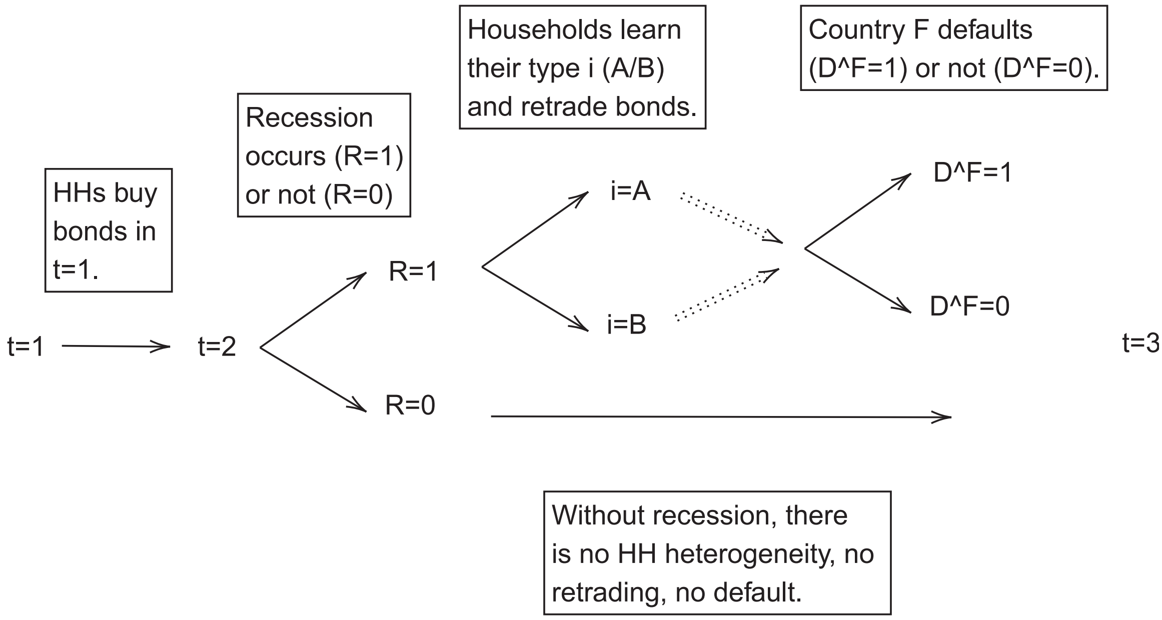
Households. Households from both countries are identical and therefore we do not distinguish between households living in H and F. Households maximise expected lifetime utility generated by consumption. They receive an exogenous income $w_{t,i}$ ("wage") in each period. The only source of household heterogeneity is income in period 2, which can be low ("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. Bonds are zero-coupon bonds and do not pay interest in period 2.

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 is identical for all households and equal to $w_{2,O}$. Figure 2 illustrates the sequence in which decisions are taken and uncertainties are resolved.

Household Optimisation. We describe the households' optimisation recursively. Households enter period 2 with bonds purchased in period 1 (b_1^H, b_1^F), which they can retrade

[1] 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).

Figure 2: Model Timing



$(db_{2,i}^H, db_{2,i}^F)$. Households of type $i = A$ or B solve

$$V_{2,i}(b_1^H, b_1^F) = \max_{\{db_{2,i}^H, db_{2,i}^F\}} u(c_{2,i}) + \beta E_2 \left[u(c_{3,i}(D^F))\right] \tag{1}$$

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

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

$$b_1^H + db_{2,i}^H \geq 0 \qquad \text{(no-short-selling constraint on H-bond)} \tag{4}$$

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

where the per-period utility function u has standard properties regarding continuity and derivatives, and where E_2 is the expectation operator based on information available in period 2. In period 2, there is retrading 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 $c = H, F$). Retrading 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).[2] At this point in time, the only uncertainty remaining is whether country F will default in period 3 or not.

We assume that bond supply is low enough such that in recessions, type-A households sell all their bonds to type-B households. In recessions, type-A households experience a steeper decline in income and want to resell their bonds to compensate for the income loss. We consider the equilibria where there is a shortage of safe assets, meaning that, in recessions, type-A households would be willing to resell 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 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 all the bargaining power belongs to sellers, meaning that the prices are such that type-B households are indifferent between buying one more or one fewer marginal unit of both bonds.[3]

Now turning our attention to period 1, households solve

$$V_1 = \max_{\{b_1^H, b_1^F\}} u(c_1) + \beta E_1 \left[V_{2,i}(b_1^H, b_1^F) \right] \tag{6}$$

$$s.t. \qquad c_1 = w_1 - p_1^H b_1^H - p_1^F b_1^F \tag{7}$$

where p_1^H and p_1^F are the equilibrium bond prices in period 1, respectively, and where E_1

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

[3] 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 that the prices that make type-A households indifferent.

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 become illiquid in recessions and that the convenience yield is the premium paid by investors for having the option of retrading such 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 no default) but cannot be sold in period 2:

$$CY_1^c = \log\left(\frac{p_1^c}{\tilde{p}_1^c}\right) \tag{8}$$

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 A.12.

3.2 Results

Our model analysis provides three main results, which are derived analytically and illustrated numerically. We solve for all variables analytically in the Appendix Section A. To derive analytically how variables vary with key parameters, we resort to the special case in which a recession happens with certainty ($P_R = 1$). Proofs are presented in the Appendix. While less realistic, this special case preserves the essential mechanisms and considerably simplifies expressions. The numerical results help build intuition and investigate the robustness of our analytical results when $P_R \leq 1$. Our illustrations use $P_R = 0.7$ but remain qualitatively unchanged for alternative parametrisations.[4]

[4]The full calibration used to produce the numerical results is: $P_R = 0.7, P_D = 0.5, P_A = 0.5, \beta = 0.99, B_1^H = B_1^F = 0.04, w_1 = w_3 = 0.3, w_{2,A} = 0.2, w_{2,B} = 0.4$.

3.2.1 Option to Retrade Bonds in a Recession Gives Rise to Convenience Yields

The convenience yields of home and foreign, derived in Appendix A, can be written as

$$CY_1^H = \log\left(\frac{(1-P_R)u'(c_{3,O}) + P_R(1-P_A)E_2\left[u'(c_{3,B})\right]\left[1+\frac{P_A}{1-P_A}\overbrace{\frac{u'(c_{2,A})}{u'(c_{2,B})}}^{\text{benefit}^H}\right]}{(1-P_R)u'(c_{3,O}) + P_R(1-P_A)E_2\left[u'(c_{3,B})\right]\left[1+\frac{P_A}{1-P_A}\underbrace{\frac{E_2\left[u'(c_{3,A})\right]}{E_2\left[u'(c_{3,B})\right]}}_{\text{cost}^H}\right]}\right) \tag{9}$$

$$CY_1^F = \log\left(\frac{(1-P_R)u'(c_{3,O}) + P_R(1-P_A)E_2\left[u'(c_{3,B})\right]\left[1+\overbrace{\frac{P_A}{1-P_A}\frac{u'(c_{2,A})}{u'(c_{2,B})}}^{\text{benefit}^F}\right](1-P_D)}{(1-P_R)u'(c_{3,O}) + P_R(1-P_A)E_2\left[u'(c_{3,B})\right]\left[1+\underbrace{\frac{P_A}{1-P_A}\frac{u'(c_{3,A(D^F=0)})}{u'(c_{3,B(D^F=0)})}}_{\text{cost}^F}\right](1-P_D)}\right) \tag{10}$$

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 realisation to the rich (type-B) income realisation 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 $CY_1^F = 0$).

3.2.2 Higher Default Risk Erodes the Convenience Yield

We investigate the role of default risk by assessing how the convenience yields depend on the probability of default of the foreign country P_D. Recall that the home country has no default risk.

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

(i) $CY_1^F < CY_1^H$ if $0 < P_D$ and $CY_1^F = CY_1^H$ 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 (1.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, both convenience yields are identical, Analytical Result (1.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.[5]

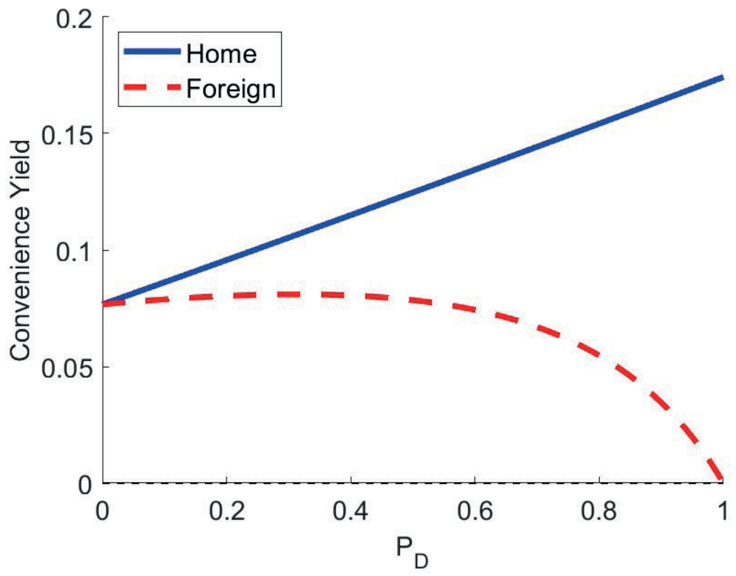
Intuition. Convenience yields reflect the value of being able to sell a bond if income is low (type A) in a recession. Bonds that trade at a higher price in a recession are therefore more valuable as insurance and earn a larger convenience yield. Default risk drives down the price of the (foreign) bond in a recession because it reduces the expected return of the (foreign) bond. In consequence, risky foreign bonds earn a smaller convenience yield than home bonds. We investigate the strength of the relationship between convenience yields and default risk in the data in Section 4.5.

Numerical Results (1). For the general case when $P_R < 1$, Figure 3 plots both countries' convenience yields as a function of the default probability of the foreign country (conditional on a recession). It confirms that the home convenience yield is systematically higher than the foreign convenience yield, except when there is no default risk and both are equal. It also shows that the difference between the two convenience yields increases with the foreign

[5]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.

default probability because the foreign bond becomes relatively less useful as insurance. 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 3: A Larger Convenience Yield for Safer Home Bonds



3.2.3 Higher Bond Supply Erodes Convenience Yields

We are ultimately interested in 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 (2). 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 Results (2.i) shows that *both* home and foreign convenience yields decrease when the supply of home bonds increases. Analytical Results (2.ii) shows the same response for an increase in the supply of foreign bonds.

Intuition. The convenience yield reflects the value of the insurance services provided by a sovereign bond and we would expect this value to decline with bond supply following the standard logic of supply and demand. The results provide sufficient conditions for this logic to apply, ensuring that an increase in bond supply increases the total amount of available insurance in a recession $(p_2^H b_1^H + p_2^F b_1^F)$, i.e., is not offset by declines in bond prices.

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.[6] Therefore, there is evidence suggesting the conditions are met.

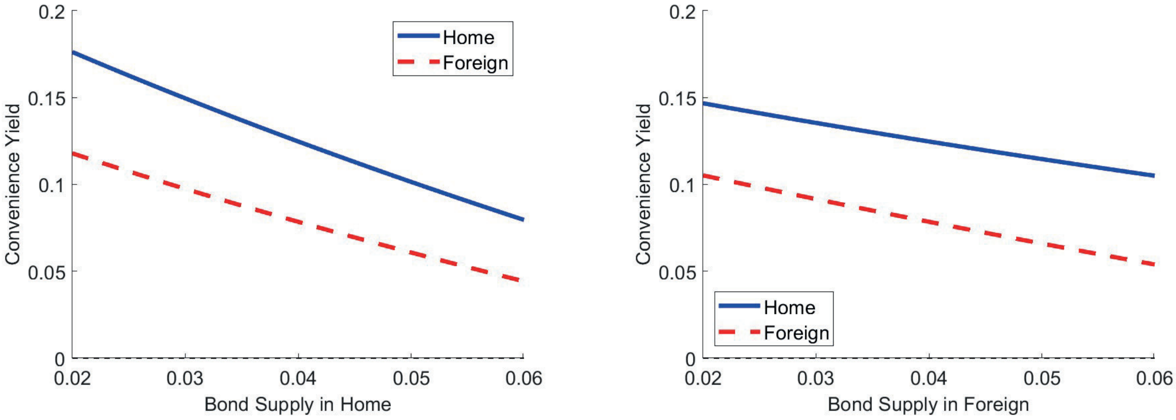
These conditions are sufficient to ensure that the value of transfers from rich to poor households (akin to insurance payouts) increases with home bond supply (and respectively with foreign bond supply).[7] In turn, greater insurance facilitated by more home bonds (or more foreign bonds) reduces the appetite for more insurance and reduces both convenience yields.

Numerical Results (2). Turning to the case when $P_R < 1$, Figure 4 supports the generality of the analytical results. Either convenience yield declines if either country issues more bonds (holding the other country's bond supply fixed).

[6] Among others, Attanasio and Weber (1995) estimates 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.

[7] We show in the Appendix that the conditions ensure that higher bond quantity is not offset by lower bond prices in period 2, thereby allowing for greater exchanges across households with different types. 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 value of retraded bonds (the value being the price times the quantity).

Figure 4: Convenience Yields Decline with Bond Supply



(a) Changing Bond Supply in *Home* (b) Changing Bond Supply in *Foreign*

3.2.4 Convenience Yield Spillovers Decrease with Default Risk Differential

Having shown that both convenience yields react to a change in bond supply in either country, our next objective is to compare the magnitude of these reactions across countries. Technically, we examine the ratio of the marginal responses of convenience yields to a marginal increase in home bond supply 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 (3). 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 characterised by strong prudence (u''' is positive and large enough).

Intuition. The extreme cases considered in Analytical Results (3.i) and (3.ii) are straightforward. When the foreign country is as safe as the home country (Analytical Result 3.i), the two bonds offer identical payoffs, their convenience yields are the same, they move one-to-one 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 3.ii), the foreign convenience yield is constant and equal to zero, because the price of the foreign in a recession is 0. Thus, there is no spillover to the foreign convenience yield.

