Bond Convenience Yields in the Eurozone Currency Union*

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Abstract

This paper analyzes bond convenience yields in a currency union. The intertemporal government budget constraint requires member countries' bond convenience yields and default spreads to adjust in response to shocks to their government surpluses. In the data, adjustments to convenience yields explain a larger fraction of the variation in Eurozone bond yields than default spreads. Higher convenience yields are correlated with stronger fiscal conditions both in the cross-section and in the time series. These findings imply large fiscal costs especially on the peripheral countries. If all Eurozone countries could have issued sovereign bonds at the same convenience yields as Germany, they would have raised an extra 281 billion euros in cumulative revenues from bond issuance between 2003 and 2020, representing 2.6% of 2020 Eurozone GDP.

Key words: bond pricing, fiscal policy, sovereign default, convenience yield, currency union

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1 Introduction

Government bonds offer safety and liquidity services that investors value. In return, some bond market investors are willing to forgo a sizable return to own such safe assets. We refer to this forgone return as the convenience yield. This paper studies convenience yields on sovereign bonds in a currency union, with a focus on the Eurozone. Because most Eurozone sovereign bonds are denominated in euros and Eurozone financial markets are sufficiently well integrated, there is a common nominal risk-free yield curve. Differences in bond yields between any two Eurozone countries must be due to either convenience yields or default spreads. Since we observe default spreads from CDS data, we can back out convenience yield differentials between any two sovereign bonds.

Within the Eurozone, Germany is the bond market's preferred safe asset supplier. As a result of its safe haven status, the German government can finance its debt at a below-market rates, raising additional seigniorage revenue when issuing new debt. One can construct a synthetic German bond from any other Eurozone sovereign bond by removing the differential credit risk.

Figure 1: The Time Series of Convenience Yield Differentials

Notes: This figure plots the convenience yield differential between each country's government bond and Germany government bond. The convenience yields are constructed from 5-year bond yields and 5-year CDS spreads. Reported in percentage points.

The price of such a synthetic German bond is almost always lower than the price of an actual German bond. Put differently, the yield on the synthetic German bond is higher than the yield on the actual German bond. We refer to this interest rate wedge as the convenience yield differential. Figure 1 plots these convenience yield differentials for various Eurozone countries at the five-year tenor. For most of the sample, the German bond has a higher convenience yield than other Eurozone country bonds, resulting in negative differentials. Convenience yield differentials vary substantially both across countries and over time. Notably, convenience yield differentials peak during the Eurozone sovereign debt crisis of 2012. They spike again during the Covid-19 crisis in March 2020.

We conduct a variance decomposition of Eurozone sovereign bond yield differentials with Germany. Contrary to the popular belief that bond yields differ mostly due to default spreads, convenience yields are the main driver of bond yield differentials. In the 2008—2020 subsample, in which the bond yields diverge significantly across Eurozone countries, nearly two-thirds of the variation in bond yield differentials is due to convenience yields, while only one-third is accounted for by default spreads. In the 2002—2007 subsample, in which the bond yields are much more similar across Eurozone countries, 99% of the variation in bond yield differentials is due to convenience yields.

In a monetary union, convenience yields play an important role in enforcing the intertemporal government budget constraint. From the budget constraint, the market value of government debt in each country is determined by the present value of its current and future primary surpluses. At the same time, the market value of bonds outstanding today depends on the current nominal risk-free yield curve, the current default spread, and the current convenience yield. Since financial markets are integrated in the Eurozone, the risk-free nominal yield curve cannot respond to country-specific fiscal shocks to enforce the inter-temporal government budget condition. Nor can these national governments resort to creating inflation surprises to erode the real value of debt. This opens up the possibility for the convenience yield to do some—or much—of the adjustment.

To analyze these forces, we develop a variance decomposition of the market's valuation of government debt. In a monetary union with integrated capital markets, the conditional variance of the market's relative debt valuation can be decomposed into a convenience yield component, the covariance between the valuation and the relative convenience yield on the country's debt, and a default risk component, given by minus the covariance between the valuation and the relative default risk component. The relative market value of a country's debt responds to a positive country-specific primary surplus shock if either the bond's relative convenience yield increase or if the relative default risk premium decreases. For a country like Germany that produces safe, default-free debt, only the convenience channel remains. In our Eurozone sample, we find that convenience yields account for between one-third and two-thirds of the variation in the relative valuation of government surpluses.

Convenience yields will naturally adjust to fiscal shocks provided that the demand for safe assets is downward-sloping. Under that assumption, a country that experiences positive short-run fiscal news will need to issue less debt today and in the future, which increases the convenience yield on its outstanding debt today.

Consistent with the theory, we find a positive relationship between Eurozone governments' short-run fiscal conditions and convenience yields both in the cross-section and in the time series. Countries with higher primary surpluses earn higher convenience yields than countries with lower primary surpluses on average. In addition, when a country improves its fiscal condition, its convenience yield rises. This relationship is economically significant. A one standard-deviation increase in the government surplus/GDP ratio, which is about 2.4% points, is associated with a 26 basis point increase in the convenience yield. Like other asset prices, convenience yields are forward-looking. We obtain data on forecasts of government surpluses from Consensus Economics and the IMF. We find that expectations of improving fiscal conditions are also associated with higher convenience yields. This set of empirical results highlights the fiscal roots of convenience yields.

When convenience yields move when fiscal conditions change, as we find, they amplify the effects of fiscal shocks on the government's funding costs. In a world without convenience yields, bond prices are determined by the present value of government primary surpluses. Negative shocks to government surpluses lower bond valuation. In the presence of convenience yields, there is an additional stream of government revenue akin to seigniorage revenue. Since negative shocks to government surpluses also drive down the convenience yields, they reduce not only the present value of the government surpluses but also of seigniorage revenues, leading to a further decline in the bond valuation.

We conduct a simple analysis to quantify the fiscal costs of convenience yields. In the counterfactual, all countries earn the same amount of convenience yield as Germany at each point of time. We calculate the amount of additional revenue each country would have raised from the actual amount of bonds it issued. We then compound these revenue at German bond yields to obtain a measure of cumulative revenue loss that each country suffers because their bonds do not earn the same amount of convenience yield as German bonds. We find the cumulate revenue losses over the period 2003–2020 is 10.5% of 2020 GDP for Ireland, 4.4% for Italy, and 7.7% for Spain, amounting to 39, 72, and 87 billions euros, respectively. Even "core" countries such as Austria and the Netherlands suffer revenue losses are as large as 1% of 2019 GDP. Together, the cumulative revenue losses amount to 2.6% of the aggregate GDP in the Eurozone (including Germany GDP), a sizeable number.

In March of 2015, the ECB started the Public Sector Purchase Programme (PSPP) as part of its large-scale asset purchases, allowing for large purchases (by the national central banks) of sovereign bonds issued by Eurozone countries. ECB purchases may amplify the convenience yields' response to fiscal shocks. On the one hand, the PSPP may have muted the response of CDS spreads to adverse fiscal news by eliminating short-run roll-over risk in peripheral countries' sovereign bond markets. This would create a larger role for the convenience yield channel to absorb fiscal shocks. On the other hand, the PSPP may have increased convenience yields in core countries (Germany and its bond market substitutes) by increasing the scarcity of the safe asset. This would further increase core countries' funding cost advantages (see Corradin, Grimm, and Schwaab, 2021, for evidence). The net effect of these two forces for convenience yield differentials is an empirical question. An event study of key PSPP announcements suggests that the former channel dominates.

Related Literature Our results help shed light on the potential effects of transforming the Eurozone into a fiscal union. Bilbiie, Monacelli, and Perotti (2020) highlights the importance of fiscal policy in the Eurozone, given that monetary policy tools are not available to respond to country-specific shocks. Our paper shows that convenience yields and hence government funding costs can and do vary across countries, and respond to shocks to fiscal conditions.

In the wake of the Eurozone crisis of 2012, there was an extensive debate on the merits of an increased fiscal union.[1] While the Eurozone did not and still does not produce a safe asset that can rival U.S. Treasurys, the European Union started issuing debt backed by tax revenue of all the EU member states on June 15th 2021 as part of the NextGenerationEU scheme. Such new Eurozone debt, backed by joint and several liability of each member's fiscal authority, should trade at the same overall yield and the same level of convenience yields as German bunds. Our results indicate that this may lead to substantial cost savings especially for peripheral countries. A large-scale Eurozone fiscal union, which is not quite in sight yet, would equalize convenience yields for all countries. This would lead to a revenue transfer from Germany to other Eurozone countries. The distributional effects might be offset by the additional convenience revenue generated by the creation of a new global safe asset, which would benefit both Germany and other Eurozone countries.

Textbook finance would imply that governments in the Eurozone borrow at the same interest rates, after correcting for default risk differences. This is not what we find. Within the Eurozone, bond market investors have assigned the role of safe asset supplier to Germany. The resulting gap

[1] This debate is summarized by Claessens, Mody, and Vallee (2012) and Tumpel-Gugerell, Bénassy-Quéré, Bento, Bishop, Hoogduin, Mazák, Romana, Šimonytė, Vihriälä, and Weder di Mauro (2014). Proposals for the creation of union-wide safe assets ranged from eurobonds with joint liability, contemplated by the of the European Communities (2011) and Ubide (2015), to intermediate solutions with joint liability for some of the debt, like the blue and red bond proposal of Delpla and Von Weizsäcker (2010) and the eurobills proposal of Hellwig and Philippon (2011), to the ESBies proposal of Brunnermeier, Garicano, Lane, Pagano, Reis, Santos, Thesmar, Van Nieuwerburgh, and Vayanos (2011, 2016); Brunnermeier, Langfield, Pagano, Reis, Van Nieuwerburgh, and Vayanos (2017) which would create a safe asset through pooling and tranching of existing sovereign bonds without any joint liability. Corsetti, Feld, Koijen, Reichlin, Reis, Rey, and di Mauro (2016) discuss broad institutional reform to Eurozone institutions in the wake of the twin eurozone debt and refugee crises.

in convenience yields does not represent an arbitrage opportunity as long as the marginal Eurozone bond investor derives safety and liquidity benefits from a cash position in German bonds. Investors that do not value these benefits may view the sovereign CDS-bond basis as an arbitrage opportunity. Fontana and Scheicher (2016) compute the CDS-bond bases for Eurozone government bonds in the sample from 2007 to 2012, and attribute these bases to short-selling and funding frictions. Gyntelberg, Hördahl, Ters, and Urban (2013, 2017) also study these Eurozone convenience yields and relate them to market microstructure issues such as transaction costs and liquidity. Our paper provides a complementary perspective by analyzing the role of fiscal conditions as determinants of convenience yields. We view both convenience yields and liquidity as endogenous outcomes that evolve together with fiscal conditions. Consistent with this view, we find that convenience yields and bid-ask spreads are correlated. However, fiscal shocks remain a significant predictor of the convenience yield, even after controlling for the bid-ask spread.

In related work, Chernov, Schmid, and Schneider (2020) analyze the CDS premium on U.S. Treasurys and relate this to macro fundamentals. Augustin, Sokolovski, Subrahmanyam, and Tomio (2020) find that fiscal constraints help to explain the reaction of sovereign default spreads to economic shocks. Our paper theoretically and empirically examines the response of convenience yields to fiscal shocks.

Our paper contributes to the broader literature on the convenience yields of government debt (Krishnamurthy and Vissing-Jorgensen, 2012; Du, Im, and Schreger, 2018). These convenience yields are quantitatively important. Jiang, Krishnamurthy, and Lustig (2018, 2020) estimate that foreign investors have enjoyed convenience yields in excess of 200 bps per annum on their holdings Treasurys. Koijen and Yogo (2020) obtain similar estimates using a demand system approach. Jiang, Richmond, and Zhang (2020) quantify the privilege of the U.S. by studying drivers of capital flows. Jiang, Lustig, Van Nieuwerburgh, and Xiaolan (2019) investigate the extent to which convenience yields can help resolve the U.S. government debt valuation puzzle, and Jiang, Lustig, Van Nieuwerburgh, and Xiaolan (2020) study how exposure of convenience yields to output risk affects the trade-off between insuring bondholders and taxpayers against macro-economic risk.

This literature emphasizes that U.S. Treasurys take a special place in global financial markets. Investors are typically willing to pay more for an actual Treasury than for a synthetic Treasury manufactured from corporate bonds (Longstaff, Mithal, and Neis, 2005; Bai and Collin-Dufresne, 2019), TIPS (Fleckenstein, Longstaff, and Lustig, 2014), or foreign sovereign bonds (Du, Im, and Schreger, 2018; Jiang, Krishnamurthy, and Lustig, 2021). The yield difference is a measure of the extra safety and liquidity services produced by a cash position in U.S. Treasurys for the marginal bond investor. Similarly, actual German bonds have lower yields than synthetic German yields created from other Eurozone sovereign bonds.