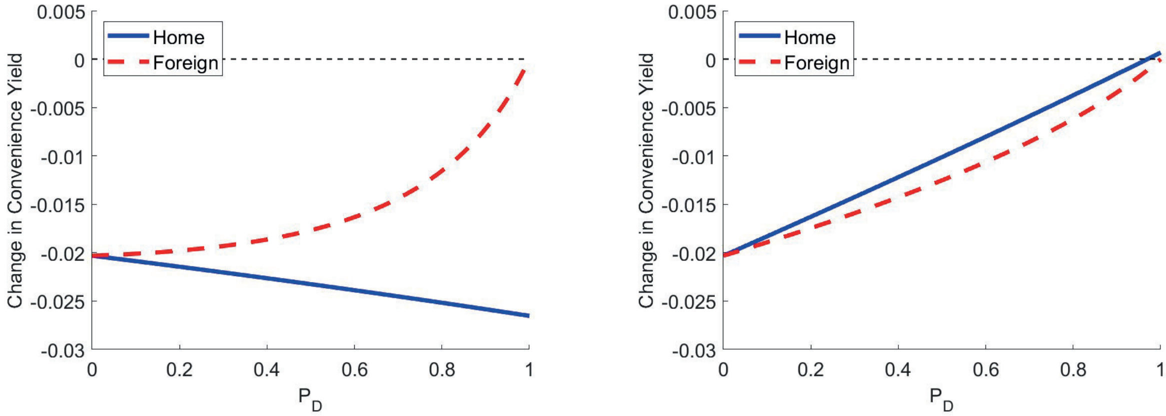
To get intuition about spillover magnitudes in between the extreme cases as considered in Analytical Result (3.iii), analytical derivations are helpful to realize that all the difference in the magnitude of the convenience yields' response comes from the *cost* component.

An increase in the probability of default makes type-B households poorer in period 3 in expectation. When the utility function is characterised 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.

Numerical Results (3). Turning to the case when $P_R < 1$, an examination of the analytical expression of convenience yields (equations 9 and 10) and Figure 3 reveal another role for default risk. 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.

Numerical results in Panel (A) of Figure 5 illustrate how both countries' convenience yields change when the supply of home bonds increases by 20%, 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. The magnitude of this change for home bonds is not substantially affected by the default risk of foreign bonds, at least in comparison with changes for the foreign country. The foreign convenience yield also falls with B_1^H, but this spillover effect very much depends on the level of default risk. Panel (A) of Figure 5 confirms that when there is no default risk, bonds are perfect substitutes and hence the spillover is 1-for-1. As default risk increases, the magnitudes of the two responses diverge and the spillover effect weakens. 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. Our empirical analysis in Section 5 quantifies the magnitude of these convenience yield spillovers.

FIGURE 5: Spillovers in Convenience Yields from Bond Supply Shocks



(A) Change in CYs (Higher B_1^H)

(B) Change in CYs (Higher B_1^F)

Numerical results also allow us to explore changes in additional variables. Figure 5, Panel (B) plots the change in both countries' convenience yields when foreign bond supply increases by 20%. Qualitatively, the effects align with the effects of an increase in the supply of home bonds. An increase in the supply of foreign bonds leads to a fall in both convenience yields, except for some very high probability of default when it increases the home convenience yield.[8] The graph also suggests that the spillover effects tend to decline with foreign bond default risk.

Figure 11 in the Appendix plots the change in both countries' convenience yields when the supply of *both* bonds increases by 20%. Both convenience yields fall, but not necessarily homogeneously.[9]

[8] This exception is a deviation from results obtained in the special case with $P_R = 1$.

[9] This aligns with the findings of Gnewuch (2022), who finds heterogeneous effects on euro area convenience yields of a relatively homogeneous debt supply shock (the ECB's PSPP).

4 Empirical Strategy

We now outline our empirical methodology. In Section 4.1, we discuss our strategy for identifying the spillover effects of changes in one country's debt supply. Sections 4.2 and 4.3 explain in more detail the measurement of debt supply shocks for Germany and France, respectively. In Section 4.4, we outline the estimation techniques that we employ to estimate spillover effects, using our identified debt supply shocks. Section 4.5 describes the data that we use to implement the analysis.

4.1 Identification of News about Debt Supply

Our main objective is to estimate how changes in the debt supply of euro area countries affect the convenience yields of other euro area countries. There are two major challenges to identifying this spillover effect.

First, convenience yields—and sovereign yields more generally—are not only exposed to debt supply shocks but also to a variety of other shocks. Therefore, the high correlation among euro area sovereign (convenience) yields, especially among countries with low sovereign risk premia (Jiang et al., 2020), does not necessarily imply large spillover effects, as it can also reflect common shocks. In line with the model presented in Section 3, common debt supply shocks (e.g., the ECB's asset purchases) as well as common income shocks affect all convenience yields simultaneously, thereby creating a positive co-movement. Conversely, changes in investors' perception of or aversion to (default) risk can lead them to reallocate their portfolios between bonds of safer and riskier countries, generating a negative convenience yield co-movement.

Second, changes in the supply of sovereign debt are usually anticipated well in advance. With financial markets that are sufficiently forward-looking, the effects of debt supply changes on sovereign yields are priced in before any actual debt issuance takes place.

To deal with these two issues, we identify and collect *news* about the country-specific supply of sovereign debt. Utilising news about debt supply allows us to cut through confounding shocks. Moreover, since this type of news contains information that is not perfectly anticipated by investors, using it resolves the foresight issue. Finally, we demonstrate that this type of news is quickly reflected in sovereign yields, both of the source country and of other receiving countries.

Our source of news about the supply of sovereign debt are official announcements of public debt management agencies (DMOs). The approach is inspired by the literature identifying monetary policy shocks from official central bank communication (e.g., Kuttner 2001; Rigobon and Sack 2004) but has also been used in the context of fiscal announcements (e.g., Phillot 2024; Ray et al. 2024). We focus on DMO announcements in Germany and France. The different institutional settings in these two countries require us to use slightly different identification strategies and we discuss each country in detail below.

4.2 German Debt Supply Shocks

The *Federal Republic of Germany - Finance Agency* (henceforth, German Finance Agency) is responsible for the German federal government's debt management, borrowing, and cash management. It publishes its annual 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.[10] Due to this institutional setup, the issuance plan publications provide an ideal setting for a high-frequency event-study analysis as commonly used to identify causal effects of monetary policy.

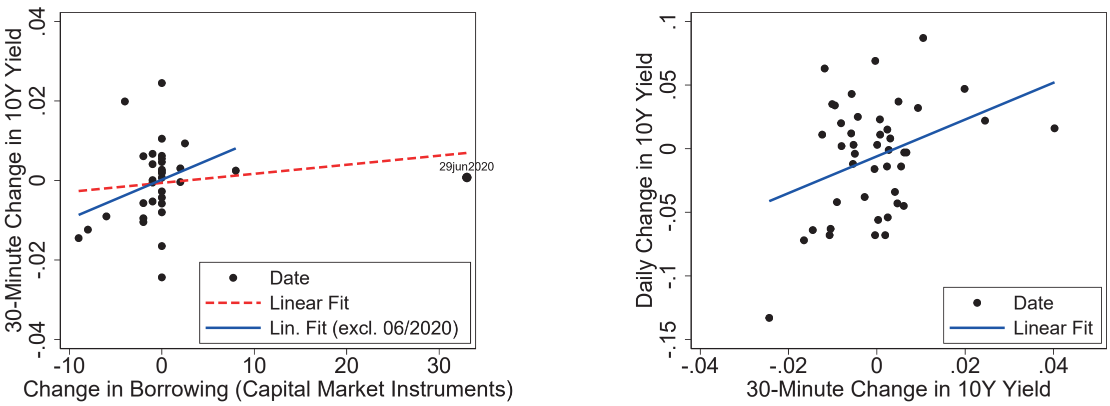
To measure the surprise component of a given publication, we compute the change in German sovereign yields in a narrow 30-minute window around the publication, which takes place at 10:00 CET. That is, we compute the change in the median yield between 10:20 CET and 10:25 CET and the median yield between 09:50 CET and 09:55 CET. Figure 1 illustrates that these publications contain information that is quickly incorporated into yields. On this occasion, yields at various maturities jumped within the first minute of the announcement. We use the yield of the 10-year benchmark bond since bonds with a longer residual maturity provide a better signal-to-noise ratio.[11]

We do not directly use the information on the quantities announced by the German Finance Agency, since we do not know what quantities investors were expecting to be announced and,

[10] For example, on December 14, 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).

[11] News about debt supply should matter for yields of all maturities, but risk-free interest rates—another driver of sovereign 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.

FIGURE 6: 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.

therefore, to what extent the announced quantities differed from expectations.[12] Nonetheless, the left panel of Figure 6 illustrates that there is a positive correlation between quantity revisions and 30-minute changes in the 10-year yield.

The shocks have a standard deviation of 1.1 basis points and are significant predictors of daily changes in German 10-year yields ($t = 2.19$), as panel (B) of Figure 6 shows. They are even better predictors of daily changes in the German 10-year convenience yield ($t = 3.55$).

4.3 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

[12]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.

final issuance plan when the budget process is concluding, typically in December. In some years, it announced 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, it is 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 well 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.

4.4 Estimation Methods

To estimate the spillover effects of debt supply shocks, we use OLS, IV, and heteroskedasticity-based estimation techniques, taking into account that convenience yield changes around DMO announcements may not only reflect news but also idiosyncratic and common noise.

We start from the following measurement equation, expressing that a change in expected debt supply will change some measure of the bond yield of the home country H:

$$\Delta Y_t^H = \Delta B_t^{S,H} + \beta^{FH} \Delta B_t^{S,F} + \eta_t^H \tag{11}$$

where $\Delta B_t^{S,H}$ is the (unobserved and normalised) debt supply shock in the home country, $\beta^{FH} \Delta B_t^{S,F}$ captures spillovers, if any, from a debt supply shock in the foreign (F) country $\Delta B_t^{S,F}$ and η_t^H is noise that is uncorrelated with the supply shocks by definition and can reflect both home-country-specific and common shocks. An analogous equation applies for the foreign country where β^{HF} is the coefficient of interest measuring the spillover effect from the home country on the yield of the foreign country.

Note that we have effectively normalised the shock to have an effect of 1 on the home yield, such that β^{HF} measures the spillover effect, i.e., the effect on the foreign yield *relative* to the domestic effect. This is necessary because we do not directly observe the change in expected debt supply and therefore cannot disentangle the domestic yield change into the change in debt (in billions) and the effect of a given change in debt on the domestic yield. Importantly, this normalisation does not interfere with our estimation of the spillover effect of a given change in the domestic yield in response to a debt supply shock.

In practice, we rearrange equation (11) and the analog equation for the foreign country to obtain our estimation system of equations:

$$\Delta Y_t^H = \beta^{FH} \Delta Y_t^F + \epsilon_t^H + \nu_t^{Common} \tag{12}$$

$$\Delta Y_t^F = \beta^{HF} \Delta Y_t^H + \epsilon_t^F + \theta \nu_t^{Common} \tag{13}$$

where each ϵ_t^i is a country-specific shock that potentially includes the country-specific supply shock $\Delta B_t^{S,i}$, and ν_t^{Common} is noise common to both countries but which potentially has heterogeneous effects ($\theta \neq 1$).

In the following, we describe three methods of estimating the coefficient of interest β^{FH} (or, β^{HF}). The first two methods require knowledge about the precise timing of the announcement and can therefore only be applied in the context of German debt supply changes.

Method 1: High-Frequency Spillovers using OLS. With a precisely timed announcement and high-frequency data, we can neglect noise, allowing us to infer the supply shock $\Delta B_t^{S,H}$ from the yield change. In our setting, we use minute data and follow the literature (Gürkaynak et al., 2004; Swanson, 2021) in focusing on a 30-minute window around the announcement. Precisely, we assume that noise and variations in other variables in a tight window around the announcement are negligible ($\eta_t^i \approx 0$ for $i = H$ and F, $\Delta B_t^{S,F} \approx 0$ and $\nu_t^{Common} \approx 0$). Under these assumptions, equation (11) simplifies to $\Delta_{30m} Y_t^H = \Delta B_t^{S,H}$.

Hence, the coefficient of interest (β_{30m}^{HF}) can be estimated using the second equation in (13) with a simple OLS regression. Under our assumptions, we can recover β_{30m}^{HF} by regressing the change in the outcome variable ($\Delta_{30m} Y_t^F$) on the change in the yield of the origin country ($\Delta_{30m} Y_t^H$).

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 shocks. Common shocks ν_t, like news about monetary policy, can bias spillover estimates because they correlate with yield changes in the origin country as well as in the destination country (i.e., ΔY_t^H and ΔY_t^F).

However, when a high-frequency measure of the shock 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 high-frequency window. To do so, we use an instrument-variable approach and estimate equation (13) by instrumenting $\Delta_{1day} Y_t^H$ with $\Delta_{30min} Y_t^H$. Under our assumptions, $\Delta_{30min} Y_t^H$ is correlated with $\Delta_{1day} Y_t^H$ but uncorrelated with ν_t.

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 large supply shocks to consistently estimate the spillover coefficient β. In our context, we assume that debt supply shocks have a higher variance 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 on all 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.

A more detailed discussion of the methodology and its implementation through an instrumental variable approach are relegated to Appendix B.

4.5 Data and Definitions

We use two main datasets, one with daily time series covering 9 major euro area sovereign bond issuers (Germany, Netherlands, Finland, France, Austria, Belgium, Italy, Spain, and Portugal) and a second one with intra-day time series for a subset of countries. In both datasets, we consider interest rates at the 5-year and 10-year maturity. When extending our results, we additionally examine daily data on EU, US, and UK bonds and the associated exchange rates, as well as daily data on the German, French, and European stock markets and euro area corporate bond indexes.

The intra-day dataset contains minute-by-minute sovereign bond yields for Germany, France, Italy, and Spain, from January 1, 2007 to December 31, 2023 that we obtained from Bloomberg.

The daily dataset contains sovereign bond yields for our 9 euro countries, euro-denominated credit default swap (CDS) rates, and Overnight Index Swap (OIS) rates for the 2009-2023 period. The bond yields and OIS data were collected from Bloomberg, while the CDS rates were obtained from two different sources: Bloomberg and Eikon. All observations are based on mid yields.

We follow the literature and use the euro OIS rates to proxy for "risk-free" rates, and the CDS rates to capture default risk premia. The OIS is a derivative contract that swaps a fixed rate in exchange for a floating rate.[13] It is bought for hedging interest rate exposure and is closely tied to investors' expectations of future short-term interest rates. Lloyd (2021) argues that liquidity premia are expected to be minimal because there is no initial cash flow, and because counterparty risk is limited since there is no exchange of principal (Feldhütter and Lando, 2008). Further, OIS trades are often collateralised and thus have minimal credit risk (Tabb and Grundfest, 2013).

The market for CDS contracts is not as liquid as the markets for sovereign debt and OIS contracts, in particular for low-risk countries. Therefore, new information may not be reflected in CDS rates as quickly as in sovereign yields and OIS rates. As a remedy, we work with data from two different sources (Bloomberg and EIKON) and exclude all episodes from our analysis when changes in CDS rates are inconsistent across the two data providers.[14]

At the daily frequency, we adopt the approach outlined in Jiang et al. (2020) and in Gnewuch

[13]We rely on OIS rates using the Euro OverNight Index Average (EONIA) as the underlying floating rate and, after October 2019, the Euro Short-Term Rates (€STR).

[14]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.

(2022) to decompose bond yields as:

$$Y_t^i = R_t + \delta_t^i - CY_t^i \tag{14}$$

where Y_t^i denotes the bond yield for country i at time t, R_t represents the risk-free rate as measured using OIS rates, δ_t^i captures the default risk premium as measured using CDS rates, and CY_t^i is the convenience yield premium. An increase in the convenience yield represents 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. This formulation applies to each available maturity.

Table 1 presents summary statistics of convenience yields, yields, and CDS rates for all countries over all the business days in our sample period. We rank countries from the largest to smallest average convenience yield. Average convenience yields range from 37 basis points for Germany to a negative value of -32 basis points for Portugal.

The comparison between average convenience yields and CDS rates aligns very well with our first theoretical result. Riskier countries, as measured by the CDS rate, have lower convenience yields. The country ranking is extremely similar—only Austria and Spain are one spot too low. Throughout, we refer to the group of countries with an average CDS rate above 1 percentage point as "risky" countries. This group includes Italy, Spain, and Portugal. The group of countries with an average CDS rate below 1 percentage point is referred to as "safe" (or "low-risk") countries.

In our analysis, we focus on the days with identified shocks to the supply of sovereign bonds. We start with 68 announcements from the German Finance Agency over 2007-2023 (four per year over this 17-year period) and 43 announcements from the French Treasury over 2007-2023. To cleanly isolate the effects of DMO announcements, we proceed by dropping announcement dates that are less than one day apart, and by dropping the four dates that coincided with major but unrelated European events.[15] We also remove all announcements with missing yield, OIS and CDS rate values for any of the 9 EU countries.

[15] We exclude the September 28, 2022 announcement from the German Finance Agency because of the heightened volatility caused by the sabotage of the Nordstream pipeline on September 26. We exclude the March 22, 2016 announcement that coincided with the Brussels terrorist attack, and the June 25, 2012 announcement that coincided with Spain's request for support from the European Stability Mechanism. We excluded the September 27, 2011 announcement that occurred as the Parliament was dissolved in Spain and as Chancellor Merkel hosted the Greek Prime Minister for a key meeting.

TABLE 1: Descriptive 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.

As a result, our baseline estimation sample for analysing spillovers covers the years 2009-2023 and focuses on 44 announcements for Germany and 22 announcements for France. As shown in Figure 10, announcement dates in the baseline sample are evenly spread across the full estimation period. We use the baseline sample throughout our analysis, thereby facilitating comparisons across methods and results. For some specific estimations, we are able to use more observations and we present robustness checks in the Appendix on larger samples, when available. For example, for the intra-day analyses, we do not need CDS rates and we also consider a sample where we reintroduce observations that were excluded because of missing or outlier CDS values.

Table 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 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.

5 Estimates of Spillover Effects

We focus on estimating spillover effects from news about changes in the supply of German debt as we can apply the strongest identification strategy in this case. The German setting allows us to implement a wide range of estimation techniques (event-study OLS estimation with minute data and IV estimation in Section 5.1; RS estimation in Section 5.2). We then examine spillovers from France, in which case we have fewer observations and where fewer estimation techniques apply (Section 5.3). Finally, we estimate spillover effects from Germany beyond the market for euro-area sovereign debt (Section 5.4).

5.1 Event-study OLS and IV Estimations with Minute Data

As we know the exact time of the German Finance Agency's announcements, we start by exploiting intra-day data on yields.

We measure German debt supply shocks as changes in the German 10-year yield in a 30-minute window around debt issuance announcements. We also observe minute variations for a few other sovereign bond yields, allowing us to estimate yield spillovers at this very high frequency. Table 3 shows that spillovers to French yields are large and statistically significant, confirming the anecdotal evidence presented in Figure 1.

A 10 basis point increase in the German yield leads to an 8.7 basis point increase in the French yield. Spillovers to Italy and Spain are also significant, but somewhat smaller.

An important limitation of the high-frequency analysis is that many outcomes 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 spillovers persist through the end of business days.

To investigate yield spillovers at the daily frequency, we instrument daily changes in the German 10-year yield with the 30-minute change around the DMO announcement. Table 4

Table 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)	(2)	(3)	(4)	(5)	(6)	(7)
	sd_{T-1}	sd_T	$sd_{T-1} = sd_T$ p-value	β_{T-1}	$\beta_{T-1} = 0$ p-value	β_T	$\beta_T = 0$ p-value
Germany							
ΔCY_{DE}	0.018	0.024	0.067	1.000	.	1.000	.
ΔCY_{NL}	0.015	0.022	0.011	0.375	0.000	0.700	0.000
ΔCY_{FI}	0.032	0.053	0.001	0.883	0.000	1.577	0.022
ΔCY_{FR}	0.021	0.027	0.091	0.694	0.002	0.918	0.000
ΔCY_{AT}	0.016	0.024	0.009	0.436	0.006	0.613	0.000
ΔCY_{BE}	0.031	0.041	0.069	0.378	0.372	0.498	0.040
ΔCY_{IT}	0.054	0.054	0.972	0.248	0.422	0.333	0.367
ΔCY_{ES}	0.043	0.049	0.384	0.688	0.004	0.526	0.192
ΔCY_{PT}	0.054	0.093	0.001	0.599	0.148	0.544	0.294
Observations	44	44	.	44	.	44	.
France							
ΔCY_{FR}	0.016	0.024	0.054	1.000	.	1.000	.
ΔCY_{DE}	0.011	0.028	0.000	0.403	0.037	0.730	0.005
ΔCY_{NL}	0.014	0.022	0.047	0.384	0.181	0.740	0.008
ΔCY_{FI}	0.020	0.029	0.099	0.694	0.010	0.676	0.012
ΔCY_{AT}	0.017	0.024	0.102	0.754	0.003	0.791	0.000
ΔCY_{BE}	0.018	0.024	0.154	0.395	0.151	0.735	0.000
ΔCY_{IT}	0.041	0.045	0.711	0.139	0.814	-0.028	0.904
ΔCY_{ES}	0.033	0.035	0.822	0.478	0.442	0.685	0.021
ΔCY_{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 France following issuance plan announcements by the French Treasury, while the second panel focuses on spillovers from Germany and its Finance Agency's issuance plan announcements. The first and second columns reports 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) reports the p-value of a significance test with robust standard errors.

displays the results, which are quite similar to the spillover estimates at the higher frequency. This indicates that the spillovers captured in 30-minute windows are also present at a lower frequency. Spillovers are very close to unity and highly statistically significant for France, the Netherlands, Austria, Belgium, and Finland. In contrast, spillovers are again weaker in

TABLE 3: Intraday Yield Spillovers - German Debt Supply Shocks

	(1) ΔY_{FR}	(2) ΔY_{IT}	(3) ΔY_{ES}
ΔY_{DE}	0.875***	0.623***	0.506**
	(0.101)	(0.213)	(0.237)
Constant	0.000	0.003	0.001
	(0.001)	(0.002)	(0.002)
Observations	44	43	39
R^2	0.800	0.199	0.199

Notes: Each column displays coefficients from a separate regression: $\Delta Y_{receiving} = \beta_0 + \beta_1 * \Delta Y_{DE} + \epsilon$. Standard errors are reported in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

magnitude and not significantly different from zero for Italy, Spain, and Portugal. While using raw yields rather than convenience yields, these findings align well with our third theoretical result, predicting that spillovers between safe issuers are (close to) one-to-one and that spillovers are smaller between a safe and riskier country.

TABLE 4: Daily Yield Spillovers - German Debt Supply Shocks

	(1) ΔY_{FR}	(2) ΔY_{NL}	(3) ΔY_{FI}	(4) ΔY_{AT}	(5) ΔY_{BE}	(6) ΔY_{IT}	(7) ΔY_{ES}	(8) ΔY_{PT}
ΔY_{DE}	0.989***	0.984***	1.088***	1.034***	1.175***	0.529	0.557	0.883
	(0.116)	(0.072)	(0.090)	(0.112)	(0.288)	(0.474)	(0.373)	(0.650)
Cons.	0.004	0.001	0.003	0.002	0.006	0.015*	0.009	0.016
	(0.003)	(0.002)	(0.002)	(0.003)	(0.006)	(0.008)	(0.008)	(0.012)
Obs.	44	44	44	44	44	44	44	44
R^2	0.830	0.958	0.938	0.849	0.470	0.288	0.335	0.150

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

Our theory is centred on convenience yields rather than on simple yields and we now move to the study of convenience yield spillovers. This removes the effects of confounding common shocks, such as to risk-free interest rates.

Table 5 shows our estimated convenience yield spillovers, where we instrument daily changes in the German convenience yield with the 30-minute yield change. We again estimate spillovers to France, the Netherlands, Austria, Belgium, and Finland to be close to unity and statistically significant. Spillovers to Italy, Spain, and Portugal remain statistically insignificant.

Comparing the results in Table 5 and Table 2 highlights the importance of our identification strategy. Column 4 in Table 2 shows estimates of the unconditional correlations between country convenience yields and the German convenience yield on 'normal' days without salient bond supply shocks. Correlations are low and largely insignificant. In contrast, our empirical strategy based on the identification of arguably exogenous supply shocks, results in higher and more significant conditional correlations.

Table 5: Daily Convenience Yield Spillovers - German Debt Supply Shocks

	(1) ΔCY_{FR}	(2) ΔCY_{NL}	(3) ΔCY_{FI}	(4) ΔCY_{AT}	(5) ΔCY_{BE}	(6) ΔCY_{IT}	(7) ΔCY_{ES}	(8) ΔCY_{PT}
ΔCY_{DE}	0.917***	0.972***	1.193***	0.674***	1.140**	0.795	-0.429	1.617
	(0.233)	(0.254)	(0.210)	(0.239)	(0.559)	(0.851)	(0.905)	(1.045)
Constant	-0.002	0.004	-0.003	-0.002	-0.002	-0.007	-0.013	-0.007
	(0.002)	(0.006)	(0.003)	(0.003)	(0.006)	(0.008)	(0.008)	(0.014)
Observations	44	44	44	44	44	44	44	44
R^2	0.525	0.423	0.585	0.372	.	.	.	.

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

In Appendix B.1, we provide a number of robustness checks, which confirm our main results (Table 5). Table 11 shows results when using bonds and swaps with a maturity of 5 years instead of 10 years, Table 12 shows results when we use CDS data from EIKON instead of Bloomberg, and Table 13 shows results when we relax our approach for excluding outliers. In all cases, we confirm that spillovers are significant and close to unity for low-risk countries (France, Netherlands, Finland, Austria, Belgium), but mostly weaker and insignificant to riskier countries (Italy, Spain, Portugal).

5.2 Heteroskedasticity-based Estimation

Our final empirical approach to estimating spillover effects draws on the RS estimator. This estimator exploits the higher variance of convenience yields, caused by bond supply shocks, in comparison to a set of dates without such shocks.

Estimates of spillover from Germany using the RS estimator are shown in Table 6. We also consider alternative implementations of this estimator in the appendix (Table 14 uses a smaller sample with a stricter exclusion rule for outliers and Tables 15-16 show results with alternative 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 14 and significant coefficient estimates are very consistent across alternative implementations.

In all cases, spillovers to safer countries like France, the Netherlands, Finland, Austria, and Belgium are close to one. They are less precisely estimated than with high-frequency data and OLS and IV methods, but they are still mostly significant. One exception is the spillover to the Netherlands, as estimates can be very large in some implementations but also very imprecise (and statistically not different from one). Compared with results in the previous section, the difference between the spillover estimates across methods is statistically insignificant given the imprecision of the RS estimates. Additionally, spillover estimates continue to be systematically insignificant for Italy, Spain, and Portugal.

TABLE 6: Convenience yield spillovers from German supply shocks using the RS estimator

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	ΔCY_{FR}	ΔCY_{NL}	ΔCY_{FI}	ΔCY_{AT}	ΔCY_{BE}	ΔCY_{IT}	ΔCY_{ES}	ΔCY_{PT}
ΔCY_{DE}	0.932***	2.872*	1.090***	1.326**	0.888	0.541	-0.301	0.082
	(0.291)	(1.604)	(0.375)	(0.525)	(1.028)	(0.998)	(1.199)	(1.325)
Constant	-0.004*	-0.008	-0.002	-0.004	-0.005	-0.010	0.002	-0.008
	(0.002)	(0.007)	(0.003)	(0.003)	(0.005)	(0.006)	(0.007)	(0.010)
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: This table report coefficient estimates of equation $\Delta CY_{receiving} = \alpha + \beta \Delta CY_{DE} + \varepsilon$ using the RS estimator described in Section 4.4. Each column corresponds to a different receiving 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 origin and receiving 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 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.*

5.3 Spillover Effects from Debt Supply Shocks in Other Countries.

Turning our attention to France, the institutional setting only allows us to estimate spillovers at the daily frequency. We 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 that are based on intra-day data.

Table 7 presents spillover estimates from France to other euro area countries. The results are strikingly similar to those for Germany. We find a spillover effect from France to Germany which is very close to unity and highly significant. Spillovers to the Netherlands, Finland, Austria, and Belgium are also close to unity. In addition, spillovers to Italy and Spain are smaller and not or only barely significant. They are extremely imprecisely estimated for Portugal and insignificant.

TABLE 7: Convenience yield spillovers from French supply shocks using the RS estimator

	(1) ΔCY_{DE}	(2) ΔCY_{NL}	(3) ΔCY_{FI}	(4) ΔCY_{AT}	(5) ΔCY_{BE}	(6) ΔCY_{IT}	(7) ΔCY_{ES}	(8) ΔCY_{PT}
ΔCY_{FR}	1.259***	0.852**	0.772*	0.906***	0.949***	-0.192	0.735	1.664
	(0.388)	(0.350)	(0.430)	(0.272)	(0.307)	(0.542)	(0.636)	(4.142)
Constant	0.001	0.002	-0.001	-0.001	-0.001	0.003	0.003	0.017
	(0.003)	(0.002)	(0.002)	(0.002)	(0.002)	(0.006)	(0.005)	(0.018)
N	44	44	44	44	44	44	44	44
Weak IV	4.576	5.131	3.926	3.950	4.848	3.969	3.991	7.614
Overid.	0.235	0.755	0.482	0.455	0.743	0.830	0.793	0.236

*Notes: This table report coefficient estimates of equation $\Delta CY_{receiving} = \alpha + \beta \Delta CY_{FR} + \varepsilon$ using the RS estimator described in Section 4.4. Each column corresponds to a different receiving 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 receiving 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 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.*

We perform a large number of robustness checks that confirm the strength of our results for France. As in the case of German spillovers, we consider estimates based on a smaller sample with a stricter exclusion rule for outliers (Table 17), alternative implementations of the heteroskedasticity-based estimator (Tables 18-19), and results for 5-year instead of 10-year yields (Table 20) in the appendix.