Farhi and Maggiori (2018); Gourinchas and Rey (2016); He, Krishnamurthy, and Milbradt (2019) analyze the theoretical determinants of safe asset demand in the international financial system. He, Krishnamurthy, and Milbradt (2019) emphasize the importance of relative macro fundamentals in determining the safety of a country's outstanding debt. When investors coordinate on a single, safe asset supplier based on relative fundamentals, roll-over risk is reduced, and that country's debt becomes safer.

Finally, there is strong evidence for our assumption of downward-sloping demand curves for safe government debt. Krishnamurthy and Vissing-Jorgensen (2012) document a strong negative relation between the supply of U.S. Treasurys and their convenience yield. Koijen and Yogo (2020) estimate a global demand system for safe and risky assets, backing out demand elasticities for U.S Treasuries from prices and holdings data. In a similar setting, Koijen and Yogo (2017); Koijen, Koulischer, Nguyen, and Yogo (2021) study the effect of ECB bond purchases on the demand for safe and risky assets in the Eurozone. In the long-run, countries that reap the rewards of larger convenience yields can run smaller surpluses (Brunnermeier, Merkel, and Sannikov, 2020; Reis, 2021).

The rest of the paper is organized as follows. Section 2 studies the economics of convenience yields in a currency union. Turning to the data, Section 3 decomposes bond yields into default spreads and convenience yields and measures the relative importance of each. Section 4 studies the fiscal determinants of convenience yields in the data. Section 5 studies the PSPP as a case study impacting Eurozone convenience yields. Section 6 computes revenue losses from convenience yield differentials with Germany. Section 7 concludes.

2 Economics of Convenience Yields in a Currency Union

We will approach the Eurozone as a fully integrated financial market. The Eurozone has implemented many measures to foster financial market integration. In 2009, the Eurozone adopted The Single Rulebook for financial institutions with the Eurozone, which seeks to harmonize the implementation of regulatory standards across different member states.

2.1 General Characterizations

Let i index the countries. For simplicity, we assume governments issue nominal debt of various maturities, all denominated in the Euro. Let $P_t^{i,k}$ denote the k-year yield and let $Q_t^{i,k}$ denote the par value. If the government does not default at time t, the intertemporal government budget condition is

$$T_t^i - G_t^i = Q_{t-1}^{i,1} + \sum_{h=1}^{H-1} Q_{t-1}^{i,h+1} P_t^{i,h} - \sum_{h=1}^{H} Q_t^{i,h} P_t^{i,h}.$$

We assume that capital markets in the Eurozone are integrated, and there is a market-wide nominal pricing kernel $M_{t,t+j}$ for all these countries. In this case, only the union-wide shocks affect the nominal discount rate $1/\mathbb{E}_t\left[M_{t,t+1}\right]$. Idiosyncratic shocks to one particular country do not affect the nominal discount rate. Put differently, even if risk-sharing between the Eurozone countries is incomplete, we assume investors agree on the price of a risk-free one-period bond denominated in euros.

We use χ_t^i to indicate the event of government default at time t. If the default event happens, we assume there is no recovery and all existing debt is wiped out. After the default, the government may or may not maintain access to the credit market. If the government does main the access, it can issue new debt. Moreover, we assume the bonds carry a country- and tenor-specific Euler equation wedge $c_t^{i,k}$, which represents how much risk-adjusted return the investors are willing to forgo to hold the bonds. The Euler equations for bonds with maturity 1 and $h+1$ are

$$\begin{aligned} E_t[M_{t,t+1}(1-\chi_{t+1}^i)]\exp(c_t^{i,1}) &= P_t^{i,1} \\ E_t[M_{t,t+1}P_{t+1}^{i,h}(1-\chi_{t+1}^i)]\exp(c_t^{i,h+1}) &= P_t^{i,h+1}. \end{aligned}$$

For the marginal bond investor, these Euler equation wedges measure the extra safety and liquidity provided by these bonds, compared to other bonds hat promise identical payoffs. For these investors, these wedges do not represent arbitrage opportunities.

The following proposition characterizes the intertemporal government budget condition (Jiang, Lustig, Van Nieuwerburgh, and Xiaolan (2019, 2020)).

Proposition 1 (Intertemporal Government Budget Condition)**.** In the presence of sovereign default and convenience yield, the intertemporal government budget condition is

$$\sum_{h=0}^{H} Q_{t-1}^{i,h+1}P_t^{i,h} = \mathbb{E}_t\left[\sum_{j=0}^{\infty} M_{t,t+j}(T_{t+j}^i - G_{t+j}^i)\right] + \mathbb{E}_t\left[\sum_{j=0}^{\infty} M_{t,t+j}\sum_{h=1}^{H} Q_{t+j}^{i,h}P_{t+j}^{i,h}(1-e^{-c_{t+j}^{i,h}})\right] \quad (1)$$

if the following transversality condition holds,

$$\lim_{\tau\to\infty}\mathbb{E}_t\left[M_{t,t+\tau}\sum_{h=1}^{H} Q_{t+\tau}^{h}P_{t+\tau}^{h}\right] = 0.$$

The proof is in the appendix. The right-hand side of (1) contains two terms. The first term is the present value of government surpluses, which can be thought of as the fundamental cash flows. The second term is the present value of seigniorage revenues, resulting from the fact that investors are willing to accept a lower expected return on these bonds with convenience yields. The bond portfolio has a higher valuation when the present value of government surpluses or that of seigniorage revenues increases.

The left-hand side of (1) denotes the market value of debt outstanding at the start of period

t, which consists of the nominal government debt with various maturities h. We can further decompose the bond price into a risk-free rate component $r_t^h = -\frac{1}{h}\log \mathbb{E}_t[M_{t,t+h}]$, a default spread component $\delta_t^{i,h}$ and a convenience yield component $\lambda_t^{i,h}$:

$$-\frac{1}{h}\log P_t^{i,h} = r_t^h + \delta_t^{i,h} - \lambda_t^{i,h}, \tag{2}$$

where the default spread component captures the risk-neutral expectation of sovereign default for country i's bond,

$$\delta_t^{i,h} \quad = \quad -\frac{1}{h}\log \mathbb{E}_t\left[M_{t,t+h}\prod_{j=1}^{h}(1-\chi_{t+j}^i)\right] + \frac{1}{h}\log \mathbb{E}_t[M_{t,t+h}],$$

and the convenience yield component captures the wedge between the bond yield and the yield of a hypothetical bond with the same default spread but no Euler equation wedge:

$$\lambda_t^{i,h} \quad = \quad \frac{1}{h}\log \mathbb{E}_t\left[M_{t,t+h}\prod_{j=1}^{h}(1-\chi_{t+j}^i)\exp(c_{t+j-1}^{i,h-j+1})\right] - \frac{1}{h}\log \mathbb{E}_t\left[M_{t,t+h}\prod_{j=1}^{h}(1-\chi_{t+j}^i)\right].$$

The bond convenience yield $\lambda_t^{i,h}$ can be regarded as the present value of the Euler equation wedges $\{c_{t+j}^i\}$ that investors enjoy until the maturity of the bond. In particular, if the bond matures in one period, then the bond convenience yield can be simplified to $\lambda_t^{i,1} = c_t^{i,1}$.

Substituting in the bond price, Eq. (1) can be rewritten as

$$\begin{aligned}\sum_{h=0}^{H} Q_{t-1}^{i,h+1}\exp(-(r_t^h+\delta_t^{i,h}-\lambda_t^{i,h})h) \quad &= \quad \mathbb{E}_t\left[\sum_{j=0}^{\infty} M_{t,t+j}(T_{t+j}^i - G_{t+j}^i)\right] \\ &+ \quad \mathbb{E}_t\left[\sum_{j=0}^{\infty} M_{t,t+j}\sum_{h=1}^{H} Q_{t+j}^{i,h}P_{t+j}^{i,h}(1-e^{-c_{t+j}^{i,h}})\right].\end{aligned}$$

Relation to fiscal theory of price level We can also rewrite (1) in real terms:

$$\frac{\sum_{h=0}^{H} Q_{t-1}^{i,h+1}P_t^{i,h}}{\Pi_t^i} = \mathbb{E}_t\left[\sum_{j=0}^{\infty} m_{t,t+j}(\tau_{t+j}^i - g_{t+j}^i)\right] + \mathbb{E}_t\left[\sum_{j=0}^{\infty} m_{t,t+j}\frac{\sum_{h=1}^{H} Q_{t+j}^{i,h}P_{t+j}^{i,h}(1-e^{-c_{t+j}^{i,h}})}{\Pi_{t+j}^i}\right]$$

where m, τ and g are the real pricing kernel, real tax revenue and real government spending, and Π_t^i is the price level in country i. When the real present value of government surpluses or seigniorage revenues declines, the price level can adjust upwards to absorb the shock, thereby restoring the intertemporal government budget condition.

Our model describes a new but similar adjustment mechanism in a monetary union. If the law of one price holds for each good and households choose the same consumption baskets, different countries' price levels Π^i have to be the same. In this case, the country-specific convenience yields, instead of the inflation, can adjust in response to the country's fiscal shocks as well as shocks to future seigniorage revenues.

Special case with a single debt maturity News about future seigniorage revenue and future surpluses has to be matched by innovations in the current risk-free interest rates, default risk premia and convenience yields:

$$\begin{aligned}\sum_{h=0}^{H} Q_{t-1}^{i,h}(\mathbb{E}_t - \mathbb{E}_{t-1}) \exp(-(r_t^h + \delta_t^{i,h} - \lambda_t^{i,h^i})h) &= (\mathbb{E}_t - \mathbb{E}_{t-1}) \left[\sum_{j=0}^{\infty} M_{t,t+j}(T_{t+j}^i - G_{t+j}^i)\right] \\ &+ (\mathbb{E}_t - \mathbb{E}_{t-1}) \left[\sum_{j=0}^{\infty} M_{t,t+j} \sum_{h=1}^{H} Q_{t+j}^{i,h} P_{t+j}^{i,h} (1 - e^{-c_{t+j}^{i,h}})\right].\end{aligned}$$

Without loss of generality, we can use a single zero-coupon bond to re-express this equation:

$$\begin{aligned}Q_{t-1}^{i,*}(\mathbb{E}_t - \mathbb{E}_{t-1}) \exp(-(r_t^{h^i} + \delta_t^{i,h^i} - \lambda_t^{i,h^i})h_{t-1}^i) &= (\mathbb{E}_t - \mathbb{E}_{t-1}) \left[\sum_{j=0}^{\infty} M_{t,t+j}(T_{t+j}^i - G_{t+j}^i)\right] \\ &+ (\mathbb{E}_t - \mathbb{E}_{t-1}) \left[\sum_{j=0}^{\infty} M_{t,t+j} \sum_{h=1}^{H} Q_{t+j}^{i,h} P_{t+j}^{i,h} (1 - e^{-c_{t+j}^{i,h}})\right],\end{aligned}$$

where h_{t-1}^i denotes the average maturity country i's debt.

Since the risk-free rate $r_t^{h^i}$ is the same across all Eurozone countries, the convenience yield λ_t^{i,h^i} and the default spread δ_t^{i,h^i} are more likely to adjust endogenously when the fiscal condition or the seigniorage revenue changes. In this paper, we empirically investigate to what extent the cross-country differences in bond yields are driven by the convenience yield λ_t^{i,h^i} and by the default spread δ_t^{i,h^i}.

Special case without convenience yields and default spreads To build intuition, consider a case without convenience yields and default spreads: $\delta_t^{i,h^i} = c_{t+j}^{i,h} = 0$. Then, equation (1) can be rewritten as:

$$\sum_{h=0}^{H} Q_{t-1}^{i,h+1}(\mathbb{E}_t - \mathbb{E}_{t-1}) \exp(-r_t^h h_{t-1}) = (\mathbb{E}_t - \mathbb{E}_{t-1}) \left[\sum_{j=0}^{\infty} M_{t,t+j}(T_{t+j}^i - G_{t+j}^i)\right].$$

For simplicity, assume each country's government debt portfolio consists of zero-coupon bonds with a single maturity. Then,

$$Q_{t-1}^{i,*}(\mathbb{E}_t - \mathbb{E}_{t-1}) \exp(-r_t^{h^i} h_{t-1}^i) = (\mathbb{E}_t - \mathbb{E}_{t-1}) \left[\sum_{j=0}^{\infty} M_{t,t+j}(T_{t+j}^i - G_{t+j}^i)\right],$$

where h_t^i denotes the aggregate maturity of country i's debt portfolio. $r_t^{h^i}$ denotes the nominal risk-free yield on a zero-coupon bond with maturity h_t^i.

The (weakly) positive variance of the valuation of the government surpluses has to be attributed to a negative covariance between the risk-free rate and the value of a claim to country i's future surpluses:

$$Q_{t-1}^{i,*}\mathrm{Cov}_{t-1}\left(\exp(-r_t^{h^i}h_{t-1}^i), \sum_{j=0}^{\infty} M_{t,t+j}(T_{t+j}^i - G_{t+j}^i)\right) \quad = \quad \mathrm{Var}_{t-1}\left(\sum_{j=0}^{\infty} M_{t,t+j}(T_{t+j}^i - G_{t+j}^i)\right).$$

In other words, if risk-free rates do not covary with the value of a claim to country i 's surpluses, then the present value of government surpluses has to be measurable at time $t-1$, which is a very tight constraint on the dynamics of country i's fiscal budgets.