In Appendix B.2, we also discuss spillovers from Italy, which are more challenging to estimate than those from Germany or France. While we apply a similar approach, Italy's institutional setting offers investors a more limited information set, and the analysis is further complicated by debt issuance announcements that occur when markets are closed. This precludes using high-frequency identification and complicates the usage of the RS estimator.

5.4 Spillovers from Germany Beyond Euro Area Sovereign Bonds

We have established that changes in the supply of euro area sovereign bonds have sizeable spillover effects on the yields of other euro area sovereign bonds. These large effects are plausible in view of the fact that euro area sovereign bonds share many characteristics. We now investigate spillover effects to other assets that are also potential substitutes for euro area sovereign bonds but differ with respect to certain 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 lack the status of sovereign bonds. Second, we study spillovers to German, French, and European stocks, which are also euro-denominated, but an entirely different asset class. Finally, we study yields of highly-rated non-euro sovereign issuers to investigate the role of the currency.

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, confirming our hypothesis that these bonds are close substitutes. Spillovers to euro area investment-grade corporate bonds are also highly significant and close to unity (Table 8).[16] This supports the idea that also highly-rated corporate bonds are close substitutes for highly-rated government bonds, despite lacking the sovereign-issuer status.

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 indices, confirming 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

[16] For the results in Table 8, 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.

Table 8: Daily Spillovers to Other Euro Area Variables

	(1) ΔY_{EU}	(2) ΔAAA	(3) ΔAA	(4) ΔA	(5) ΔBBB	(6) ΔDAX	(7) ΔCAC40	(8) ΔStoxx50
ΔY_{DE}	0.801***	0.909***	1.045***	1.071***	1.107***	0.029	0.026	0.025
	(0.116)	(0.178)	(0.168)	(0.214)	(0.283)	(0.057)	(0.068)	(0.068)
Constant	0.001	0.003	0.005	0.007*	0.010*	-0.001	-0.001	-0.001
	(0.002)	(0.003)	(0.003)	(0.004)	(0.006)	(0.001)	(0.002)	(0.002)
Observations	38	44	44	44	44	44	44	44
R^2	0.860	0.810	0.774	0.686	0.496	0.066	0.059	0.056

Notes: Each column displays coefficients from a separate regression: $\Delta Y_{EU} = \beta_0 + \beta_1 * \Delta Y_{DE} + \epsilon$ for column (1); $\Delta Corporate\ Yield\ Index = \beta_0 + \beta_1 * \Delta Y_{DE} + \epsilon$ for columns (2) - (5); $\Delta log(StockIndex) = \beta_0 + \beta_1 * \Delta Y_{DE} + \epsilon$ 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. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

and higher supply of bonds which serve as a hedge against risk.[17]

Spillovers to Non-Euro-Area Sovereign Bonds. Table 9 shows that there are also spillovers to sovereign bond yields outside the euro area. For the US 10-year yield, the effect is insignificant while for the UK 10-year yield, the effect is close to unity and highly significant, suggesting that UK bonds are highly substitutable with safe euro area bonds, despite the different currency. To the extent that changes in interest rates are less than one-for-one, the uncovered interest rate parity (UIP) predicts an appreciation of the euro vis-à-vis other currencies, following an increase in the supply of German bonds. In line with the UIP, we observe an appreciation, albeit insignificant, of the euro vis-à-vis the US dollar. The appreciation of the euro against the British pound is smaller and also insignificant.[18]

6 Conclusion

We build 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

[17] With intraday data, spillovers to stock prices remain insignificant. See Table 10 in the Appendix.

[18] In Table 10 in the Appendix, we confirm the results for the US 10-year yield and the US dollar using intraday data. For the UK, the coefficient for the yield spillover is lower (but still highly significant) and the coefficient on the pound is positive and significant, as predicted by UIP condition.

Table 9: Daily Spillovers Beyond Euro Area Sovereign Bonds

	(1) ΔY_{US}	(2) ΔY_{GB}	(3) ΔUSD	(4) ΔGBP
ΔY_{DE}	0.460	1.033***	0.052	0.039
	(0.369)	(0.276)	(0.033)	(0.030)
Constant	-0.008	0.000	0.000	0.001
	(0.006)	(0.004)	(0.001)	(0.001)
Observations	44	44	44	44
R^2	0.207	0.706	0.149	.

Notes: Each column displays coefficients from a separate regression: $\Delta Y_{receiving} = \beta_0 + \beta_1 * \Delta Y_{DE} + \epsilon$ for columns (1) and (2); $\Delta log(ExchangeRate) = \beta_0 + \beta_1 * \Delta Y_{DE} + \epsilon$ for columns (3) - (4), where the daily change in the German yield is instrumented with the 30-minute change. Standard errors are reported in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

safe country, and (iii) a spillover effect that declines with the default risk of the receiving country.

We examine empirically the relationships between convenience yields across countries predicted by our model. We do so by building a novel dataset that comprises debt supply shocks in Germany, identified using announcements of annual bond issuance plans made by the German DMO as well as minute and daily data on bond (convenience) yields.

We employ a number of estimation techniques, ranging from high-frequency event-study methods (*à la* Gürkaynak et al., 2004) to the heteroskedasticity-based estimator of Rigobon (2003). Our findings align well with the model's predictions as 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 insignificant. We confirm our results by estimating spillovers originating from France.

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 internalised 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 harmonised debt management strategies within the euro area.

References

Alpanda, S. and S. Kabaca (2020). International spillovers of large-scale asset purchases. *Journal of the European Economic Association 18*(1), 342–391.

Antonakakis, N. and K. Vergos (2013). Sovereign bond yield spillovers in the euro zone during the financial and debt crisis. *Journal of International Financial Markets, Institutions and Money 26*, 258–272.

Arai, N. (2017). The effects of monetary policy announcements at the zero lower bound. *International Journal of Central Banking 13*(2), 159–196.

Attanasio, O. P. and G. Weber (1995). Is consumption growth consistent with intertemporal optimization? evidence from the consumer expenditure survey. *Journal of political Economy 103*(6), 1121–1157.

Brunnermeier, M., S. Merkel, and Y. Sannikov (2024). Safe assets. *Journal of Political Economy forthcoming*.

Burriel, P., M. Delgado-Téllez, I. Kataryniuk, and J. J. Pérez (2024). Estimating the contribution of macroeconomic factors to sovereign bond spreads in the euro area.

Caporale, G. M. and A. Girardi (2013). Fiscal spillovers in the euro area. *Journal of International Money and Finance 38*, 84–e1.

Chetty, R. (2006). A new method of estimating risk aversion. *American Economic Review 96*(5), 1821–1834.

Ehrmann, M. and M. Fratzscher (2017). Euro area government bonds–fragmentation and contagion during the sovereign debt crisis. *Journal of International Money and Finance 70*, 26–44.

Farhi, E. and M. Maggiori (2018). A model of the international monetary system. *The Quarterly Journal of Economics 133*(1), 295–355.

Feldhütter, P. and D. Lando (2008). Decomposing swap spreads. *Journal of Financial Economics 88*(2), 375–405.

Galariotis, E. C., P. Makrichoriti, and S. Spyrou (2016). Sovereign cds spread determinants and spill-over effects during financial crisis: A panel var approach. *Journal of Financial Stability 26*, 62–77.

Gnewuch, M. (2022). Spillover effects of sovereign debt-based quantitative easing in the euro area. *European Economic Review 145*, 104133.

Gomez Cram, R., H. Kung, and H. N. Lustig (2024). Can us treasury markets add and subtract? *Available at SSRN*.

Gürkaynak, R. S., B. Sack, and E. T. Swanson (2004). Do actions speak louder than words? the response of asset prices to monetary policy actions and statements. *Finance and economics discussion series 2004*(66), 1–43.

Jiang, Z., H. N. Lustig, S. Van Nieuwerburgh, and M. Z. Xiaolan (2020). Bond convenience yields in the eurozone currency union. *Columbia Business School Research Paper Forthcoming*.

Kaldorf, M. and J. Röttger (2023). Convenient but risky government bonds.

Krishnamurthy, A. and A. Vissing-Jorgensen (2012). The aggregate demand for treasury debt. *Journal of Political Economy 120*(2), 233–267.

Kuttner, K. N. (2001). Monetary policy surprises and interest rates: Evidence from the fed funds futures market. *Journal of monetary economics 47*(3), 523–544.

Lengyel, A. (2022). Treasury supply shocks and the term structure of interest rates in the uk.

Lengyel, A. and M. Giuliodori (2021). Demand shocks for public debt in the eurozone. *Journal of Money, Credit and Banking 54*(7), 1997–2028.

Lloyd, S. P. (2021). Overnight indexed swap-implied interest rate expectations. *Finance Research Letters 38*, 101430.

Mian, A. R., L. Straub, and A. Sufi (2022). A goldilocks theory of fiscal deficits. Technical report, National Bureau of Economic Research.

Nagel, S. (2016). The liquidity premium of near-money assets. *The Quarterly Journal of Economics 131*(4), 1927–1971.

Phillot, M. (2024). U.s. treasury auctions: A high frequency identification of supply shocks. *American Economic Journal: Macroeconomics*.

Ray, W., M. Droste, and Y. Gorodnichenko (2024). Unbundling quantitative easing: Taking a cue from treasury auctions. *Journal of Political Economy*.

Reis, R. (2022). Debt revenue and the sustainability of public debt. *Journal of Economic Perspectives 36*(4), 103–124.

Rigobon, R. (2003). Identification through heteroskedasticity. *Review of Economics and Statistics 85*(4), 777–792.

Rigobon, R. and B. Sack (2004). The impact of monetary policy on asset prices. *Journal of monetary economics 51*(8), 1553–1575.

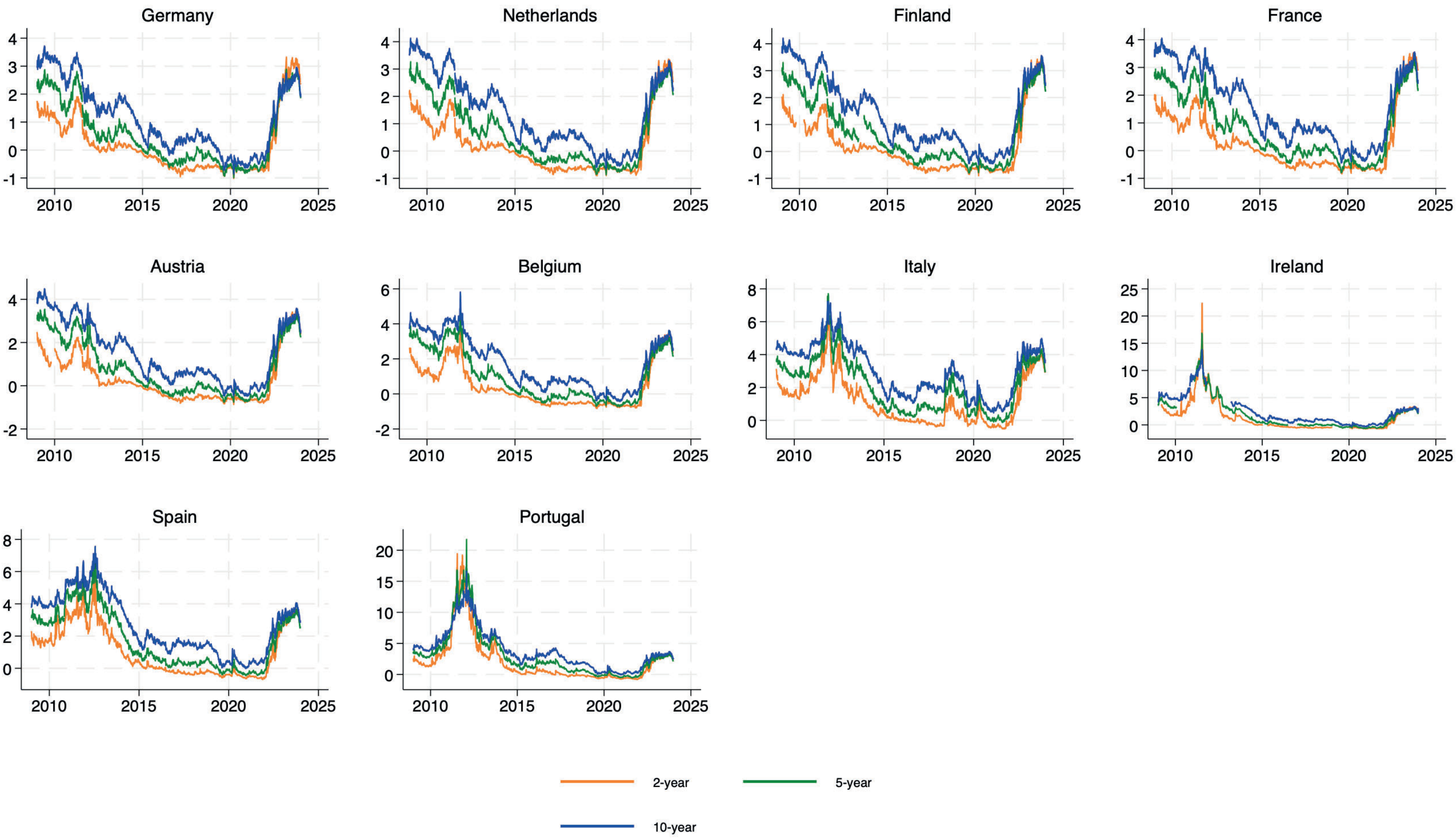
Swanson, E. T. (2021). Measuring the effects of federal reserve forward guidance and asset purchases on financial markets. *Journal of Monetary Economics 118*, 32–53.

Tabb, R. and J. Grundfest (2013, 07). Alternatives to LIBOR. *Capital Markets Law Journal 8*(3), 229–260.

Umar, Z., Y. Riaz, and A. Zaremba (2021). Spillover and risk transmission in the components of the term structure of eurozone yield curve. *Applied Economics 53*(18), 2141–2157.

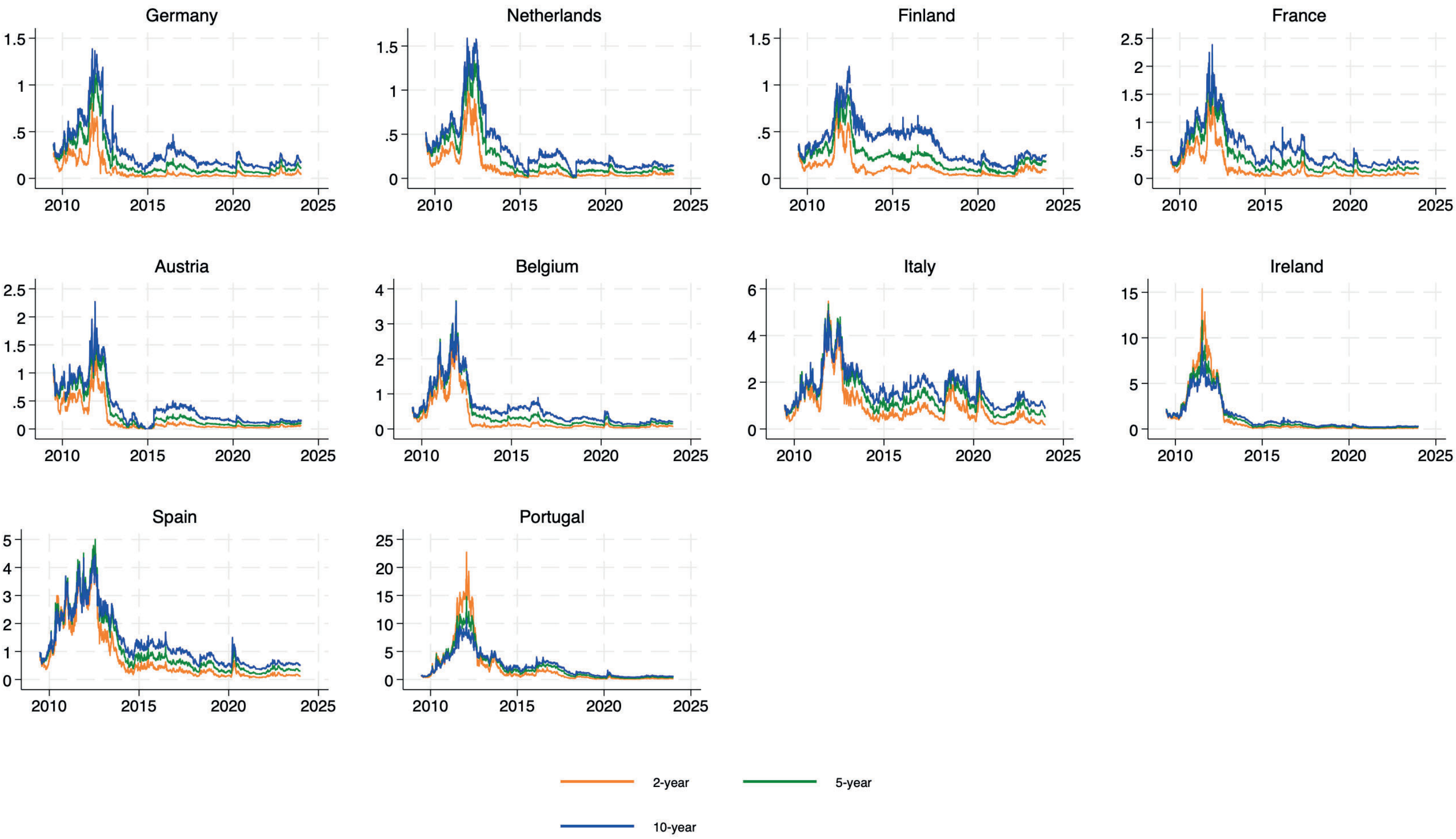
Summary Statistics and Graphs

Figure 7: The Time Series of Yields



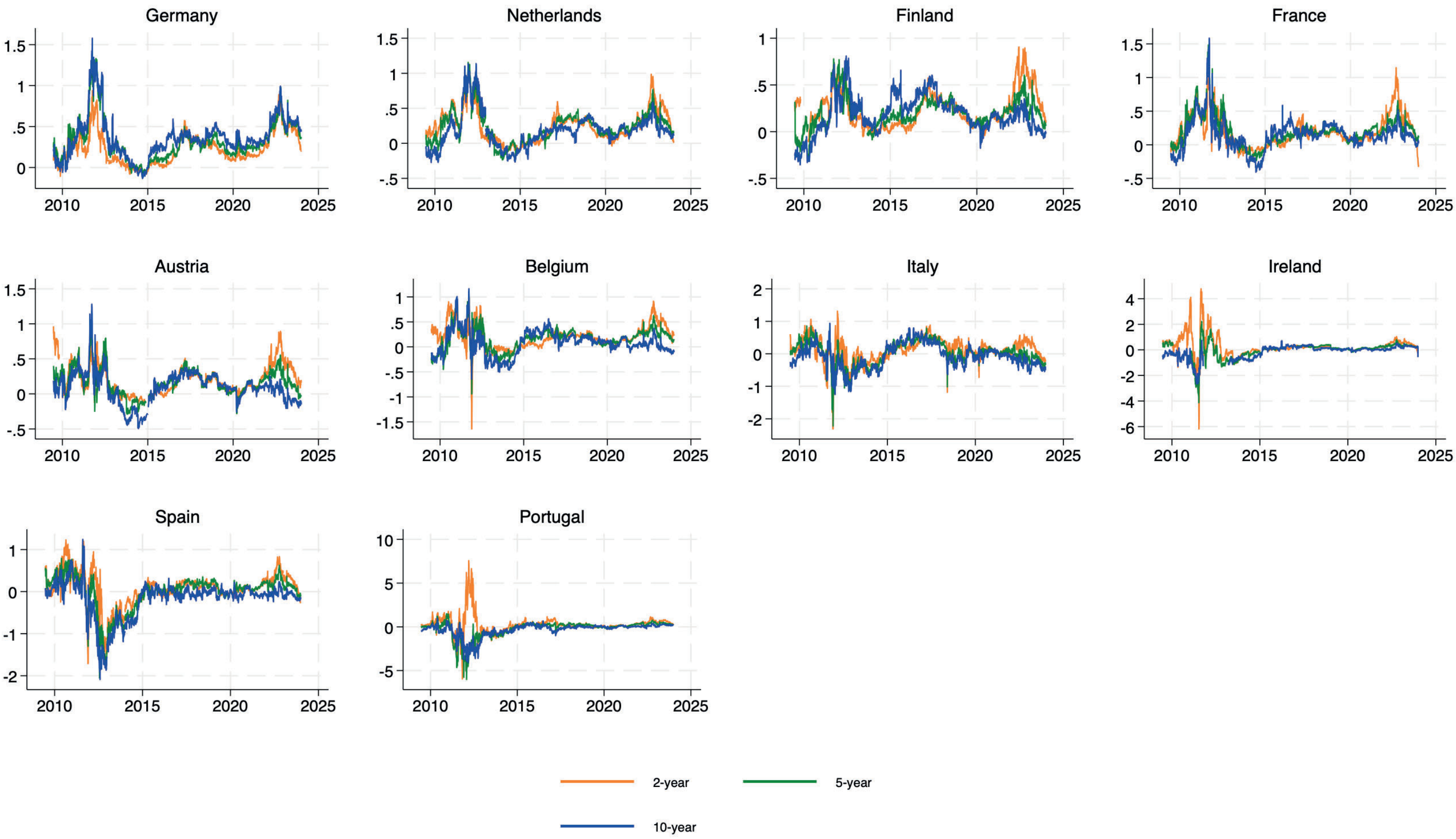
Note: Sovereign bond yields for the Eurozone countries in our sample; various tenors. The yields are in percentage points.

Figure 8: The Time Series of CDS Spread



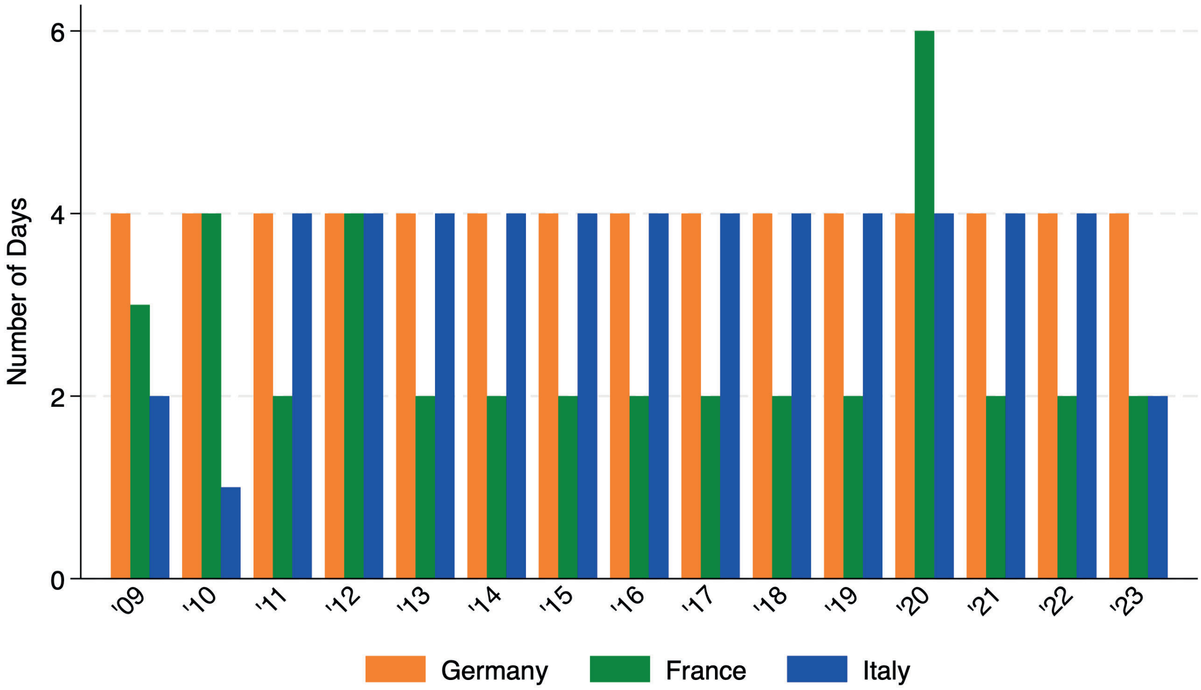
Note: The CDS spreads are in percentage points.

Figure 9: The Time Series of Convenience Yields



Note: The convenience yields are in percentage points.

Figure 10: Distribution of Policy Dates by Country and Year



A Theory Appendix

A.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:

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

A.2 Period 2 With a Recession

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

$$\begin{aligned} & V_{2,i}(b^H_1, b^F_1) = \\ & \quad \max_{\{c_{2,i}, db^H_{2,i}, db^F_{2,i}\}} u(c_{2,i}) + \beta\left[P_D u(w_3 + b^H_1 + db^H_{2,i}) + (1-P_D)u(w_3 + b^H_1 + db^H_{2,i} + b^F_1 + db^F_{2,i})\right] \\ & \qquad s.t. \quad c_{2,i} = w_{2,i} - p^H_2 db^H_{2,i} - p^F_2 db^F_{2,i} \\ & \qquad\qquad\; b^H_1 + db^H_{2,i} \geq 0 \qquad \text{(no-short-selling constraint on H-bond)} \\ & \qquad\qquad\; b^F_1 + db^F_{2,i} \geq 0 \qquad \text{(no-short-selling constraint on F-bond)} \end{aligned}$$

The three first order conditions for the choice variables are

$$\begin{aligned} u'(c_{2,i}) - \lambda_{2,i} &= 0 \\ \beta\left[P_D u'(w_3 + b^H_1 + db^H_{2,i}) + (1-P_D)u'(w_3 + b^H_1 + db^H_{2,i} + b^F_1 + db^F_{2,i})\right] - \lambda_{2,i}p^H_2 + \mu^H_{2,i} &= 0 \\ \beta(1-P_D)u'(w_3 + b^H_1 + db^H_{2,i} + b^F_1 + db^F_{2,i}) - \lambda_{2,i}p^F_2 + \mu^F_{2,i} &= 0 \end{aligned}$$

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

$$\begin{aligned} 0 &= \lambda_{2,i}\left(c_{2,i} - w_{2,i} - p^H_2 db^H_{2,i} - p^F_2 db^F_{2,i}\right) \\ 0 &= \mu^H_{2,i}\left(b^H_1 + db^H_{2,i}\right) \\ 0 &= \mu^F_{2,i}\left(b^F_1 + db^F_{2,i}\right) \end{aligned}$$

Type-A households' income declines more strongly to the point that they wish to resell some of their bond holdings. We assume that the quantity of bonds issued in period 1 was low, to the point that type-A households sell all their holdings, meaning $P_A db^H_{2,A} = -P_A b^H_1 = -(1-P_A)db^H_{2,B}$ and $P_A db^F_{2,A} = -P_A b^F_1 = -(1+P_A)db^F_{2,B}$. In other words, bonds were rationed, type-A households would have want to hold more and are now constrained in period 2 by the no-short-selling assumption. Having solved for re-traded quantities, we solve for consumption:

$$c_{2,A} = w_{2,A} + p^H_2 b^H_1 + p^F_2 b^F_1$$
$$c_{2,B} = w_{2,B} - \frac{P_A}{(1-P_A)}(p^H_2 b^H_1 + p^F_2 b^F_1)$$

A.3 Bond Prices in a Recession

We presently consider the case where bond prices are such that type-A households are at the point where they do not want to sell any more bonds, or equivalently, when the short-selling constraint is not strictly binding. Let us denote such prices $p^Z_{2,A}$ and $p^F_{2,A}$. In this case, the associated Lagrange multipliers are null ($\mu^H_{2,A} = \mu^F_{2,A} = 0$). Furthermore, type-A households' first order conditions simplify to

$$u'(w_{2,A} + p^H_2 b^H_1 + p^F_2 b^F_1) = \lambda_{2,A}$$
$$\beta u'(w_3) = \lambda_{2,A} p^H_2$$
$$\beta(1-P_D)u'(w_3) = \lambda_{2,A} p^F_2$$

and we obtain

$$p^H_{2,A} = \frac{\beta u'(w_3)}{u'(w_{2,A} + p^H_{2,A}[b^H_1 + (1-P_D)b^F_1])} \quad (15)$$
$$p^F_{2,A} = p^H_{2,A}(1-P_D) \quad (16)$$

where $p^H_{2,A}$ is implicitly defined by equation 15.