In addition, we also know that this equation holds at the aggregate level of the entire monetary union:

$$Q_{t-1}^{a,*}\mathrm{Cov}_{t-1}\left(\exp(-r_t^{h^i}h_{t-1}^a), \sum_{j=0}^{\infty} M_{t,t+j}(T_{t+j}^a - G_{t+j}^a)\right) \quad = \quad \mathrm{Var}_{t-1}\left(\sum_{j=0}^{\infty} M_{t,t+j}(T_{t+j}^a - G_{t+j}^a)\right),$$

However, there is only one Euro risk-free rate. So, if the Eurozone countries' debt portfolios have similar maturities, while the Euro risk-free yield curve can help to enforce the aggregate debt valuation equation at the Eurozone level, the Euro yield curve cannot also enforce all of these valuation equations at the country-level.

2.2 Variance Decomposition of Debt Valuation

We develop a variance decomposition of the log of the market's valuation of future government surpluses. We use the following notation for the log of the market value of debt in country i:

$$d_t^i = \log\left(\mathbb{E}_t\left[\sum_{j=0}^{\infty} M_{t,t+j}(T_{t+j}^i - G_{t+j}^i)\right] + \mathbb{E}_t\left[\sum_{j=0}^{\infty} M_{t,t+j}\sum_{h=1}^{H} Q_{t+j}^{i,h}P_{t+j}^{i,h}(1-e^{-c_{t+j}^{i,h}})\right]\right).$$

To develop a formal variance decomposition, we take logs of the country-level expression for the valuation of the surpluses:

$$d_t^i = -(r_t^{h^i} + \delta_t^{i,h^i} - \lambda_t^{i,h^i})h_{t-1}^i + q_{t-1}^{i,*}.$$

The innovation in the market valuation of future surpluses has to coincide with an innovation in the current risk-free rate, the current convenience yield or the current default risk premium:

$$(\mathbb{E}_t - \mathbb{E}_{t-1})\, d_t^i = -h_{t-1}^i\, (\mathbb{E}_t - \mathbb{E}_{t-1})\, (r_t^{h^i} + \delta_t^{i,h^i} - \lambda_t^{i,h^i}).$$

Following this expression, the conditional variance of the log market value of debt of country i can be decomposed into a convenience yield, a yield curve and a default risk premium component:

$$\mathrm{Var}_{t-1}\left(d_t^i\right) \;=\; h_{t-1}^i\left[\mathrm{Cov}_{t-1}\left(\lambda_t^{i,h^i}, d_t^i\right) - \mathrm{Cov}_{t-1}\left(r_t^{h^i}, d_t^i\right) - \mathrm{Cov}_{t-1}\left(\delta_t^{i,h^i}, d_t^i\right)\right].$$

Similarly, we can also take logs of the Euro-zone level expression for the valuation of the surpluses:

$$d_t^a = -(r_t^{h^a} + \delta_t^{a,h^a} - \lambda_t^{a,h})h_{t-1}^a + q_{t-1}^{a,*}.$$

By subtracting the Eurozone level expression from the country-level expression, we obtain the following expression for the deviation of the valuation from the Euro-zone level $\widehat{d}_t^i$:

$$\widehat{d}_t^i = -(r_t^{i,h^i} h_{t-1}^i - r_t^{h^a} h_{t-1}^a) + (\delta_t^{i,h^i} h_{t-1}^i - \delta_t^{a,h^a} h_{t-1}^a) - (\lambda_t^{i,h^i} h_{t-1}^i - \lambda_t^{a,h} h_{t-1}^a) + \widehat{q}_{t-1}^{i,*}$$

The innovations to $\widehat{d}_t^i$ largely measures the innovations to the *cash flow component*, because we are comparing the valuation of the surplus for country i relative to valuation of the aggregate surplus using the same SDF. As a result, we interpret the innovations to $\widehat{d}_t^i$ as fiscal news in country i.

Finally, we derive the variance decomposition for the log valuation of country i's in deviation from the Eurozone aggregate level:

$$\begin{aligned}\mathrm{Var}_{t-1}\left(\widehat{d}_t^i\right) \;&=\; h_{t-1}^i\left[\mathrm{Cov}_{t-1}\left(\lambda_t^{i,h^i}, \widehat{d}_t^i\right) - \mathrm{Cov}_{t-1}\left(r_t^{h^i}, \widehat{d}_t^i\right) - \mathrm{Cov}_{t-1}\left(\delta_t^{i,h^i}, \widehat{d}_t^i\right)\right] \\ &-\; h_{t-1}^a\left[\mathrm{Cov}_{t-1}\left(\lambda_t^{a,h^a}, \widehat{d}_t^i\right) - \mathrm{Cov}_{t-1}\left(r_t^{h^i}, \widehat{d}_t^i\right) - \mathrm{Cov}_{t-1}\left(\delta_t^{a,h^a}, \widehat{d}_t^i\right)\right].\end{aligned}$$

We analyze a natural benchmark case in which $h^i = h^a$. Define $\widehat{\lambda}_t^{i,h} = \lambda_t^{i,h} - \lambda_t^{a,h}$, and $\widehat{\delta}_t^{i,h} = \delta_t^{i,h} - \delta_t^{a,h}$. Then, we obtain a relative variance decomposition.

Result 1. In a monetary union with integrated capital markets, if country i's outstanding debt has the same duration as the aggregate monetary union's debt portfolio ($h_{t-1}^i = h_{t-1}^a$), the conditional variance of the log market value in deviation of the monetary union aggregate is given by a convenience yield and a default risk component:

$$\mathrm{Var}_{t-1}\left(\widehat{d}_t^i\right) \;=\; h_{t-1}\mathrm{Cov}_{t-1}\left(\widehat{\lambda}_t^{i,h}, \widehat{d}_t^i\right) - h_{t-1}\mathrm{Cov}_{t-1}\left(\widehat{\delta}_t^{i,h}, \widehat{d}_t^i\right).$$

The conditional variance of the log market value in deviation from the Euro-level aggregate can be decomposed into to a convenience yield component and default risk component. There is no risk-free yield curve contribution. The nominal risk-free yield curve plays not role, because the country and the Eurozone share the same nominal pricing kernel and nominal risk-free rate.

A positive conditional variance has to coincide either with a positive conditional covariance of the current convenience yield (in deviation from the Euro-level aggregate) with the market value of debt, in deviation from the Euro-level aggregate, or with a negative conditional covariance of the market value with the default risk premium (in deviation from the Euro-level aggregate), or with a combination of both.

In Section 4, we develop measure fiscal news in country i, $\widehat{d}_t^i$, and estimate a regression of the convenience yield differentials on the fiscal news, to compute the slope coefficient:

$$1 \quad = \quad h_{t-1} \frac{\text{Cov}_{t-1}\left(\widehat{\lambda}_t^{i,h}, \widehat{d}_t^i\right)}{\text{Var}_{t-1}\left(\widehat{d}_t^i\right)} - h_{t-1} \frac{\text{Cov}_{t-1}\left(\widehat{\delta}_t^{i,h}, \widehat{d}_t^i\right)}{\text{Var}_{t-1}\left(\widehat{d}_t^i\right)}. \tag{3}$$

Positive fiscal news for country i relative to the other countries in the monetary union has to coincide with an increase in the current convenience yield or a decrease in the current default risk premium:

$$\left(\mathbb{E}_t - \mathbb{E}_{t-1}\right) \widehat{d}_t^i = h_{t-1} \left(\mathbb{E}_t - \mathbb{E}_{t-1}\right) \left(\widehat{\lambda}_t^{i,h} - \widehat{\delta}_t^{i,h}\right).$$

In a monetary union, in the absence of duration differences, good fiscal news in country i has to be reflected in the country-specific convenience yield or default risk premium today. The nominal risk-free yield curve cannot adjust to enforce the valuation equation at the country level, unless there are differences in duration across countries.

Suppose country i's default risk premium does not respond to fiscal shock. Then, all else equal, news about higher surpluses in country i relative to the Euro-wide surpluses would have to reflected in higher convenience yields.

The ECB has started a PSPP (Public Sector Purchase Programme) in March of 2015. In peripheral countries, the ECB programme seems to have muted the response of CDS spreads to adverse fiscal news by eliminating roll-over risk, at least in the short run. This shifts the burden of adjustment to the convenience yield channel in absorbing fiscal shocks.[2] Next, we describe the economic mechanism that links convenience yields to fiscal news.

2.3 Fiscal News Channel for Convenience Yields

If the demand curve for safe assets is downward sloping, then we expect to see positive time-series covariance between innovations to the surplus process in the short run and convenience yield innovations. Negative short-run fiscal news implies an increase in supply.

Let $\kappa_{t+j} D_{t+j}$ denote the seigniorage revenue at time $t+j$, which is $\sum_{h=1}^{H} Q_{t+j}^{i,h} P_{t+j}^{i,h} (1 - e^{-c_{t+j}^{i,h}})$ in our previous expressions. The relation between fiscal news at horizon h, debt supply h periods

[2]These purchases may have increased the convenience yields on German bonds and its close substitutes by increasing the scarcity of the safe asset, thus increasing the funding cost advantage of the German government and other central country governments (see Corradin, Grimm, and Schwaab, 2021, for evidence).

from now and the returns today:

$$(\mathbb{E}_t - \mathbb{E}_{t-1}) \sum_{j=0}^{h} M_{t,t+j}(T^i_{t+j} - G^i_{t+j} + \kappa_{t+j} D_{t+j}) = -(\mathbb{E}_{t+1} - \mathbb{E}_t) M_{t+1,t+h} D_{t+h} + D_t (\mathbb{E}_{t+1} - \mathbb{E}_t)[R^D_{t+1}]. \quad (4)$$

This expression follows directly from the government budget constraint. A negative fiscal shock over horizon h, measured by

$$(\mathbb{E}_t - \mathbb{E}_{t-1}) \left[\sum_{j=0}^{h} M_{t,t+j}(T^i_{t+j} - G^i_{t+j} + \kappa_{t+j} D_{t+j}) \right] \ll 0,$$

will raise the debt supply h periods from now, unless there is a large negative debt return realization. If the debt is nominally risk-free (has zero beta), then $(\mathbb{E}_{t+1} - \mathbb{E}_t)[R^D_{t+1}] = 0$.

Given that demand for safe assets is downward sloping, the expected convenience yield $\mathbb{E}_t \lambda^1_{t+h}$ will tend to decline in the expected future supply $\mathbb{E}_t M_{t+1,t+h} \frac{D_{t+h}}{Y_t}$ (Krishnamurthy and Vissing-Jorgensen, 2012; Koijen and Yogo, 2020).

Assumption 1. Downward sloping demand curves:

$$\text{Cov}_t \left((\mathbb{E}_{t+1} - \mathbb{E}_t) M_{t+1,t+h} D_{t+h}, (\mathbb{E}_{t+1} - \mathbb{E}_t) \lambda^1_{t+h} \right) \ll 0.$$

In addition, we assume that a version of the expectations hypothesis holds for the convenience yields. We use H to denote the longest outstanding maturity in the government's debt portfolio.

Assumption 2. Expectations hypothesis for convenience yields: The expected convenience yield $\lambda^h_t = \frac{1}{h} \mathbb{E}_t \sum_{j=0}^{h-1} \lambda^1_{t+j}$.

This delivers the follow prediction for the relation between short-run fiscal shocks and convenience yields.

Result 2. In the presence of downward sloping demand curves for safe assets, and if the expectations hypothesis holds for convenience yields, then for any $h \leq H$, the covariance between fiscal news at horizon h and the convenience yield h years from now is positive:

$$\text{Cov}_t \left((\mathbb{E}_{t+1} - \mathbb{E}_t) \sum_{j=1}^{h} M_{t,t+j}(T^i_{t+j} - G^i_{t+j} + \kappa_{t+j} D_{t+j}), (\mathbb{E}_{t+1} - \mathbb{E}_t) \lambda^1_{t+h} \right) \gg 0.$$

For any $h \leq H$, the largest maturity outstanding, we have that the covariance between fiscal news and convience yields can be decomposed as follows:

$$\begin{aligned}
& \mathrm{Cov}_t\left((\mathbb{E}_t-\mathbb{E}_{t-1})\sum_{j=1}^{h} M_{t,t+j}(T^i_{t+j}-G^i_{t+j}+\kappa_{t+j}D_{t+j}),(\mathbb{E}_t-\mathbb{E}_{t-1})\lambda^1_{t+h}\right) \\
= & -\mathrm{Cov}_t\left((\mathbb{E}_t-\mathbb{E}_{t-1})M_{t+1,t+h}D_{t+h},(\mathbb{E}_t-\mathbb{E}_{t-1})\lambda^1_{t+h}\right)+D_t\mathrm{Cov}_t\left((\mathbb{E}_t-\mathbb{E}_{t-1})R^D_{t+1},(\mathbb{E}_t-\mathbb{E}_{t-1})\lambda^1_{t+h}\right).
\end{aligned}$$

This follows directly from Eq. (5). The first term on the right hand side is positive because of the downward sloping demand curves assumption 1 implies a negative covariance term. In addition, we know that the second covariance between the convenience yield and the return on the debt portfolio is positive, because higher convenience yields imply higher bond returns on the debt outstanding as a result of Assumption 2: an increase in λ^h_t results from an increase in the expected convenience yield h years from now, λ^1_{t+h}, as long as we the horizon h does not extend the longest maturity of outstanding debt, $h < H$. Once we go beyond the longest maturity, this result breaks down, because it relies on the short-run supply effects of fiscal innovations on the convenience yield of outstanding debt.