Alternatively, we consider the case where bond prices are such that type-B households are at the point where they do not want to buy any more bonds. Let us denote such prices $p^H_{2,B}$ and $p^F_{2,B}$. 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

$$u'\left(w_{2,B} - \frac{P_A}{(1-P_A)}(p_2^H b_1^H + p_2^F b_1^F)\right) = \lambda_{2,B}$$
$$\beta\left[P_D u'\left(w_3 + \left(1 + \frac{P_A}{(1-P_A)}\right) b_1^H\right) + (1-P_D)u'\left(w_3 + \left(1 + \frac{P_A}{(1-P_A)}\right)(b_1^H + b_1^F)\right)\right] = \lambda_{2,B} p_2^H$$
$$\beta(1-P_D)u'\left(w_3 + \left(1 + \frac{P_A}{(1-P_A)}\right)(b_1^H + b_1^F)\right) = \lambda_{2,B} p_2^F$$

and we obtain

$$p_{2,B}^H = \frac{\beta\left[P_D u'\left(w_3 + \frac{1}{(1-P_A)} b_1^H\right) + (1-P_D)u'\left(w_3 + \frac{1}{(1-P_A)}(b_1^H + b_1^F)\right)\right]}{u'\left(w_{2,B} - \frac{P_A}{(1-P_A)}(p_{2,B}^H b_1^H + p_{2,B}^F b_1^F)\right)} \tag{17}$$

$$\begin{aligned} p_{2,B}^F &= p_{2,B}^H \frac{(1-P_D)u'\left(w_3 + \frac{1}{(1-P_A)}(b_1^H + b_1^F)\right)}{P_D u'\left(w_3 + \frac{1}{(1-P_A)} b_1^H\right) + (1-P_D)u'\left(w_3 + \frac{1}{(1-P_A)}(b_1^H + b_1^F)\right)} \\ &= \frac{\beta(1-P_D)u'\left(w_3 + \frac{1}{(1-P_A)}(b_1^H + b_1^F)\right)}{u'\left(w_{2,B} - \frac{P_A}{(1-P_A)}(p_{2,B}^H b_1^H + p_{2,B}^F b_1^F)\right)} \end{aligned} \tag{18}$$

where $p_{2,B}^H$ is implicitly defined by equation 17. After substituting $p_{2,B}^F$ for $p_{2,B}^H$ using 18, we observe that the right-hand side of equation 17 is strictly positive and decreasing in $p_{2,B}^H$, while the left-hand side increases linearly from 0 to infinity. Therefore, this equation has a unique solution. Consequently, equation 17 also determines a unique price $p_{2,B}^F$. The foreign-to home-price ratio is hence equal to the type-B households' marginal utility in the state with default over the their marginal utility in the state without default.

For reasons that will be obvious later, let's introduce $e_2(b_1^H, b_1^F) = p_{2,B}^H b_1^H + p_{2,B}^F b_1^F$ which captures the value exchanged between type-A and type-B households in a recession. Rearranging the above expressions, we get

$$\begin{aligned} &\frac{1}{\beta} e_2(b_1^H, b_1^F) u'\left(w_{2,B} - \frac{P_A}{(1-P_A)} e_2(b_1^H, b_1^F)\right) = \\ &\quad \left[P_D u'\left(w_3 + \frac{b_1^H}{(1-P_A)}\right) + (1-P_D)u'\left(w_3 + \frac{b_1^H + b_1^F}{(1-P_A)}\right)\right] b_1^H + (1-P_D)u'\left(w_3 + \frac{b_1^H + b_1^F}{(1-P_A)}\right) b_1^F \end{aligned} \tag{19}$$

The left-hand side is increasing in e. The derivatives of the right-hand side with respect to respectively b_1^H and b_1^F are

$$P_D u'(c_{3,B}(1)) \left[\frac{\frac{b_1^H}{(1-P_A)}}{w_3 + \frac{b_1^H}{(1-P_A)}} \frac{c_{3,B}(1)u''(c_{3,B}(1))}{u'(c_{3,B}(1))} + 1 \right] + (1-P_D)u'(c_{3,B}(0)) \left[\frac{\frac{(b_1^H+b_1^F)}{(1-P_A)}}{w_3 + \frac{(b_1^H+b_1^F)}{(1-P_A)}} \frac{c_{3,B}(0)u''(c_{3,B}(0))}{u'(c_{3,B}(0))} + 1 \right]$$

and

$$(1-P_D)u'(c_{3,B}(0)) \left[\frac{\frac{(b_1^H+b_1^F)}{(1-P_A)}}{w_3 + \frac{(b_1^H+b_1^F)}{(1-P_A)}} \frac{c_{3,B}(0)u''(c_{3,B}(0))}{u'(c_{3,B}(0))} + 1 \right]$$

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

As a result we have that $\frac{\partial e_2(b_1^H, b_1^F)}{\partial b_1^H} > 0$ and $\frac{\partial e_2(b_1^H, b_1^F)}{\partial b_1^F} > 0$ 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 $\frac{b_1^H}{(1-P_A)w_3+b_1^H} \frac{c_{3,B}(1)u''(c_{3,B}(1))}{u'(c_{3,B}(1))} > -1$. 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_2^H and p_2^F are undetermined because we are in the case of a corner solution. 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 our corner equilibrium. On the other hand, type-B households are constrained from buying more bonds at the going prices (the supply constraints hold with equality) and any prices $p_2^H \leq p_{2,B}^H$ and $p_2^F \leq p_{2,B}^F$ would be consistent with our corner equilibrium. To recap, the equilibrium prices (p_2^H, p_2^F) are such that $p_{2,A}^H \leq p_2^H \leq p_{2,B}^H$ and $p_{2,A}^F \leq p_2^F \leq p_{2,B}^F$.

In what follows, we assume that sellers have all the bargaining power in all markets. This means that type-B households are able to sell at the highest possible prices, at $p_2^H = p_{2,B}^H$ and $p_2^F = p_{2,B}^F$.

A.4 Period 1

After unpacking some notations, households solve

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

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 do 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 resell in period 2 any additional unit of bonds bought in period 1.

The first order conditions with respect to b_1^H is

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

and we have a similar one for b_1^F

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

A.5 Non Re-Tradable Bond Prices and Convenience Yields

We introduce non-retradable bonds $\tilde{b}_1^H$ and $\tilde{b}_1^F$. The budget constraints in periods 1 and 3 in the households' optimisation 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 8). 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 15 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 17 and 18 that determine period 2 prices, the above equations can be rearranged into:

$$CY_1^H = \log\left(\frac{(1-P_R)u'(c_{3,O}) + P_R(1-P_A)E_2\left[u'(c_{3,B})\right]\left[1+\frac{P_A}{1-P_A}\frac{u'(w_{2,A}+p_2^H B_1^H + p_2^F B_1^F)}{u'\left(w_{2,B}-\frac{P_A}{(1-P_A)}(p_2^H B_1^H + p_2^F B_1^F)\right)}\right]}{(1-P_R)u'(c_{3,O}) + P_R(1-P_A)E_2\left[u'(c_{3,B})\right]\left[1+\frac{P_A}{1-P_A}\frac{u'(w_3)}{E_2[u'(c_{3,B})]}\right]}\right) \tag{20}$$

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

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 retrading 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 herself 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

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

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

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

Using the above, we can rewrite convenience yields for any $0 < P_R \leq 1$ as

$$CY_1^H = \log\left(1 + \frac{e^{CY_1^H(P_R=1)} - 1}{1 + \frac{1-P_R}{P_R(1-P_A)\frac{E_2\left[u'(c_{3,B})\right]}{u'(c_{3,O})}\left[1+\frac{P_A}{1-P_A}\frac{u'(w_3)}{P_D u'(c_{3,B}(1))+(1-P_D)u'(c_{3,B}(0))}\right]}}\right) \tag{23}$$

$$CY_1^F = \log\left(1 + \frac{e^{CY_1^F(P_R=1)} - 1}{1 + \frac{1-P_R}{P_R(1-P_A)(1-P_D)\frac{u'(c_{3,B}(0))}{u'(c_{3,O})}\left[1+\frac{P_A}{1-P_A}\frac{u'(w_3)}{u'(c_{3,B}(0))}\right]}}\right) \tag{24}$$

A.6 Proof of First Results when $P_R = 1$

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

$$CY_1^F - CY_1^H = \log\left(\frac{1 + \frac{P_A}{1-P_A}\frac{E_2\left[u'(c_{3,A})\right]}{E_2\left[u'(c_{3,B})\right]}}{1 + \frac{P_A}{1-P_A}\frac{u'(w_3)}{u'\left(w_3+\frac{B_1^H+B_1^F}{1-P_A}\right)}}\right) \tag{25}$$

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.

A.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 $\frac{\partial CY_1^H}{\partial B_1^H}$.

$$\frac{\partial CY_1^H}{\partial B_1^H} = \frac{\frac{P_A}{1-P_A}\frac{\partial\left(\frac{u'(c_{2,A})}{u'(c_{2,B})}\right)}{\partial B_1^H}}{1+\frac{P_A}{1-P_A}\frac{u'(c_{2,A})}{u'(c_{2,B})}} + 2\frac{\frac{P_A}{1-P_A}\frac{E_2\left[u'(c_{3,A})\right]\left(P_D u''(c_{3,B}(1))+(1-P_D)u''(c_{3,B}(0))\right)}{\left(E_2\left[u'(c_{3,B})\right]\right)^2}}{1+\frac{P_A}{1-P_A}\frac{E_2\left[u'(c_{3,A})\right]}{E_2\left[u'(c_{3,B})\right]}} \tag{26}$$

$$\frac{\partial CY_1^F}{\partial B_1^H} = \frac{\frac{P_A}{1-P_A}\frac{\partial\left(\frac{u'(c_{2,A})}{u'(c_{2,B})}\right)}{\partial B_1^H}}{1+\frac{P_A}{1-P_A}\frac{u'(c_{2,A})}{u'(c_{2,B})}} + 2\frac{\frac{P_A}{1-P_A}\frac{u'(w_3)u''(c_{3,B}(0))}{\left(u'(c_{3,B}(0))\right)^2}}{1+\frac{P_A}{1-P_A}\frac{u'(w_3)}{u'(c_{3,B}(0))}} \tag{27}$$

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 26 and 27, the first fraction is the same and can we 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 19 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 increase. 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 $\frac{\partial CY_1^H}{\partial B_1^F}$.

$$\frac{\partial CY_1^H}{\partial B_1^F} = \frac{\frac{P_A}{1-P_A}\frac{\partial\left(\frac{u'(c_{2,A})}{u'(c_{2,B})}\right)}{\partial B_1^F}}{1+\frac{P_A}{1-P_A}\frac{u'(c_{2,A})}{u'(c_{2,B})}} + 2\frac{\frac{P_A}{1-P_A}\frac{E_2\left[u'(c_{3,A})\right](1-P_D)u''(c_{3,B}(0))}{\left(E_2\left[u'(c_{3,B})\right]\right)^2}}{1+\frac{P_A}{1-P_A}\frac{E_2\left[u'(c_{3,A})\right]}{E_2\left[u'(c_{3,B})\right]}} \tag{28}$$

$$\frac{\partial CY_1^F}{\partial B_1^F} = \frac{\frac{P_A}{1-P_A}\frac{\partial\left(\frac{u'(c_{2,A})}{u'(c_{2,B})}\right)}{\partial B_1^F}}{1+\frac{P_A}{1-P_A}\frac{u'(c_{2,A})}{u'(c_{2,B})}} + 2\frac{\frac{P_A}{1-P_A}\frac{u'(w_3)u''(c_{3,B}(0))}{\left(u'(c_{3,B}(0))\right)^2}}{1+\frac{P_A}{1-P_A}\frac{u'(w_3)}{u'(c_{3,B}(0))}} \tag{29}$$

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 $\frac{\partial CY_1^H}{\partial B_1^F} \leq 0$.

A.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 26 because it is the only term that depends on P_D. We take its derivative

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

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

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 characterised 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 characterised by prudence ($u''' > 0$), we have that the first fraction is negative. If it is negative enough to imply
$\frac{(u''(c_{3,B}(1)) - u''(c_{3,B}(0)))}{-E_2[u''(c_{3,B})]} \left(1 + \frac{P_A}{1-P_A} \frac{E_2[u'(c_{3,A})]}{E_2[u'(c_{3,B})]} \right) \leq \frac{-(u'(c_{3,B}(1)) - u'(c_{3,B}(0)))}{E_2[u'(c_{3,B})]} \left(2 + \frac{P_A}{1-P_A} \frac{E_2[u'(c_{3,A})]}{E_2[u'(c_{3,B})]} \right)$
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 evaluate 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.

A.9 Log Utility when $P_A = 0.5$

Assuming that $u(c) = \ln(c)$, we can simply the expression of period 2 prices (equations 15 and 17) as follows

$$\begin{aligned}
p_2^H &= \beta\left(w_{2,B} - p_2^H B_1^H - p_2^F B_1^F\right)\left[\frac{P_D}{w_3 + 2B_1^H} + \frac{1-P_D}{w_3 + 2B_1^H + 2B_1^F}\right] \\
p_2^H &= p_2^F \frac{(w_3 + 2B_1^H + 2B_1^F)}{(1-P_D)}\left[\frac{P_D}{w_3 + 2B_1^H} + \frac{1-P_D}{w_3 + 2B_1^H + 2B_1^F}\right] \\
p_2^F &= \beta(1-P_D)\frac{w_{2,B} - p_2^H B_1^H - p_2^F B_1^F}{w_3 + 2B_1^H + 2B_1^F}
\end{aligned}$$

The solutions are

$$p_2^H = w_{2,B}\frac{\beta\left[\frac{P_D}{w_3+2B_1^H} + \frac{1-P_D}{w_3+2B_1^H+2B_1^F}\right]}{1 + \beta B_1^H\left[\frac{P_D}{w_3+2B_1^H} + \frac{1-P_D}{w_3+2B_1^H+2B_1^F}\right] + \beta B_1^F\left[\frac{1-P_D}{w_3+2B_1^H+2B_1^F}\right]} \tag{30}$$

$$p_2^F = w_{2,B}\frac{\beta\frac{1-P_D}{w_3+2B_1^H+2B_1^F}}{1 + \beta B_1^H\left[\frac{P_D}{w_3+2B_1^H} + \frac{1-P_D}{w_3+2B_1^H+2B_1^F}\right] + \beta B_1^F\left[\frac{1-P_D}{w_3+2B_1^H+2B_1^F}\right]} \tag{31}$$