This fiscal news channel is operative even if there is no long-run fiscal news, i.e. when the debt is nominally risk-free. In this case,

$$(\mathbb{E}_t-\mathbb{E}_{t-1})\sum_{j=0}^{\infty} M_{t,t+j}(T^i_{t+j}-G^i_{t+j}+\kappa_{t+j}D_{t+j})=0.$$

What matters is the short-run supply effect, which affects the covariance between the fiscal news within the next h periods and the convenience yields in h periods.

2.4 A Numerical Example

For simplicity, we assume no output growth and no default. Investors are risk-neutral and have a constant discount rate. The SDF is simply $M_{t,t+h}=\exp(-rh)$. Government debt has an exponential maturity structure:

$$Q^{i,h}_t \quad = \quad Q^i_t\exp(-\nu(h-1)).$$

We assume the Euler equation wedge is the same for debt of different maturities: $c^{i,h}_{t+k}=c^i_{t+k}$. To derive the steady-state dynamics, we assume $S^i_t=\bar{S}^i$ and $c^i_t=\bar{c}^i$ for all periods. Then, the government's intertemporal budget condition (1) implies

$$\bar{Q}^i\frac{1}{1-\exp(-r-\nu+\bar{c}^i)} \quad = \quad \frac{1}{1-\exp(-r+\bar{c}^i)}\bar{S}^i,$$

which is approximately

$$\bar{Q}^i \quad = \quad (1 + \frac{\nu}{r - \bar{c}^i})\bar{S}^i.$$

So, in a steady state, for the same level of government debt outstanding $\bar{Q}^i$, a higher Euler equation wedge $\bar{c}^i$ corresponds to a lower government surplus $\bar{S}^i$. To understand this result, we note that a higher Euler equation wedge generates a higher seigniorage revenue, which allows the government to run a lower surplus while sustaining the same level of government debt.

Next, we show that the relationship between government surplus and convenience yield can turn positive in the time series, which would be consistent with the prediction from Result 2. In particular, we assume that the log government debt follows an AR(1) process:

$$\log Q^i_{t+1} = \phi \log Q^i_t + (1-\phi)\log \bar{Q}^i + \sigma \varepsilon^i_{t+1}.$$

Also, following Assumption 1, we assume the Euler equation wedge is a decreasing function of the quantity of government debt outstanding:

$$c^i_t = \bar{c}^i \exp(-\beta(\log Q^i_t - \log \bar{Q}^i)).$$

Then, for period t, the bond convenience yield is

$$\begin{aligned} \lambda^{i,h}_t \quad &= \quad \frac{1}{h}\log \mathbb{E}_t \left[M_{t,t+h} \exp(\sum_{j=0}^{h-1} c^{i,h-j}_{t+j}) \right] - \frac{1}{h}\log \mathbb{E}_t \left[M_{t,t+h} \right] = \frac{1}{h}\log \mathbb{E}_t \left[\exp(\sum_{j=0}^{h-1} c^i_{t+j}) \right] \\ &= \quad \frac{1}{h}\mathbb{E}_t \left[\sum_{j=0}^{h-1} c^i_{t+j} \right] + Jensen \end{aligned}$$

which expresses the convenience yield as the sum of expected future Euler wedge and a Jensen's term. If the expectation hypothesis holds as in Assumption 2, the Jensen's term has to be 0. In this example, although investors are risk-neutral, the Jensen's term still exists due to higher-order terms from the expectation of exponentials. We ignore variations in the higher-order terms, effectively taking a first-order approximation.

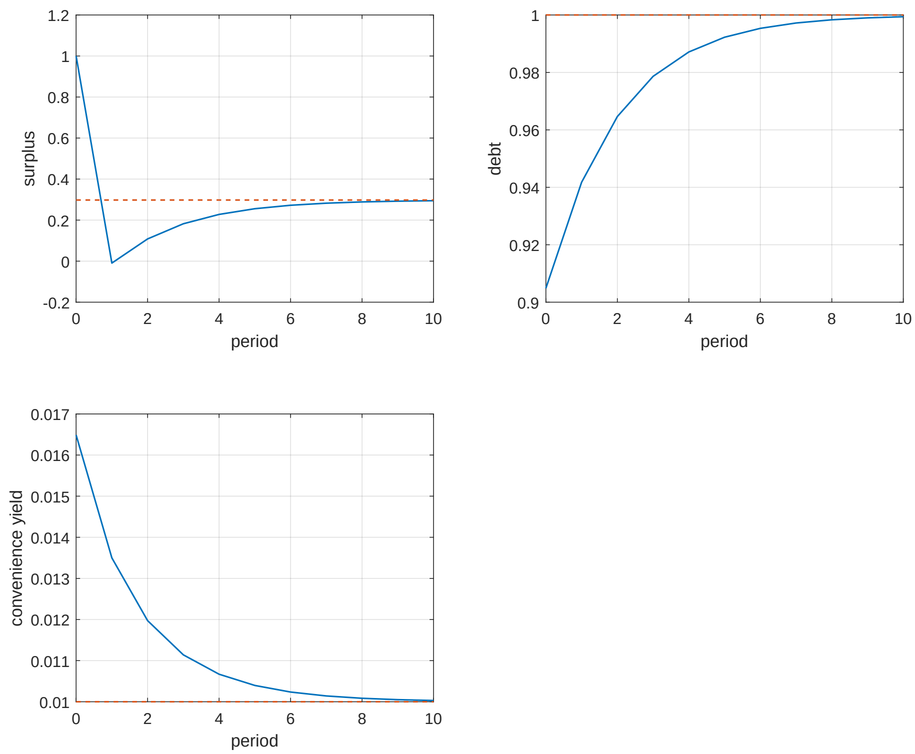
We consider a negative shock to government debt $\varepsilon_t < 0$, and then compute the responses assuming future shocks to government debt are all zero. The law of motion for the government surplus is determined by the one-period government budget condition:

$$S^i_{t+j} = \sum_{h=0}^{\infty} Q^{i,h+1}_{t+j-1} P^{i,h}_{t+j} - \sum_{h=1}^{\infty} Q^{i,h}_{t+j} P^{i,h}_{t+j} = \sum_{h=0}^{\infty} Q^i_{t+j-1} e^{-\nu h} e^{-hr + h\lambda^{i,h}_{t+j}} - \sum_{h=1}^{\infty} Q^i_{t+j} e^{-\nu(h-1)} e^{-hr + h\lambda^{i,h}_{t+j}}.$$

Figure 2 reports this impulse-response. The fiscal shock arrives in period 1, raising the government surplus and hence lowering the outstanding quantity of government debt. By Assumption 1, the convenience yield goes up. So, the spot response of the bond convenience yield is positively correlated with the shock to government surplus.

After the initial shock, it takes about 10 periods for the government debt quantity to return to its steady-state value. During this period, the convenience yield remains high. As a higher convenience yield means higher seigniorage revenue, the government can run lower government surplus in future periods.

Figure 2: Numerical Example: Impulse-Response to Fiscal Shock



Notes: This figure reports the impulse responses of government surplus, bond quantity, and bond convenience yield after a positive shock to government surplus.

3 Convenience Yields in Eurozone Sovereign Bonds

3.1 Data

Eq. (2) implies that the bond yield for a given maturity h is determined by the common nominal risk-free rate r_t^h, the default spread $\delta_t^{i,h}$, and the convenience yield $\lambda_t^{i,h}$. If we compare the bond yields between any other Eurozone countries and Germany, we can difference out the common nominal risk-free rate, and show that the differential in bond yields is driven by the differential in either the default spreads or the convenience yields:

$$(y_t^i - y_t^{DE}) \equiv \tilde{y}_t^i \quad = \quad \tilde{\delta}_t^i - \tilde{\lambda}_t^i \equiv (\delta_t^i - \delta_t^{DE}) - (\lambda_t^i - \lambda_t^{DE}), \tag{5}$$

where the tilde sign denotes the differential between country i and Germany. This equation allows us to measure the convenience yield differential.

Eq. (5) allows us to recover the convenience yield differential $\tilde{\lambda}_t^i$ from bond yields and CDS spreads. A higher value means country i's bond has a higher convenience yield. When the government bond yields and CDS spreads are correctly measured, the convenience yield differential represents a deviation from the covered interest rate parity.

Our sample is from 2002 to 2020 and includes Austria, Belgium, Finland, France, Germany, Italy, Netherlands, Portugal, and Spain. We do not include Greece since it defaulted in this sample and was excluded from the sovereign debt market. The tenors in our data include 1, 2, 3, 5, 7, 10, 15, 20, and 30 years, and our preferred tenor is 5 years because the 5-year CDS contracts tend to be the most liquid. The government bond yields are from Bloomberg par yields and the CDS spreads are from Markit, and both are Euro-denominated. Appendix Figure A.1, Figure A.2 and Figure A.3 report the time series of yield, CDS spread, convenience yield for each country and tenor.

A relevant issue in the CDS market is the bond redenomination risk (Kremens (2018)). There is a small chance that countries in the Eurozone may leave the currency union and redenominate its bonds in a different currency. Depending on the relative value of the new currency, the redenomination may lead to either capital loss or gain from the perspective of the bondholders, in which cases it is called positive and negative redenomination risk, respectively. We use the CDS spreads from the CR contracts before 2014 and we use the CR14 contracts as they become available from 2014. The CR contracts do not pay off in the event of redenomination without default for France, Germany and Italy, but not for other countries in our sample. Thus, we are missing out the positive redenomination risk in the absence of default for these three countries before 2014. However, we think this event is unlikely since countries are more likely to simultaneously default and redenominate their debt when they exit the Eurozone.

We are also missing out the negative redenomination risk. Specifically, if the German government redenominates its debt back to the Mark when Germany leaves the Euro Area in a future date, and the Mark is stronger than the Euro, then, the German sovereign yield today may be lower to reflect this valuation. Moreover, as no CDS contracts have negative payoff in this event, the valuation manifests itself as a convenience yield. We acknowledge that, given very limited data and information about the rare event Germany leaves the Eurozone, we cannot distinguish our convenience yield measure from this negative redenomination risk. Therefore, our convenience yield has a broader interpretation that contains this negative redenomination risk.

3.2 Summary Statistics

Table 1 reports the summary statistics of convenience yield spreads based on 5-year bonds and CDS, which is the most liquid. We split our sample in 2008/01/01 because the bond yield differentials, CDS premium differerntials, and convenience yield differerntials are all very close to 0 before 2008 and widen up dramatically after 2007.

On average, the convenience yield differentials against German bonds are negative, which

Table 1: Summary Statistics of Convenience Yield Differentials

Panel (a) 2002—2007							
Country	Mean	Std Dev	10th Pct	50th Pct	90th Pct	Skewness	Autocorr
Austria	−0.05	0.05	−0.14	−0.04	−0.00	−0.87	0.84
Belgium	−0.04	0.05	−0.12	−0.03	0.00	−0.97	0.88
Finland	−0.06	0.07	−0.18	−0.06	0.01	−0.96	0.86
France	−0.02	0.03	−0.06	−0.02	0.01	−0.36	0.83
Ireland	−0.05	0.06	−0.12	−0.03	0.02	−0.59	0.60
Italy	−0.02	0.05	−0.08	−0.03	0.04	−0.05	0.82
Netherlands	−0.03	0.03	−0.06	−0.03	−0.00	−0.92	0.42
Portugal	−0.06	0.06	−0.14	−0.04	−0.00	−1.13	0.84
Spain	−0.02	0.06	−0.09	−0.02	0.04	−0.92	0.85
Average	−0.04	0.05	−0.11	−0.03	0.01	−0.75	0.77
OIS-Germany	−0.16	0.08	−0.29	−0.16	−0.06	−0.26	0.87
Panel (b) 2008—2020							
Country	Mean	Std Dev	10th Pct	50th Pct	90th Pct	Skewness	Autocorr
Austria	−0.13	0.17	−0.31	−0.13	0.04	−0.42	0.83
Belgium	−0.17	0.22	−0.41	−0.13	0.08	−1.75	0.85
Finland	−0.19	0.14	−0.35	−0.16	−0.06	−1.58	0.82
France	−0.10	0.12	−0.26	−0.08	0.04	−0.98	0.60
Ireland	−0.38	0.69	−1.28	−0.15	0.08	−2.22	0.79
Italy	−0.30	0.42	−0.72	−0.18	0.11	−2.04	0.82
Netherlands	−0.12	0.09	−0.25	−0.10	−0.04	−1.17	0.72
Portugal	−0.69	1.20	−2.01	−0.24	0.05	−2.79	0.91
Spain	−0.38	0.49	−1.01	−0.24	0.07	−1.69	0.91
Average	−0.27	0.39	−0.73	−0.16	0.04	−1.63	0.81
OIS-Germany	−0.33	0.17	−0.50	−0.31	−0.15	−1.07	0.84

Notes: The convenience yield differentials $\tilde{\lambda}_t^i = \lambda_t^i - \lambda_t^{DE}$ with 5-year tenor are annualized and reported in percentage points. The data are at monthly frequency.

means the German bonds enjoy higher convenience yields than any other countries. This gap widens after 2007, averaging to 27 basis points per annum. The convenience yield differentials vary both across countries and across time: for example, France and Netherlands tend to have higher convenience yields than Italy and Portugal. In the time series, the convenience yield differentials have large standard deviations and tend to be negatively skewed. Moreover, the convenience yield differentials are relatively persistent at monthly frequency. The average autocorrelation is 0.87 before 2007 and 0.84 after 2007.

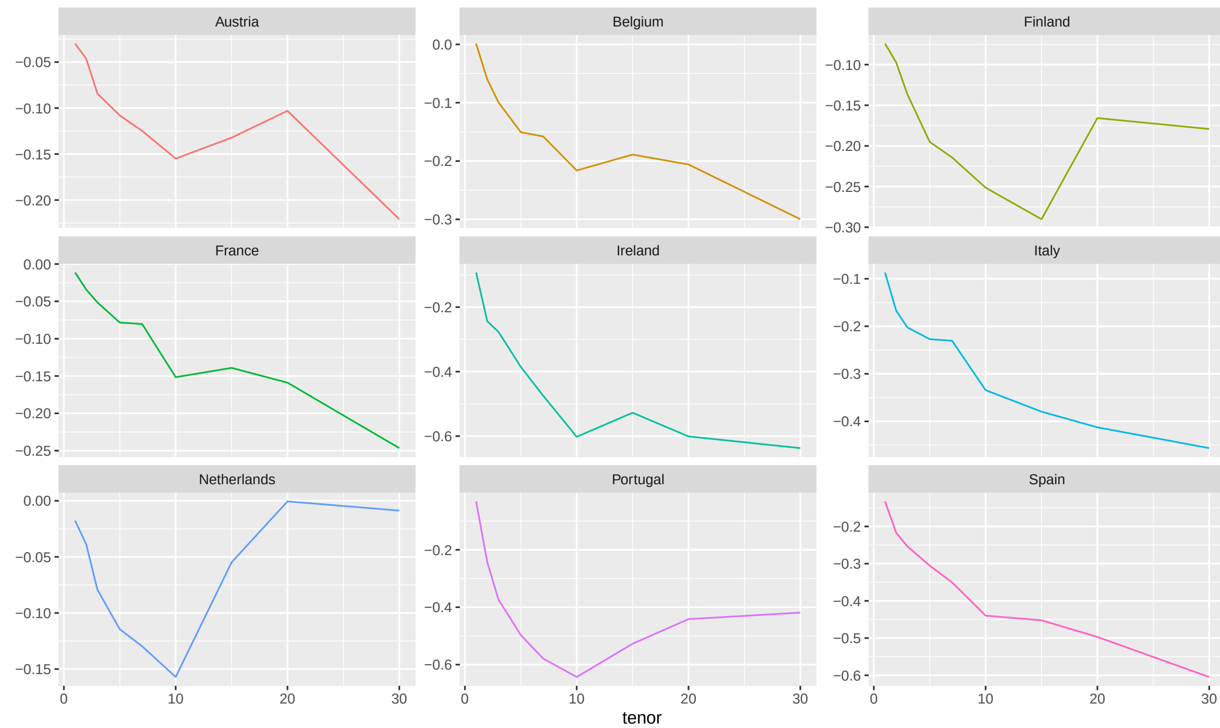
Do these bilateral convenience yield differentials between each country and Germany capture the majority of convenience yield? It is possible that all these government bonds share a baseline level of convenience yield that is differenced out in our estimate. To provide an estimate, we treat the OIS rate as another country's government bond yield, and calculate the hypothetical convenience yield differential between OIS and Germany. Assuming the OIS has no default risk, this OIS-Germany spread is

$$\tilde{\lambda}_t^{OIS} \quad = \quad (0 - \delta_t^{DE}) - (y_t^i - y_t^{DE}).$$

We further assume that the OIS rate provides no convenience benefit, then, this OIS-Germany spread $\tilde{\lambda}_t^{OIS} = \lambda_t^{OIS} - \lambda_t^{DE} = -\lambda_t^{DE}$ provides an estimate for the magnitude of German bonds' convenience yield. We report the statistics of this OIS-Germany spread in the last row of Table 1. Before 2007, this spread is -16 basis points on average, meaning that German bonds' convenience yield is about 16 basis points. This spread is much greater in magnitude than the average convenience yield differential between other countries and Germany, implying that all countries' bonds enjoy a nontrivial amount of convenience yield before 2007. After 2007, this OIS-Germany spread is -33 basis points on average, which is comparable to the average convenience yield differential between other countries and Germany. So, to the extent that the OIS rate proxies for the risk-free rate without convenience yield, the average Eurozone countries' bonds carry nearly zero convenience yield after 2007. Some countries such as Portugal even have negative convenience yield with respect to the OIS rate.

We also calculate the convenience yields of different tenors. Figure 3 reports the average term structure of convenience yield differentials for each country. For most countries, the term structure is downward-sloping, suggesting that the long-term German bonds enjoy higher convenience yields against foreign bonds than short-term German bonds. Notable exceptions include Finland and Netherlands, which may be related to their pension funds buying the long-term bonds issued by their own governments.

Figure 3: The Term Structure of Average Convenience Yields



Notes: The convenience yield differentials $\tilde{\lambda}_t^i = \lambda_t^i - \lambda_t^{DE}$ are annualized and reported in percentage points.

3.3 Variance Decomposition

We consider two ways to decompose the variance of bond yields. By Eq. (5),

$$\begin{aligned} var(\Delta\tilde{y}_t^i) &= var(\Delta\tilde{\delta}_t^i) + var(\Delta\tilde{\lambda}_t^i) - 2cov(\Delta\tilde{\delta}_t^i, \Delta\tilde{\lambda}_t^i) \\ &= cov(\Delta\tilde{y}_t^i, \Delta\tilde{\delta}_t^i) - cov(\Delta\tilde{y}_t^i, \Delta\tilde{\lambda}_t^i), \end{aligned}$$

which implies two ways to decomposition methods. First, the variance of the bond yield is equal to the variance of its default spread, plus the variance of its convenience yield, minus two times their covariance. Second, the variance of the bond yield is also equal to the covariance between the bond yield and the default spread minus the covariance between the bond yield and the convenience yield.

We apply both decomposition methods to bonds with 5-year tenors. Table 2 reports the results. Before 2008, the bond yield fluctuations display low amplitude (with a mean standard deviation of 4 basis points per month), and the convenience yield component accounts for the majority of the variance for both decompositions.

After the financial crisis, the bond yield is much more volatile (with a mean standard deviation

Table 2: Variance Decomposition of Convenience Yield Spread Movement

Country	$sd(\Delta\tilde{y}_t^i)$	$\frac{var(\Delta\tilde{\delta}_t^i)}{var(\Delta\tilde{y}_t^i)}$	$\frac{var(\Delta\tilde{\lambda}_t^i)}{var(\Delta\tilde{y}_t^i)}$	$\frac{-2cov(\Delta\tilde{\delta}_t^i,\Delta\tilde{\lambda}_t^i)}{var(\Delta\tilde{y}_t^i)}$	$\frac{cov(\Delta\tilde{y}_t^i,\Delta\tilde{\delta}_t^i)}{var(\Delta\tilde{y}_t^i)}$	$\frac{-cov(\Delta\tilde{y}_t^i,\Delta\tilde{\lambda}_t^i)}{var(\Delta\tilde{y}_t^i)}$
Panel (a) 2002—2007						
Austria	0.03	0.06	1.09	−0.15	−0.01	1.01
Belgium	0.02	0.22	1.16	−0.38	0.03	0.97
Finland	0.04	0.04	1.03	−0.07	0.01	0.99
France	0.02	0.20	1.15	−0.35	0.02	0.98
Ireland	0.05	0.03	1.04	−0.07	−0.01	1.01
Italy	0.03	0.39	1.14	−0.53	0.13	0.87
Netherlands	0.02	0.05	1.18	−0.23	−0.07	1.07
Portugal	0.06	0.06	1.06	−0.11	0.00	1.00
Spain	0.03	0.26	1.19	−0.45	0.03	0.97
Average	0.03	0.15	1.12	−0.26	0.01	0.99
Panel (b) 2008—2020						
Country	$sd(\Delta\tilde{y}_t^i)$	$\frac{var(\Delta\tilde{\delta}_t^i)}{var(\Delta\tilde{y}_t^i)}$	$\frac{var(\Delta\tilde{\lambda}_t^i)}{var(\Delta\tilde{y}_t^i)}$	$\frac{-2cov(\Delta\tilde{\delta}_t^i,\Delta\tilde{\lambda}_t^i)}{var(\Delta\tilde{y}_t^i)}$	$\frac{cov(\Delta\tilde{y}_t^i,\Delta\tilde{\delta}_t^i)}{var(\Delta\tilde{y}_t^i)}$	$\frac{-cov(\Delta\tilde{y}_t^i,\Delta\tilde{\lambda}_t^i)}{var(\Delta\tilde{y}_t^i)}$
Austria	0.10	1.27	1.24	−1.50	0.52	0.48
Belgium	0.17	0.50	0.75	−0.26	0.38	0.62
Finland	0.07	0.39	1.46	−0.85	−0.03	1.03
France	0.08	1.69	1.98	−2.67	0.35	0.65
Ireland	0.54	0.44	0.61	−0.05	0.41	0.59
Italy	0.36	0.63	0.39	−0.03	0.62	0.38
Netherlands	0.05	1.15	1.95	−2.11	0.10	0.90
Portugal	0.85	0.74	0.40	−0.14	0.67	0.33
Spain	0.34	0.49	0.40	0.11	0.54	0.46
Average	0.29	0.81	1.02	−0.83	0.40	0.60

Notes: The yields are annualized and reported in percentage points. The data are at monthly frequency.

of 30 basis points per month). Under the first method, the convenience yield component is slightly more volatile than the default spread, but convenience yields and default spreads are positively correlated. Under the second method, the convenience yield component explains 60% of the variation in the yield differential, whereas the default spread component explains the remaining 40%. In other words, the convenience yield component accounts for a greater fraction of variation in the bond yield than the default spread component.

3.4 The Common Factor in Convenience Yields

Moreover, if we use the Euro OIS as the risk-free rate in Eq. (2)[3], reproduced below,

$$r_t^h + \delta_t^{i,h} - \lambda_t^{i,h} = y_t^{i,h},$$

[3] OIS rates with maturity beyond two years are not available before 2005-06. For the earlier subsample, we use the zero-coupon curve derived from OIS.

we can measure the country-specific convenience yield $\lambda_t^{i,h}$ that is not a differential relative to Germany. By regressing this convenience yield on Germany's convenience yield,

$$\lambda_t^{i,h} = \alpha^i + \beta^i \lambda_t^{DE,h} + \varepsilon_t^i, \tag{6}$$

we can examine the common comovements in the convenience yields.

Table 3 (a) reports the results, restricting the sample to the 5-year tenor. When Germany's convenience yield is high, countries like Austria and Netherlands tend to have high convenience yields as well, whereas countries like Italy and Portugal tend to have low convenience yields. None of the β^i coefficient is above 1, which suggests that when Germany's convenience yield is higher, it also rises above other countries' convenience yields. Moreover, with the exception of Ireland and Spain, the R^2s are large, suggesting the Germany's convenience yield represents a common factor in the cross-section of convenience yields.

Table 3 (b) repeats the exercise using monthly changes of convenience yields instead of the levels. At this higher frequency, all loadings are positive—Eurozone sovereign debt's convenience yields have positive comovements.