Also, solving for $(p_2^H B_1^H + p_2^F B_1^F)$ is possible analytically

$$p_2^H B_1^H + p_2^F B_1^F = B_1^H \beta \left(w_{2,B} - p_2^H B_1^H - p_2^F B_1^F\right) \left[\frac{P_D}{w_3 + 2B_1^H} + \frac{1 - P_D}{w_3 + 2B_1^H + 2B_1^F}\right] + B_1^F \beta \frac{(w_{2,B} - p_2^H B_1^H - p_2^F B_1^F)(1 - P_D)}{w_3 + 2B_1^H + 2B_1^F}$$

$$p_2^H B_1^H + p_2^F B_1^F = w_{2,B} \frac{B_1^H \left[\frac{P_D}{w_3+2B_1^H} + \frac{1-P_D}{w_3+2B_1^H+2B_1^F}\right] + B_1^F \left[\frac{1-P_D}{w_3+2B_1^H+2B_1^F}\right]}{\frac{1}{\beta} + B_1^H \left[\frac{P_D}{w_3+2B_1^H} + \frac{1-P_D}{w_3+2B_1^H+2B_1^F}\right] + B_1^F \left[\frac{1-P_D}{w_3+2B_1^H+2B_1^F}\right]}$$

$$p_2^H B_1^H + p_2^F B_1^F = w_{2,B} - w_{2,B} \frac{1}{1 + \beta B_1^H \left[\frac{P_D}{w_3+2B_1^H} + \frac{1-P_D}{w_3+2B_1^H+2B_1^F}\right] + \beta B_1^F \left[\frac{1-P_D}{w_3+2B_1^H+2B_1^F}\right]}$$

Interestingly, this implies that

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

A.10 Quadratic Utility when $P_A = 0.5$

Assuming that $u(c) = \phi_0 + \phi_1 c - \frac{\phi_2}{2} c^2$, we can simplify the expression of period 2 prices (equations 15 and 17) as follows

$$\begin{aligned}
p_2^H &= \beta \frac{\phi_1 - \phi_2 P_D (w_3 + 2B_1^H) - \phi_2 (1 - P_D)(w_3 + 2B_1^H + 2B_1^F)}{\phi_1 - \phi_2 w_{2,B} + \phi_2 p_2^H B_1^H + \phi_2 p_2^F B_1^F} \\
p_2^F &= p_2^H \frac{\phi_1 - \phi_2 (1 - P_D)(w_3 + 2B_1^H + 2B_1^F)}{\phi_1 - \phi_2 P_D (w_3 + 2B_1^H) - \phi_2 (1 - P_D)(w_3 + 2B_1^H + 2B_1^F)} \\
p_2^F &= \beta \frac{\phi_1 - \phi_2 (1 - P_D)(w_3 + 2B_1^H + 2B_1^F)}{\phi_1 - \phi_2 w_{2,B} + \phi_2 p_2^H B_1^H + \phi_2 p_2^F B_1^F}
\end{aligned}$$

and then

$$\begin{aligned}
p_2^H &= \frac{\beta \left[\phi_1 - \phi_2 (w_3 + 2B_1^H) - 2\phi_2 (1 - P_D) B_1^F\right]}{\phi_1 - \phi_2 w_{2,B} + \phi_2 p_2^H B_1^H + \phi_2 p_2^F B_1^F} \\
0 &= \phi_2 \left(B_1^H + B_1^F \frac{\phi_1 - \phi_2 (1 - P_D)(w_3 + 2B_1^H + 2B_1^F)}{\phi_1 - \phi_2 (w_3 + 2B_1^H) - 2\phi_2 (1 - P_D) B_1^F} \right) (p_2^H)^2 \\
&\quad + (\phi_1 - \phi_2 w_{2,B}) p_2^H - \beta \left[\phi_1 - \phi_2 (w_3 + 2B_1^H) - 2\phi_2 (1 - P_D) B_1^F\right]
\end{aligned}$$

And the above equation is a standard quadratic equation in p_2^H (with a positive solution to retain and a negative solution to be excluded).

Also, solving for $(p_2^H B_1^H + p_2^F B_1^F)$ but is possible again as it is the solution of a quadratic equation (with a positive solution to retain and a negative solution to be excluded)

$$p_2^H B_1^H + p_2^F B_1^F = \beta \frac{B_1^H \left(\phi_1 - \phi_2 P_D(w_3 + 2B_1^H) - \phi_2(1-P_D)(w_3 + 2B_1^H + 2B_1^F)\right) + B_1^F \left(\phi_1 - \phi_2(1-P_D)(w_3 + 2B_1^H + 2B_1^F)\right)}{\phi_1 - \phi_2 w_{2,B} + \phi_2 p_2^H B_1^H + \phi_2 p_2^F B_1^F}$$

A.11 Additional Numerical Results

FIGURE 11: Spillovers in Convenience Yields from a Joint Bond Supply Shocks

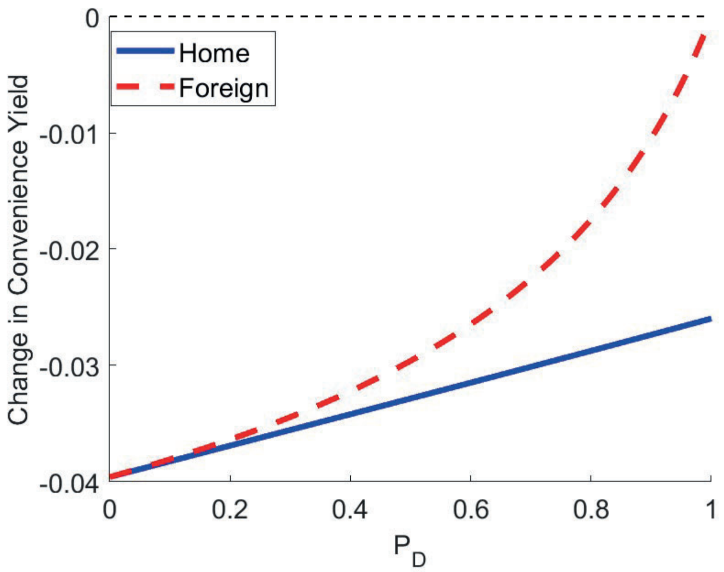


FIGURE 12: Change in CYs (Higher B_1^H and B_1^F)

A.12 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 8).

B Empirical Analysis Appendix

RS estimator

For every country, our dataset of daily changes in convenience yields is categorised into two subsets: the E subsample corresponds to dates for which an announcement is issued, while the NE subsample pertains to dates without announcements.

The challenge in estimating spillovers between convenience yields in euro area countries lies in two endogeneity issues: i. the fact that the convenience yields of different countries simultaneously influence each other; ii. the presence of unobserved common shocks.

The following set of equations offers a clear depiction of the endogeneity present in the system:

$$\Delta CY_t^H = \beta^{FH} \Delta CY_t^F + \delta Z_t + \epsilon_t \tag{32}$$

$$\Delta CY_t^F = \beta^{HF} \Delta CY_t^H + Z_t + \eta_t \tag{33}$$

where ΔCY_t^H is the daily change of the home country's convenience yield, ΔCY_t^F is the daily change of the foreign country's convenience yield and Z_t is a set of control variables. The aim of this paper is to estimate the parameter β^{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 supply shock in the home country. The simultaneity issue reflected in the above equations is depicted in Figure 13, where we simulate the data as in equations (32) and (33).

It is now clear that achieving consistent estimation for Eqs. (32) and (33) using ordinary least squares is unattainable due to the presence of simultaneous equations and omitted variables. To address these challenges, we rely on identification through heteroskedasticity, as in Rigobon (2003) and Rigobon and Sack (2004). This approach does not require the complete absence of both common and idiosyncratic shocks. Instead, it relies on a critical assumption:

$$\sigma_\epsilon^E > \sigma_\epsilon^{NE}, \tag{34}$$

$$\sigma_\eta^E = \sigma_\eta^{NE}, \tag{35}$$

$$\sigma_z^E = \sigma_z^{NE}. \tag{36}$$

This means that the variances of common shocks (z) and the shock to the foreign country (η) should be equal on both event and non-event days, while the variance of the shock to the home country (ϵ) is higher on event days compared to non-event days. This increase in variance on event days is attributed to the impact of announcements, assumed to be home country (ϵ) shocks.

With this assumption, we can determine the parameter β^{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. This intuition can be visualised in the context of the simulated data of Figure 13, and is shown in Figure 14.

Hence, we divide the daily observations in our sample into two types, events (E) and non-events (NE) and we estimate the covariance matrix Ω:[19]

$$\Omega_j = \begin{bmatrix} var_j(\Delta CY_t^H) & cov_j(\Delta CY_t^F, \Delta CY_t^H) \\ cov_j(\Delta CY_t^F, \Delta CY_t^H) & var_j(\Delta CY_t^F) \end{bmatrix}.$$

We then define the difference in the covariance matrices during events and non-events as:

$$\Delta\Omega = \Delta\Omega_E - \Delta\Omega_{NE} = \lambda \begin{bmatrix} 1 & \beta^{HF} \\ \beta^{HF} & \beta^{HF2} \end{bmatrix} \tag{37}$$

where

$$\lambda = \frac{(\sigma^2_{\epsilon,E} - \sigma^2_{\epsilon,NE})}{(1-\alpha\beta_{HF})^2}.$$

[19] j ∈ {E, NE}.

FIGURE 13: Joint Change in CY_t^H and CY_t^F

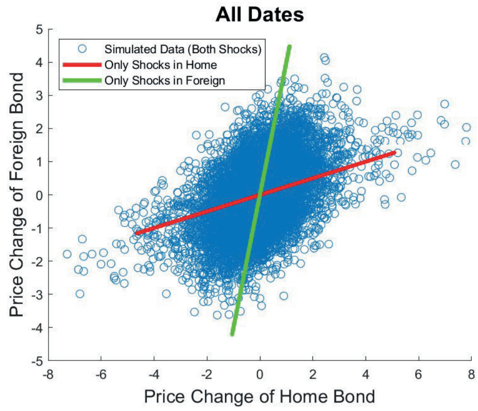
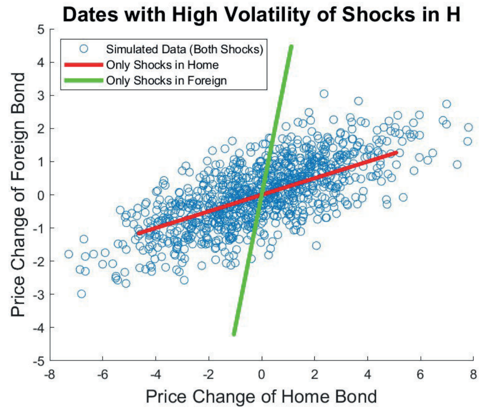


FIGURE 14: Announcement Dates Only



A nice feature of this method is that we can build the following instruments and implement it through an instrumental variable approach:

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

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

Though we could use the IV estimation using just one instrument (as in Rigobon and Sack (2004)), we prefer to follow Arai (2017) and use the orthogonality of both instruments as the moment conditions for GMM estimation, as it should provide more efficient estimates. 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 β^{HF} can be obtained by solving the minimum distance problem:

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

where $f_T(\beta^{HF}) = \sum_{t=1}^{T} f_t(\beta^{HF})$ and W is an appropriate 2×2 weighting matrix. We use the two-step GMM for the estimation, where we use the identity matrix as a weighting matrix to solve the minimisation problem, and then use the inverse of estimated variance-covariance matrix of the moment conditions in the first step as a weighting matrix in the second step.

B.1 Robustness Checks

Table 10: Intraday Spillovers Beyond Euro Area Sovereign Bonds

	(1) ΔY_{US}	(2) ΔY_{GB}	(3) ΔUSD	(4) ΔGBP	(5) ΔDAX	(6) ΔCAC 40	(7) ΔStoxx 50
ΔY_{DE}	0.498***	0.724***	0.021**	0.020**	0.023	0.027	0.013
	(0.084)	(0.130)	(0.009)	(0.009)	(0.039)	(0.036)	(0.023)
Constant	-0.001	-0.002	-0.000	0.000	-0.000	-0.000	-0.000
	(0.001)	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Observations	43	44	44	44	44	44	44
R^2	0.543	0.417	0.086	0.054	0.010	0.013	0.005

Notes: Each column displays coefficients from a separate regression: $\Delta Y_{receiving} = \beta_0 + \beta_1 * \Delta Y_{Germany} + \epsilon$ for columns (1) and (2); $\Delta log(EchangeRate) = \beta_0 + \beta_1 * \Delta Y_{Germany} + \epsilon$ for columns (3) - (6); $\Delta log(StockIndex) = \beta_0 + \beta_1 * \Delta Y_{Germany} + \epsilon$ for columns (7) - (9). Standard errors are reported in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 11: Daily Convenience Yield Spillovers: 5-Year Maturity

	(1) ΔCY_{FR}	(2) ΔCY_{NL}	(3) ΔCY_{FI}	(4) ΔCY_{AT}	(5) ΔCY_{BE}	(6) ΔCY_{IT}	(7) ΔCY_{ES}	(8) ΔCY_{PT}
ΔCY_{DE}	1.815*	1.323***	1.078***	0.849**	1.335	1.392	0.387	1.818
	(0.912)	(0.386)	(0.331)	(0.327)	(0.841)	(0.963)	(0.709)	(1.350)
Constant	-0.005	-0.000	-0.001	-0.003	-0.002	-0.011	-0.001	-0.012
	(0.007)	(0.003)	(0.002)	(0.004)	(0.006)	(0.007)	(0.006)	(0.011)
Observations	43	43	42	43	43	43	43	43
R^2	0.094	0.382	0.637	0.370	0.053	0.040	0.122	.

Notes: Each column displays coefficients from a separate regression: $\Delta CY_{5y,receiving} = \beta_0 + \beta_1 * \Delta CY_{5y,Germany} + \epsilon$, where the daily change in the German convenience yield is instrumented with the 30-minute yield change. Standard errors are reported in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 12: Daily Convenience Yield Spillovers: EIKON CDS Data

	(1) ΔCY_{FR}	(2) ΔCY_{NL}	(3) ΔCY_{FI}	(4) ΔCY_{AT}	(5) ΔCY_{BE}	(6) ΔCY_{IT}	(7) ΔCY_{ES}	(8) ΔCY_{PT}
ΔCY_{DE}	0.938***	1.161**	1.010***	1.220***	1.144	0.515	-0.026	1.272
	(0.252)	(0.427)	(0.186)	(0.269)	(0.685)	(0.803)	(1.001)	(0.922)
Constant	-0.002	0.003	-0.005**	-0.005	-0.003	-0.007	-0.008	-0.022
	(0.002)	(0.005)	(0.002)	(0.005)	(0.006)	(0.007)	(0.007)	(0.014)
Observations	39	31	25	24	38	39	39	39
R^2	0.662	0.241	0.706	0.483	.	0.087	.	.