Table 3: Loadings on German Convenience Yields

	Panel (a): Dependent variable is the level $\lambda_t^{i,h}$								
	AT	BE	FI	FR	IE	IT	NL	PT	ES
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Germany CY	0.56***	0.25***	0.45***	0.69***	0.35	−0.30**	0.74***	−2.48***	−0.31*
	(0.05)	(0.06)	(0.04)	(0.04)	(0.24)	(0.13)	(0.03)	(0.36)	(0.16)
Observations	223	223	216	223	218	223	186	223	223
Adjusted R^2	0.33	0.07	0.34	0.60	0.005	0.02	0.72	0.18	0.01
	Panel (b): Dependent variable is the monthly change $\Delta\lambda_t^{i,h}$								
	AT	BE	FI	FR	IE	IT	NL	PT	ES
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
ΔGermany CY	0.86***	0.73***	0.63***	1.00***	1.10***	0.47***	0.71***	1.12***	0.37***
	(0.07)	(0.08)	(0.05)	(0.07)	(0.31)	(0.17)	(0.05)	(0.36)	(0.14)
Observations	222	222	215	222	217	222	185	222	222
Adjusted R^2	0.41	0.27	0.40	0.45	0.05	0.03	0.57	0.04	0.03

Notes: Panel (a) reports the results of the regression (6) in the time series of each country's 5-year convenience yield. Panel (b) repeats the exercise by using the monthly changes of the convenience yields instead of the levels. *p<0.1; **p<0.05; ***p<0.01.

4 The Fiscal Origins of Convenience Yields

4.1 Explaining Cross-Country Variation in Convenience Yields

We obtain the government primary surplus and GDP data from Eurostat. The primary surplus is defined as the general government's net lending/borrowing minus the interest payable.

First, we examine the relationship between a country's average convenience yield and its average government surplus-to-GDP or debt-to-GDP ratios. We also define the surplus cyclicality as the slope coefficient β^i from

$$\Delta s_t^i = \alpha^i + \beta^i \frac{1}{N} \sum_{i=1}^{N} \Delta s_t^i + \varepsilon_t^i$$

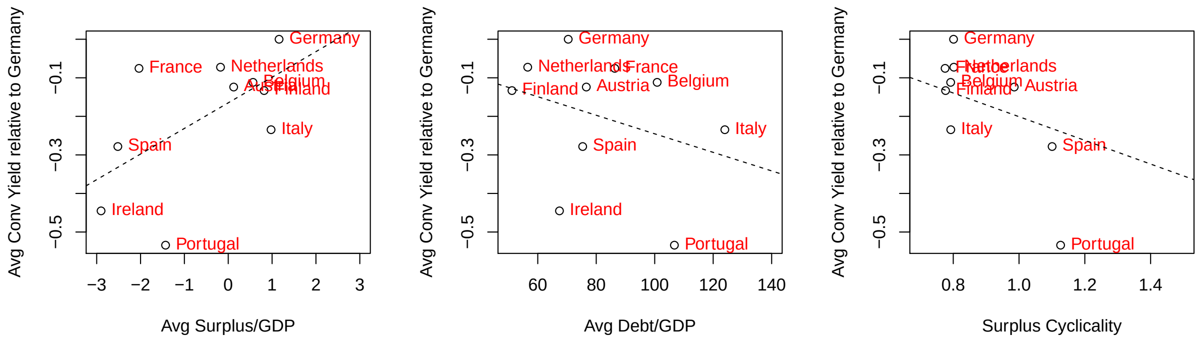
which captures how much a country's government surplus-to-GDP ratio moves when the Eurozone average moves.

Figure 4 plots these cross-sectional comparisons among 5-year bonds. On average, Germany has high government surplus-to-GDP ratio, low debt-to-GDP ratio, and low surplus cyclicality, and it earns the highest average convenience yield among the Eurozone countries. In comparison, Portugal has low surplus-to-GDP ratio, high debt-to-GDP ratio, and high surplus cyclicality, and it earns negative convenience yield relative to Germany. These findings are consistent with downward sloping demand for sovereign debt by a given issuer within the Eurozone. As countries issue more, the convenience yields on the debt declines. In addition, relative fundamentals play a role in the determination of safe asset demand, as pointed out by He, Krishnamurthy, and Milbradt (2019). As the relative fundamentals improve, a country's debt benefits from more safe asset demand within the Eurozone.

Table 4 reports these results in linear regressions. We run two specifications. In Panel (a), we run a panel regression by pooling all tenors and then control for the tenor fixed effects. The multivariate regression result in Column (5) suggests that a one-standard-deviation increase in the average surplus-to-GDP ratio (which is 1.7%) increases the average convenience yield by 6.5 basis points. Similarly, a one-standard-deviation increase in the average debt-to-GDP ratio (which is 22%) decreases the average convenience yield by 8.0 basis points, and a one-standard-deviation increase in the surplus cyclicality (which is 0.49) decreases the average convenience yield by 6.6 basis points. The predicted difference in average convenience yields between Germany and Portugal, based on the difference in their fiscal conditions and parameter estimates in Column (5), is 38 basis points, whereas the actual difference in average convenience yields between Germany and Portugal is 49 basis points.

In Panel (b), we run a cross-sectional regression of 5-year bond yields only. The coefficient estimates are similar but the statistical significance is weaker as there are only 10 data points. In

Figure 4: The Cross-Section of Convenience Yields and Fiscal Status



Notes: The left panel plots the time-series average convenience yield spread against the time-series average primary surplus-to-GDP ratio, the middle panel against the time-series average government debt-to-GDP ratio, and the right panel against the surplus cyclicality. All convenience yields are for the 5-year tenor.

Table 4: Average Convenience Yield vs. Average Fiscal Conditions.

	(1)	(2)	(3)	(4)	(5)
Panel (a) Panel with Tenor Fixed Effects					
Surplus/GDP (%)	0.06***			0.07***	0.04***
	(0.01)			(0.01)	(0.01)
Debt/GDP (%)		−0.003***		−0.004***	−0.004***
		(0.001)		(0.001)	(0.001)
Surplus Cyclicality			−0.22***		−0.13***
			(0.04)		(0.04)
Observations	90	90	90	90	90
Adjusted R^2	0.38	0.25	0.40	0.53	0.57
Panel (b) 5-Year Tenor Only					
	(1)	(2)	(3)	(4)	(5)
Surplus/GDP (%)	0.07*			0.07*	0.02
	(0.03)			(0.03)	(0.03)
Debt/GDP (%)		−0.002		−0.003	−0.003
		(0.003)		(0.002)	(0.002)
Surplus Cyclicality			−0.31**		−0.27*
			(0.11)		(0.14)
Observations	10	10	10	10	10
Adjusted R^2	0.27	-0.01	0.42	0.35	0.54

Notes: We take the average of the convenience yields and fiscal variables across time for each country and each tenor. In Panel (a), we run the panel regression and control for the tenor fixed effects. In Panel (b) we run the cross-sectional regression using 5-year bonds only. The dependent variable is the convenience yield spread relative to Germany, in percentage points. The tenors are 1, 2, 3, 5, 7, 10, 20, and 30 years. *p<0.1; **p<0.05; ***p<0.01.

Table A.1, we also control for the bonds' average bid-ask spreads, and show the coefficients for the fiscal variables remain similar.

4.2 Explaining the Time-Series Variation in Convenience Yields

Fiscal condition also helps explain the variation in convenience yield across time. We investigate how a country's bond yield, the convenience yield, and the CDS spread changes when its surplus forecast-to-debt ratio changes. Our regression equations are

$$\Delta\tilde{y}_t^i \text{ or } \Delta\tilde{\lambda}_t^i \text{ or } \Delta\tilde{\delta}_t^i = \alpha + \beta\Delta\tilde{s}_t^i + \varepsilon_t^i \tag{7}$$

where $\Delta\tilde{s}_t^i = \Delta s_t^i - \Delta s_t^{DE}$ is the the relative change in the government surplus-to-GDP ratios between country i and Germany.

We take a particular stance on the timing of these asset prices. While the government surplus data are annual from Eurostat, the asset price data are daily. We link the government surplus in year t with the yield and CDS data at the end of June in year $t+1$. In doing so, we allow 6 months for the fiscal information to affect the debt market.

Table 5(a) reports the regression results in the subsample of 5-year bonds. As shown in Column (2), higher government surpluses are associated with higher convenience yield. The point estimate suggests that a one-standard-deviation increase in the government surplus/GDP ratio (about 2.4%) is associated with a 26 basis point increase in the convenience yield. Given this regression does not include any fixed effects, the R^2 of 40% is also notable. In addition, Column (3) shows that higher government surpluses are also associated with lower default spreads, which also lead to lower bond yields.

Panel (b) and (c) control for the bonds' bid-ask spreads and the countries' GDP growth. The positive coefficient associated with convenience yields remain significant. Appendix Table A.2 repeats the regressions in the full sample with all tenors.

Returning to our relative variance decomposition in equation (9), the change in the surplus is a plausible proxy for fiscal news $\widehat{d}_t^i$. If the Eurozone countries have the same duration of debt h_t, then the implied duration would be $\frac{1}{0.11+0.21} = 3.215$ years.

$$1 \quad = \quad h_{t-1}\frac{\mathrm{Cov}_{t-1}\left(\widehat{\lambda}_t^{i,h}, \widehat{d}_t^i\right)}{\mathrm{Var}_{t-1}\left(\widehat{d}_t^i\right)} - h_{t-1}\frac{\mathrm{Cov}_{t-1}\left(\widehat{\delta}_t^{i,h}, \widehat{d}_t^i\right)}{\mathrm{Var}_{t-1}\left(\widehat{d}_t^i\right)} = 3.215 \times (0.11 - (-0.21))\,. \tag{8}$$

The convenience yield channel accounts for 0.11×3.125 or 34% of the variance, while the credit risk channel accounts for the remaining 66%. The risk-free yield curve plays no role if countries have the same duration.

Table 5: Time-Series Change in Convenience Yield vs. Change in Fiscal Conditions

Panel (a): Surplus Alone			
	(1)	(2)	(3)
	$\Delta\tilde{y}$	$\Delta\tilde{\lambda}$	$\Delta\tilde{\delta}$
ΔSurplus/GDP (%)	-0.32^{***}	0.11^{***}	-0.21^{***}
	(0.03)	(0.01)	(0.02)
Observations	160	160	160
Adjusted R^2	0.40	0.30	0.36
Panel (b): Control for Change in Bid-Ask Spread			
	(1)	(2)	(3)
	$\Delta\tilde{y}$	$\Delta\tilde{\lambda}$	$\Delta\tilde{\delta}$
ΔSurplus/GDP (%)	-0.14^{***}	0.06^{***}	-0.09^{***}
	(0.02)	(0.01)	(0.02)
ΔBid Ask Spread	9.97^{***}	-2.94^{***}	7.03^{***}
	(0.65)	(0.36)	(0.50)
Observations	160	160	160
Adjusted R^2	0.76	0.51	0.71
Panel (c): Control for GDP Growth			
	(1)	(2)	(3)
	$\Delta\tilde{y}$	$\Delta\tilde{\lambda}$	$\Delta\tilde{\delta}$
ΔSurplus/GDP (%)	-0.32^{***}	0.11^{***}	-0.21^{***}
	(0.03)	(0.01)	(0.02)
Log GDP Growth	1.29	0.07	1.36
	(2.19)	(0.91)	(1.61)
Observations	160	160	160
Adjusted R^2	0.40	0.30	0.35

Notes: Regression Results for the sample 2001—2020 at annual frequency. Rates and surpluses are differenced by their German counterparts. Rates and surplus-to-GDP ratios are in percentage points. 5-year tenor only. *p<0.1; **p<0.05; ***p<0.01.

4.3 The Explanatory Power of Fiscal Forecasts

Proposition 1 also suggests that convenience yields, like all other asset prices, can be forward-looking: not only realized fiscal conditions but also forecasts of future fiscal conditions may explain convenience yields.

We obtain a small sample of Eurozone countries (Germany, France, Italy, Netherlands, Spain) from Consensus Economics, which provides the forecasts of budget deficits in the current year and in the next year. The data is available monthly, but each country's forecast is not necessarily sampled in the same day of a month. We aggregate into quarterly frequency and take the last observation. Then, we normalize the median forecast of budget deficit by the GDP of the previous year (relative to the date in which the forecast is made).

Table 6 reports the regression results in the subsample of 5-year bonds. As with the real-

Table 6: Time-Series Change in Convenience Yield vs. Change in Fiscal Forecasts.

	(1)	(2)	(3)
Panel (a): Forecast of Current Year Surplus			
	$\Delta\tilde{y}$	$\Delta\tilde{\lambda}$	$\Delta\tilde{\delta}$
ΔSurplus Forecast/GDP (%)	-0.13^{**}	0.07^{***}	-0.05
	(0.06)	(0.02)	(0.05)
Observations	230	230	230
Adjusted R^2	0.02	0.03	0.001
Panel (b): Forecast of Next Year Surplus			
	(1)	(2)	(3)
	$\Delta\tilde{y}$	$\Delta\tilde{\lambda}$	$\Delta\tilde{\delta}$
ΔSurplus Forecast/GDP (%)	-0.06	0.05^{*}	-0.01
	(0.06)	(0.03)	(0.05)
Observations	230	230	230
Adjusted R^2	-0.001	0.01	-0.004
Panel (c): Average Forecast of Current and Next Year Surpluses			
	(1)	(2)	(3)
	$\Delta\tilde{y}$	$\Delta\tilde{\lambda}$	$\Delta\tilde{\delta}$
ΔSurplus Forecast/GDP (%)	-0.11^{*}	0.07^{**}	-0.04
	(0.07)	(0.03)	(0.06)
Observations	230	230	230
Adjusted R^2	0.01	0.02	-0.002

Notes: Regression results are for 2002–2020 at quarterly frequency. Rates and surplus forecasts are differenced by their German counterparts. Rates and surplus-to-GDP ratios are in percentage points. 5-year tenor only. *p<0.1; **p<0.05; ***p<0.01.

ized government surplus, a higher government surplus forecast-to-GDP ratio is associated with a higher convenience yield. The economic magnitude is comparable to the results using realized government surpluses in the previous section: A 1% increase in the government surplus forecast-to-GDP ratio is associated with a 6 basis points increase in the convenience yield. Appendix Table A.3 reports the regression results in the subsample of 5-year bonds, controlling for changes in bid-ask spreads.

Returning to our relative variance decomposition in equation (9), the change in the surplus is a plausible proxy for fiscal news $\widehat{d}_t^i$. If the Eurozone countries have the same duration of debt h_t, then the implied duration would be $\frac{1}{0.07+0.05} = 8.3$ years.

$$1 \quad = \quad h_{t-1}\frac{\mathrm{Cov}_{t-1}\left(\widehat{\lambda}_t^{i,h}, \widehat{d}_t^i\right)}{\mathrm{Var}_{t-1}\left(\widehat{d}_t^i\right)} - h_{t-1}\frac{\mathrm{Cov}_{t-1}\left(\widehat{\delta}_t^{i,h}, \widehat{d}_t^i\right)}{\mathrm{Var}_{t-1}\left(\widehat{d}_t^i\right)} = 8.3 \times (0.07 - (-0.05)). \tag{9}$$

When we use survey data, the convenience yield channel accounts for 0.07×8.3 or 58% of the variance, while the credit risk channel accounts for the remaining 42%.

5 The Public Security Purchase Programme

Although ECB monetary policy is not directly modeled in this paper, our framework may be useful for thinking about the effects of the PSPP on bond convenience yields of the various Eurozone sovereigns. As part of its quantitative easing program, it expanded the set of securities eligible for purchase by the ECB to sovereign bonds announced in January 2015. The PSPP remains active today.

Theoretically, ECB sovereign bond purchases could have two effects. First, PSPP purchases further increase the scarcity of safe assets. With downward-sloping demand curves for safe assets, the PSPP should raise bond prices, lower bond yields, and increase convenience yields. This effect should be particularly strong for Germany and, by extension, for bonds issued by core countries such as Finland or the Netherlands that are close substitutes for German bunds. Second, the PSPP may have signaled to bond markets that the ECB stands ready to absorb a substantial amount of debt issued by all Eurozone countries for the forseeable future, irrespective of the fiscal situation they may find themselves in. As such, the PSPP may have muted the response of CDS spreads to adverse fiscal news by eliminating short-run roll-over risk. This consideration is particularly relevant for peripheral countries such as Italy, Spain, Portugal, and Ireland. With CDS spreads insulated, the PSPP could amplify the response of convenience yields to fiscal shocks. The net result of these two effects for convenience yield differentials is an empirical question.

We perform an event study around key PSPP announcements.[4] Specifically, the ECB made two major announcements. The first announcement took place on January 22, 2015. In a press conference, then ECB President Mario Draghi announced that the ECB would engage in monthly purchases of public and private sector securities amounting to 60 billion euros. The second key announcement took place on March 13, 2020. In a blog post, ECB Chief Economist Philip Lane announced that extra asset purchases intended to stabilize sovereign bond yields during flight-to-safety episodes, reversing a press release by ECB President Christine Lagarde the previous day.

Figures 5 and 6 plot the 5-year bond convenience yield differentials between each country and Germany around these two announcement dates. We observe that, prior to each announcement, convenience yield differentials had been widening. Both announcements closed the convenience yield differentials in the days and weeks after the announcement. The effect is particularly pronounced for peripheral countries such as Italy, Portugal, and Spain. In these countries, the response is as large as 20 to 30 basis points for the 2015 announcement and 40 to 50 basis points for the 2020 announcement. The increase in the relative convenience yield of peripheral coun-

[4]We have monthly data of PSPP purchases by country. However, there is little information in the actual purchase amounts, after the relevant announcement has passed, for two reasons. First, we do not observe when exactly the ECB makes these purchases, and it has incentives to hide its trades. Second, the actual purchases are highly predictable since they follow the ECB capital key. Put differently, the relevant information is likely contained in the announcement, not in the subsequent purchases.

Figure 5: Convenience Yield Differential around January 22, 2015 Announcement

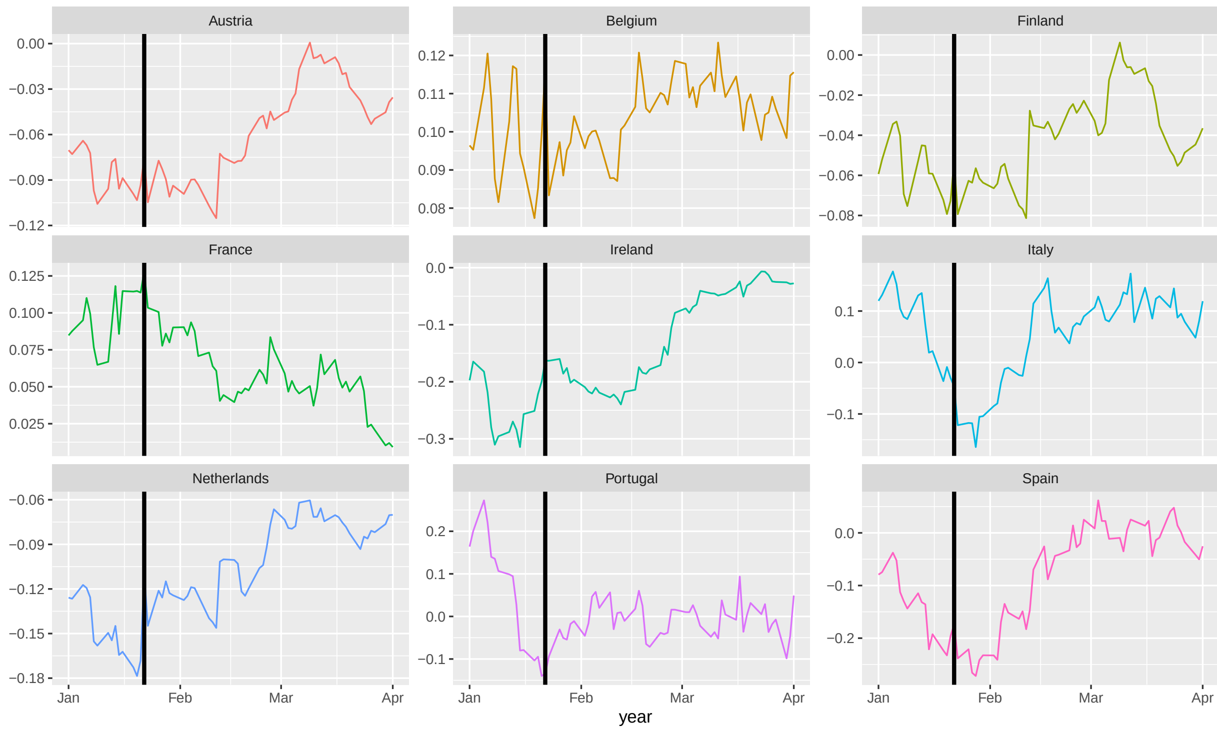
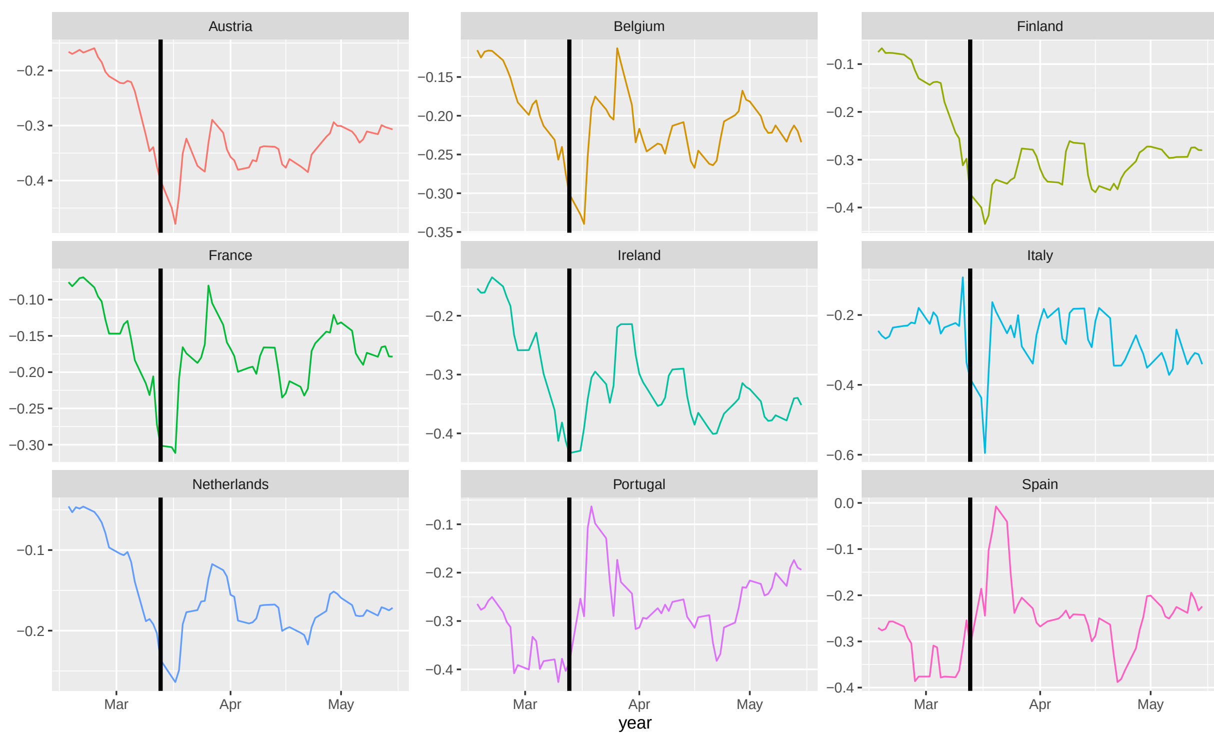


Figure 6: Convenience Yield Differential around March 13, 2020 Announcement



tries in response to the announcement suggests that the net effect of the PSPP was to amplify the response of convenience yields to fiscal shocks. While this analysis is suggestive, event studies of QE programs are subject to the usual caveat that they do not arise in a vacuum, complicating causal attribution.

6 The Fiscal Costs of Convenience Yields

In this section, we compute each country's revenue loss from bond issuance at a convenience yield lower than that of the German bond's. For each bond issuance, the revenue loss is equal to the product of the issuance amount I_t^i, the bond's duration τ_t^i, and the convenience yield differential relative to Germany $\tilde{\lambda}_t^i$:

$$\mathcal{L}_t^i \quad = \quad I_t^i \cdot \tau_t^i \cdot \tilde{\lambda}_t^i. \tag{10}$$

If the annualized convenience yield is constant across the term structure, a bond with higher duration will suffer a higher revenue loss.

We report this revenue loss under two assumptions. First, we use the 5-year convenience yield differential relative to Germany at date t to measure $\tilde{\lambda}_t^i$. The 5-year CDS is the most liquid tenor, and we apply the convenience yield at that tenor to the entire term structure. Second, we obtain convenience yields for each tenor (1, 2, 3, 5, 7, 10, 20, and 30 years). At each date t, we interpolate the convenience yield differential using a cubic spline fit to these tenors.