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

Table 13: Daily Convenience Yield Spillovers: Less Restrictive Sample

	(1) ΔCY_{FR}	(2) ΔCY_{NL}	(3) ΔCY_{FI}	(4) ΔCY_{AT}	(5) ΔCY_{BE}	(6) ΔCY_{IT}	(7) ΔCY_{ES}	(8) ΔCY_{PT}
ΔCY_{DE}	0.902***	0.969***	1.213***	0.779***	1.055*	0.607	-0.795	1.969*
	(0.227)	(0.243)	(0.205)	(0.221)	(0.538)	(0.876)	(1.079)	(1.124)
Constant	-0.002	0.004	-0.003	-0.002	-0.003	-0.013	-0.015	-0.012
	(0.002)	(0.006)	(0.003)	(0.003)	(0.006)	(0.009)	(0.010)	(0.014)
Observations	47	47	47	47	47	47	47	47
R^2	0.533	0.422	0.593	0.366	.	.	.	.

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

TABLE 14: Convenience yield spillovers from German supply shocks using the RS estimator: 1^{st} alternative implementation on a subsample

	(1) ΔCY_{FR}	(2) ΔCY_{NL}	(3) ΔCY_{FI}	(4) ΔCY_{AT}	(5) ΔCY_{BE}	(6) ΔCY_{IT}	(7) ΔCY_{ES}	(8) ΔCY_{PT}
ΔCY_{DE}	1.018***	1.352***	1.315***	1.636***	1.436	1.126	1.274	4.223
	(0.273)	(0.391)	(0.407)	(0.630)	(1.089)	(1.389)	(1.158)	(4.137)
Constant	-0.001	-0.003*	-0.003	-0.002	-0.004	-0.003	0.003	-0.011
	(0.002)	(0.002)	(0.002)	(0.003)	(0.005)	(0.006)	(0.004)	(0.013)
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 report coefficient estimates of equation $\Delta CY_{receiving} = \alpha + \beta \Delta CY_{Germany} + \varepsilon$ using the RS estimator described in Section 4.4. This table is similar to Table 6, expect that results are obtained on a smaller sample that additionally excludes observations with potential outliers for yield variations in the receiving 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 receiving country yields. Again, we use the two-step GMM estimator. Each column corresponds to a different receiving 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 15: Convenience yield spillovers from German supply shocks using the RS estimator: 2^{nd} alternative implementation with different instruments

	(1) ΔCY_{FR}	(2) ΔCY_{NL}	(3) ΔCY_{FI}	(4) ΔCY_{AT}	(5) ΔCY_{BE}	(6) ΔCY_{IT}	(7) ΔCY_{ES}	(8) ΔCY_{PT}
ΔCY_{DE}	0.637**	1.259**	1.116***	0.890***	-0.328	-0.398	0.538	-1.134
	(0.252)	(0.596)	(0.155)	(0.239)	(0.409)	(0.618)	(0.764)	(1.015)
Constant	-0.002	-0.004	-0.003*	-0.002	0.001	-0.004	0.001	0.002
	(0.002)	(0.004)	(0.002)	(0.002)	(0.003)	(0.005)	(0.004)	(0.007)
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 report coefficient estimates of equation $\Delta CY_{receiving} = \alpha + \beta \Delta CY_{Germany} + \varepsilon$ using the RS estimator described in Section 4.4. This table is similar to Table 6, expect 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 receiving country yields. Again, we use the two-step GMM estimator. Each column corresponds to a different receiving 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 16: Convenience yield spillovers from German supply shocks using the RS estimator: 3^{rd} alternative implementation with different instruments

	(1) ΔCY_{FR}	(2) ΔCY_{NL}	(3) ΔCY_{FI}	(4) ΔCY_{AT}	(5) ΔCY_{BE}	(6) ΔCY_{IT}	(7) ΔCY_{ES}	(8) ΔCY_{PT}
ΔCY_{DE}	1.178	2.699	1.169**	0.863	0.716	0.551	-0.090	0.669
	(0.729)	(1.812)	(0.471)	(0.530)	(0.908)	(1.018)	(1.199)	(1.280)
Constant	-0.005	-0.007	-0.002	-0.003	-0.003	-0.010	0.000	-0.012
	(0.003)	(0.008)	(0.003)	(0.003)	(0.005)	(0.006)	(0.007)	(0.010)
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 report coefficient estimates of equation $\Delta CY_{receiving} = \alpha + \beta \Delta CY_{Germany} + \varepsilon$ using the RS estimator described in Section 4.4. This table is similar to Table 6, expect 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 receiving country yields). Again, we use the two-step GMM estimator. Each column corresponds to a different receiving 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.*

TABLE 17: Convenience yield spillovers from French supply shocks using the RS estimator: 1^{st} alternative implementation on a restricted sample

	(1) ΔCY_{DE}	(2) ΔCY_{NL}	(3) ΔCY_{FI}	(4) ΔCY_{AT}	(5) ΔCY_{BE}	(6) ΔCY_{IT}	(7) ΔCY_{ES}	(8) ΔCY_{PT}
ΔCY_{FR}	1.125***	0.917**	0.886***	0.965***	0.998***	-0.408	0.481	0.877
	(0.310)	(0.406)	(0.292)	(0.231)	(0.293)	(0.559)	(0.428)	(1.036)
Constant	0.001	0.002	-0.000	-0.001	-0.001	0.001	0.005	0.005
	(0.002)	(0.001)	(0.002)	(0.002)	(0.002)	(0.007)	(0.005)	(0.008)
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 report coefficient estimates of equation $\Delta CY_{receiving} = \alpha + \beta \Delta CY_{France} + \varepsilon$ using the RS estimator described in Section 4.4. This table is similar to Table 7, expect that results are obtained on a smaller sample that additionally excludes observations with potential outliers for yield variations in the receiving countries. or every column, we use the two instrument variables based on the change in the variance-covariance matrix of the origin and receiving country yields. Again, we use the two-step GMM estimator. Each column corresponds to a different receiving 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 18: Convenience yield spillovers from French supply shocks using the RS estimator: 2^{nd} alternative implementation with different instruments

	(1) ΔCY_{DE}	(2) ΔCY_{NL}	(3) ΔCY_{FI}	(4) ΔCY_{AT}	(5) ΔCY_{BE}	(6) ΔCY_{IT}	(7) ΔCY_{ES}	(8) ΔCY_{PT}
ΔCY_{FR}	0.709***	0.521***	0.904***	0.582***	0.716***	-0.270	0.456	1.771
	(0.203)	(0.200)	(0.232)	(0.202)	(0.173)	(0.341)	(0.325)	(2.190)
Constant	0.001	0.002	-0.004*	0.000	-0.001	0.002	0.002	0.000
	(0.002)	(0.001)	(0.002)	(0.002)	(0.002)	(0.005)	(0.004)	(0.015)
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 report coefficient estimates of equation $\Delta CY_{receiving} = \alpha + \beta \Delta CY_{France} + \varepsilon$ using the RS estimator described in Section 4.4. This table is similar to Table 7, expect that results are obtained with different instruments. or every column, we use the instrument variables based on the change in the variance-covariance matrix of the origin country and the 8 receiving country yields. Again, we use the two-step GMM estimator. Each column corresponds to a different receiving 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 19: Convenience yield spillovers from French supply shocks using the RS estimator: 3^{rd} alternative implementation with different instruments

	(1) ΔCY_{DE}	(2) ΔCY_{NL}	(3) ΔCY_{FI}	(4) ΔCY_{AT}	(5) ΔCY_{BE}	(6) ΔCY_{IT}	(7) ΔCY_{ES}	(8) ΔCY_{PT}
ΔCY_{FR}	0.940**	0.962*	0.638	0.827***	1.032**	-0.201	0.751	-2.809
	(0.373)	(0.516)	(0.471)	(0.294)	(0.433)	(0.539)	(0.642)	(5.402)
Constant	0.002	0.003	-0.002	-0.001	-0.002	0.003	0.003	0.008
	(0.003)	(0.002)	(0.003)	(0.002)	(0.003)	(0.007)	(0.005)	(0.023)
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 report coefficient estimates of equation $\Delta CY_{receiving} = \alpha + \beta \Delta CY_{France} + \varepsilon$ using the RS estimator described in Section 4.4. This table is similar to Table 7, expect that results are obtained with different instruments. or 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 receiving country yields). Again, we use the two-step GMM estimator. Each column corresponds to a different receiving 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.*

TABLE 20: Convenience yield spillovers from French supply shocks using the RS estimator: 4^{th} alternative implementation using 5-year yields

	(1) ΔCY_{DE}	(2) ΔCY_{NL}	(3) ΔCY_{FI}	(4) ΔCY_{AT}	(5) ΔCY_{BE}	(6) ΔCY_{IT}	(7) ΔCY_{ES}	(8) ΔCY_{PT}
ΔCY_{FR}	1.415***	1.280***	0.985***	1.182***	1.097***	-1.473	1.130	-0.212
	(0.321)	(0.264)	(0.191)	(0.202)	(0.203)	(2.753)	(0.689)	(1.190)
Constant	-0.001	-0.000	0.000	-0.001	-0.004**	0.012	0.000	-0.004
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.011)	(0.003)	(0.007)
N	44	44	44	44	44	44	44	44
Weak IV	6.474	3.714	6.209	7.035	4.499	3.255	3.342	3.300
Overid.	0.957	0.568	0.230	0.098	0.866	0.150	0.976	0.278

*Notes: This table report coefficient estimates of equation $\Delta CY_{5y,receiving} = \alpha + \beta \Delta CY_{5y,France} + \varepsilon$ using the RS estimator described in Section 4.4. This table is similar to Table 7, expect that we use 5-year instead of 10-year yields. or every column, we use the two instrument variables based on the change in the variance-covariance matrix of the origin and receiving country yields. Again, we use the two-step GMM estimator. Each column corresponds to a different receiving 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.*

B.2 Italian Debt Supply Shocks

The *Dipartimento del Tesoro* (henceforth, the Italian Treasury), which is part of the Ministry of Economy and Finance, issues government bonds and manages the liabilities of the central state administrations with a dedicated directorate general. The Italian Treasury employs a different policy for announcements of future bond issuances compared to both Germany and France.

Press releases are published at the end of each quarter and provide a broad view of the government's plan over the following three months. The Treasury provides information about new issues and re-openings of previously issued bonds. The information is more limited compared to the German and French announcements. In fact, the quarterly releases contain information only for bonds with maturities ranging from 2 to 10 years and the Treasury does not disclose the actual notional amount of each bond issue. In the releases, only the minimum amounts that will be offered before issuing another bond with a similar maturity are disclosed. In addition, the Italian Treasury does not provide forward guidance for auctions of short-term bonds (i.e. for maturities below 1 year), bonds with maturities over 10 years and off-the-run bonds. Hence, while investors have full information on scheduled German bond auctions, they have more limited information on scheduled Italian bond auctions.

While these factors preclude high-frequency identification, the institutional setting still allows us to follow the same approach used for France and apply it to estimate spillovers originating from Italy. Hence, by knowing the dates of the announcements, we can possibly employ the RS estimator.

As discussed in more detail in Subsection 4.5 for Gemany and France, we check the conditions that support the use of the RS estimator. Table 21 presents key descriptive statistics on changes in convenience yields for the set of DMO's announcement dates and the set of the preceding dates for Italy. Unlike the cases of Germany and France, the differences between the two group of dates following Italian announcement dates are almost systematically insignificant. The right panel also shows that co-movements of changes in convenience yields across countries tend to be similar whether it is on announcement dates or on the preceding day. This stock of evidence suggests that Italian DMO's announcements do *not* generate shocks that move the convenience yields more than in normal days.

Despite these limitations, we applied the RS estimator, obtaining largely imprecise and statistically insignificant estimates (Table 22). These findings underscore the need for alternative methodologies when dealing with markets characterised by limited transparency and after-hours announcements. This constitutes a highly interesting avenue for future research.

TABLE 21: Variances and correlations on announcement (T) and non-announcement ($T-1$) dates

	Price change, std. dev. by dates			Corr. with source shock by dates			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	sd_{T-1}	sd_T	$sd_{T-1} = sd_T$ p-value	β_{T-1}	$\beta_{T-1} = 0$ p-value	β_T	$\beta_T = 0$ p-value
Italy							
ΔCY_{IT}	0.082	0.077	0.635	1.000	.	1.000	.
ΔCY_{NL}	0.031	0.039	0.116	0.293	0.000	0.319	0.054
ΔCY_{FI}	0.027	0.036	0.054	0.040	0.536	0.000	0.998
ΔCY_{FR}	0.025	0.026	0.642	0.096	0.206	0.089	0.439
ΔCY_{AT}	0.033	0.042	0.072	0.184	0.016	0.302	0.177
ΔCY_{BE}	0.049	0.035	0.015	0.390	0.002	0.308	0.018
ΔCY_{DE}	0.022	0.026	0.244	0.070	0.155	0.082	0.435
ΔCY_{ES}	0.081	0.036	0.000	0.784	0.000	0.146	0.142
ΔCY_{PT}	0.119	0.102	0.269	0.781	0.006	0.835	0.028
Observations	53.000	53.000	.	0.000	.	0.000	.

Notes: The panel focuses on spillovers from Italy following issuance plan announcements by the Italian Treasury. 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 $\Delta CY_{receiving} = \alpha + \beta \Delta CY_{Italy} + \varepsilon$ 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) reports the p-value of a significance test with robust standard errors.

Table 22: Convenience yield spillovers from Italian supply shocks using the RS estimator

	(1) ΔCY_{FR}	(2) ΔCY_{NL}	(3) ΔCY_{FI}	(4) ΔCY_{AT}	(5) ΔCY_{BE}	(6) ΔCY_{DE}	(7) ΔCY_{ES}	(8) ΔCY_{PT}
ΔCY_{IT}	0.761	-0.407	0.098	0.567	1.546	-0.210	1.130***	-3.303
	(2.096)	(2.102)	(0.897)	(0.964)	(2.266)	(0.748)	(0.226)	(5.322)
Constant	0.006	-0.009	0.001	0.002	0.021	-0.002	0.004	-0.053
	(0.033)	(0.033)	(0.014)	(0.016)	(0.035)	(0.012)	(0.006)	(0.083)
N	106	106	106	106	106	105	105	105
Weak IV	0.342	0.396	0.266	1.298	0.772	0.285	18.656	0.294
Overid.	0.308	0.440	0.711	0.455	0.856	0.460	0.136	0.736

Notes: This table report coefficient estimates of equation $\Delta CY_{receiving} = \alpha + \beta \Delta CY_{Italy} + \varepsilon$ *using the RS estimator described in Section 4.4. Each column corresponds to a different receiving 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 receiving 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 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.*

European Stability Mechanism

6a Circuit de la Foire Internationale
L-1347 Luxembourg

Tel: +352 260 292 0

www.esm.europa.eu

info@esm.europa.eu

Publications Office
of the European Union