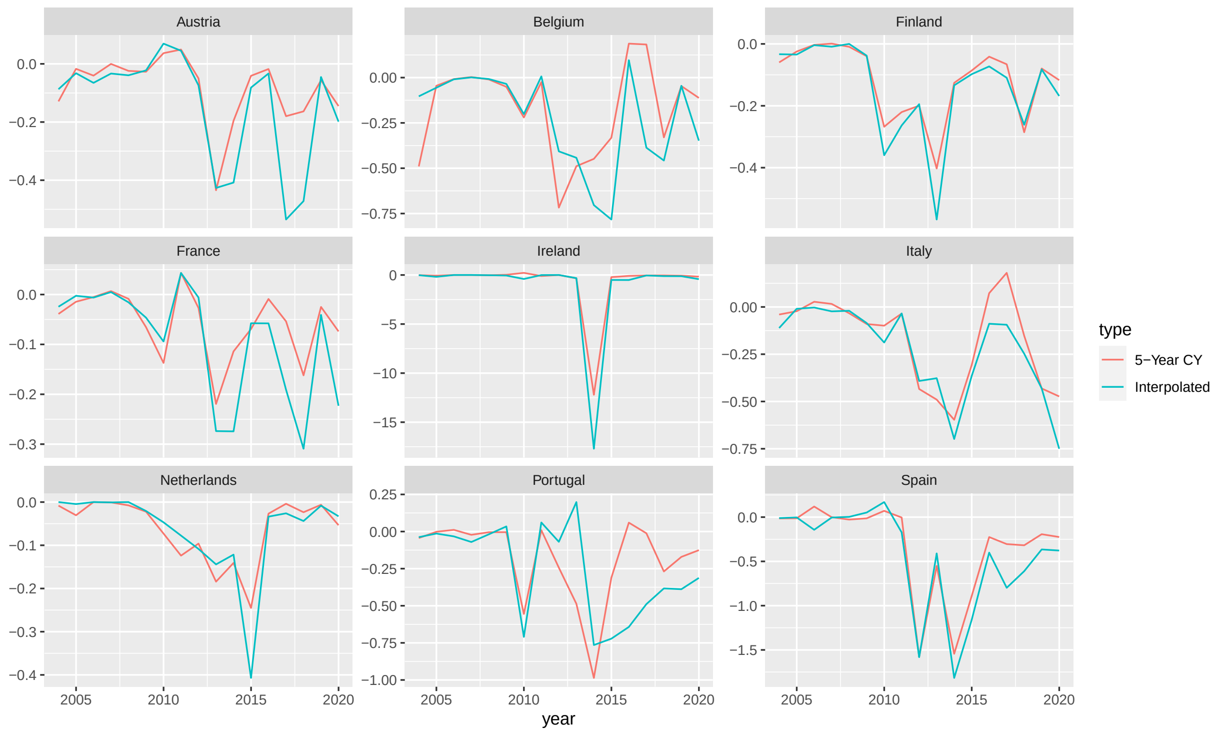
We obtain the list of active bonds from Eikon. We use Datastream to obtain their characteristics: price, yield-to-maturity, total debt outstanding, and duration. For bonds with missing data on Datastream, we supplement with Bloomberg data. With this dataset in hand, we are able to calculate a time-series of net issuance, duration, and market value for each country's sovereign debt portfolio. In our sample, the great majority of Eurozone sovereign debt is denominated in euros. Appendix Figure A.4 reports the coverage of our bond issuance database.[5]

Figure 7 plots the annual revenue loss as a fraction of current GDP, measured in the year of issuance, under both assumptions on the convenience yields. For countries like Italy, Portugal and Spain, the revenue loss is as high as 0.75% of their GDP per year in the depth of the Eurozone sovereign bond crisis.

Figure 8 reports the cumulative loss of revenue for each issuer. This measure compounds the annual revenue loss using the German 5-year bond yield. It normalizes the amount in euros by the current year's GDP of the issuing country. Using the 5-year convenience yield differentials

[5]For all countries except Belgium and Spain, the amount of bonds available in our issuance database is smaller than the total amount of government bonds outstanding. Because these missing bonds may also have lower convenience yield relative to German bonds, our estimate of the revenue loss is a conservative one. Since the bond data are not always available upon issuance, we estimate duration as the duration reported on the first day of available data + the number of years between the issuance date and the first day of available data.

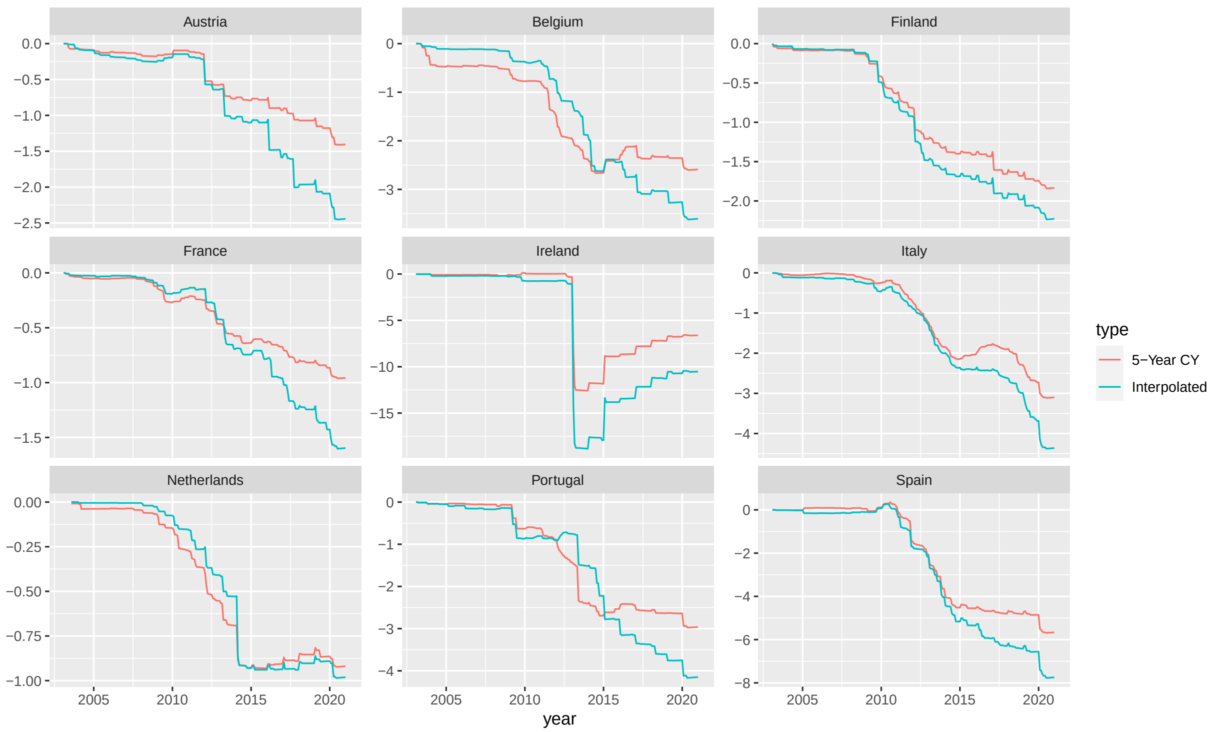
Figure 7: Annual Revenue Loss due to Convenience Yield Differentials



to calculate the revenue loss, Ireland, Italy, Portugal and Spain have lost 3% to 6% of their 2020 GDP by having a lower convenience yield than Germany. Even for core countries like Austria, France, and the Netherlands, cumulative revenue losses are around 1% of GDP. Using the term structure of convenience yield differentials, the revenue losses grow further. The larger revenue losses occur because the average term structure of convenience yield differentials is downward sloping; see Figure 3.

These results imply that, as a whole, the Eurozone could have raised 2.6% of 2020 GDP in additional revenue from its historical bond issuance had all countries benefited from the same convenience yields as Germany. This number provides an indication of the benefits from a deeper fiscal union. Eurobonds, like the NextGenerationEU bonds issued first in June 2021, would benefit from the same convenience yields as Germany at least at the margin. Widespread adoption may trigger general equilibrium effects. On the one hand, there may be a redistribution of convenience revenue from germany to the other Eurozone members. On the other hand, creating a rival to the U.S. Treasury may result in a level shift of the convenience yield of a eurobond.

Figure 8: Cumulative Loss due to Convenience Yield Differentials



7 Conclusion

We presents a theoretical framework to study bond convenience yields in a currency union. Consistent with the model, convenience yields are a major determinant of sovereign bond yields in the Eurozone. They are strongly related to measures of fiscal conditions. Convenience yields, or the lack thereof, imply large fiscal costs for the peripheral countries. Our findings speak to the costs and benefits of deepening the fiscal union in the Eurozone.

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A Proofs

Proof of Proposition 1

Proof. Start from the government budget constraint

$$T_t^i - G_t^i \quad = \quad Q_{t-1}^{i,1} + \sum_{h=1}^{H-1} Q_{t-1}^{i,h+1} P_t^{i,h} - \sum_{h=1}^{H} Q_t^{i,h} P_t^{i,h}.$$

Consider the period-$(t+1)$ constraint, multiplied by $M_{t+1}(1-\chi_{t+1}^i)$ and by $M_{t+1}(\chi_{t+1}^i)$ respectively, and take expectations conditional at time t:

$$\begin{aligned} & E_t\left[M_{t,t+1}(T_{t+1}^i - G_{t+1}^i)(1-\chi_{t+1}^i)\right] \\ = \;& E_t\left[M_{t,t+1}(1-\chi_{t+1}^i)Q_t^{i,1} + \sum_{h=1}^{H-1} M_{t,t+1}(1-\chi_{t+1}^i)Q_t^{i,h+1}P_{t+1}^{i,h} - \sum_{h=1}^{H} M_{t,t+1}(1-\chi_{t+1}^i)Q_{t+1}^{i,h}P_{t+1}^{i,h}\right] \\ = \;& Q_t^1 P_t^{i,1} e^{-c_t^{i,1}} + \sum_{h=1}^{H-1} Q_t^{i,h+1} P_t^{i,h+1} e^{-c_t^{i,h+1}} - E_t\left[\sum_{h=1}^{H} M_{t,t+1}(1-\chi_{t+1}^i)Q_{t+1}^{i,h}P_{t+1}^{i,h}\right]. \end{aligned}$$

and

$$E_t\left[M_{t,t+1}(T_{t+1}^i - G_{t+1}^i)\chi_{t+1}^i\right] = E_t\left[-\sum_{h=1}^{H} \chi_{t+1}^i M_{t,t+1} Q_{t+1}^{i,h} P_{t+1}^{i,h}\right].$$

So

$$\begin{aligned} & E_t\left[M_{t,t+1}(T_{t+1}^i - G_{t+1}^i)\right] \\ = \;& Q_t^1 P_t^{i,1} e^{-c_t^{i,1}} + \sum_{h=1}^{H-1} Q_t^{i,h+1} P_t^{i,h+1} e^{-c_t^{i,h+1}} - E_t\left[\sum_{h=1}^{H} M_{t,t+1} Q_{t+1}^{i,h} P_{t+1}^{i,h}\right]. \end{aligned}$$

Combine with the period-t constraint, the sum is

$$\begin{aligned} & (T_t^i - G_t^i) + E_t\left[M_{t,t+1}(T_{t+1}^i - G_{t+1}^i)\right] \\ = \;& Q_{t-1}^{i,1} + \sum_{h=1}^{H-1} Q_{t-1}^{i,h+1} P_t^{i,h} - \sum_{h=1}^{H} Q_t^{i,h} P_t^{i,h}(1 - e^{-c_t^{i,h}}) - E_t\left[\sum_{h=1}^{H} M_{t,t+1} Q_{t+1}^{i,h} P_{t+1}^{i,h}\right]. \end{aligned}$$

We can iterate this expression to the infinite horizon. If the following transversality condition holds,

$$\lim_{\tau\to\infty} E_t\left[M_{t,t+\tau} \sum_{h=1}^{H} Q_{t+\tau}^h P_{t+\tau}^h\right] \quad = \quad 0,$$

then debt value is the present value of current and future surpluses and seignorage revenues from issuing bonds that earn convenience yields:

$$Q^{i,1}_{t-1} + \sum_{h=1}^{H-1} Q^{i,h+1}_{t-1} P^{i,h}_t = E_t \left[\sum_{j=0}^{\infty} M_{t,t+j}(T_{t+j} - G_{t+j}) \right] + E_t \left[\sum_{j=0}^{\infty} M_{t,t+j} \sum_{h=1}^{H} Q^{i,h}_{t+j} P^{i,h}_{t+j} (1 - e^{-c^{i,h}_{t+j}}) \right].$$

$\square$

Solution of Steady-State Variables For each country, suppose the convenience yields are the same across all tenors at each point of time:

$$c^{i,h}_{t+1} = c^i_{t+1} = \bar{c}^i.$$

Under these assumptions, the bond prices are

$$P^{i,h}_t \quad = \quad \mathbb{E}_t \left[M_{t,t+h} \prod_{j=1}^{h} (1 - \chi^i_{t+j}) \exp(c^{i,h-j+1}_{t+j-1}) \right] = \exp(-(r + \bar{\omega}^i - \bar{c}^i)h).$$

Then, the market value of outstanding government debt is

$$\sum_{h=0}^{\infty} Q^{i,h+1}_{t-1} P^{i,h}_t \quad = \quad \bar{Q}^i \sum_{h=0}^{\infty} \exp(-(r + \bar{\omega}^i + \nu - \bar{c}^i)h) = \frac{\bar{Q}^i}{1 - e^{-(r+\bar{\omega}^i+\nu-\bar{c}^i)}}.$$

Similarly,

$$\sum_{h=1}^{\infty} Q^{i,h}_{t+j} P^{i,h}_{t+j} \quad = \quad \bar{Q}^i \sum_{h=1}^{\infty} \exp(-\nu(h-1)) \exp(-(r + \bar{\omega}^i - \bar{c}^i)h) = \frac{\bar{Q}^i \exp(-(r + \bar{\omega}^i - \bar{c}^i))}{1 - e^{-(r+\bar{\omega}^i+\nu-\bar{c}^i)}}.$$

Then, the intertemporal government budget condition is

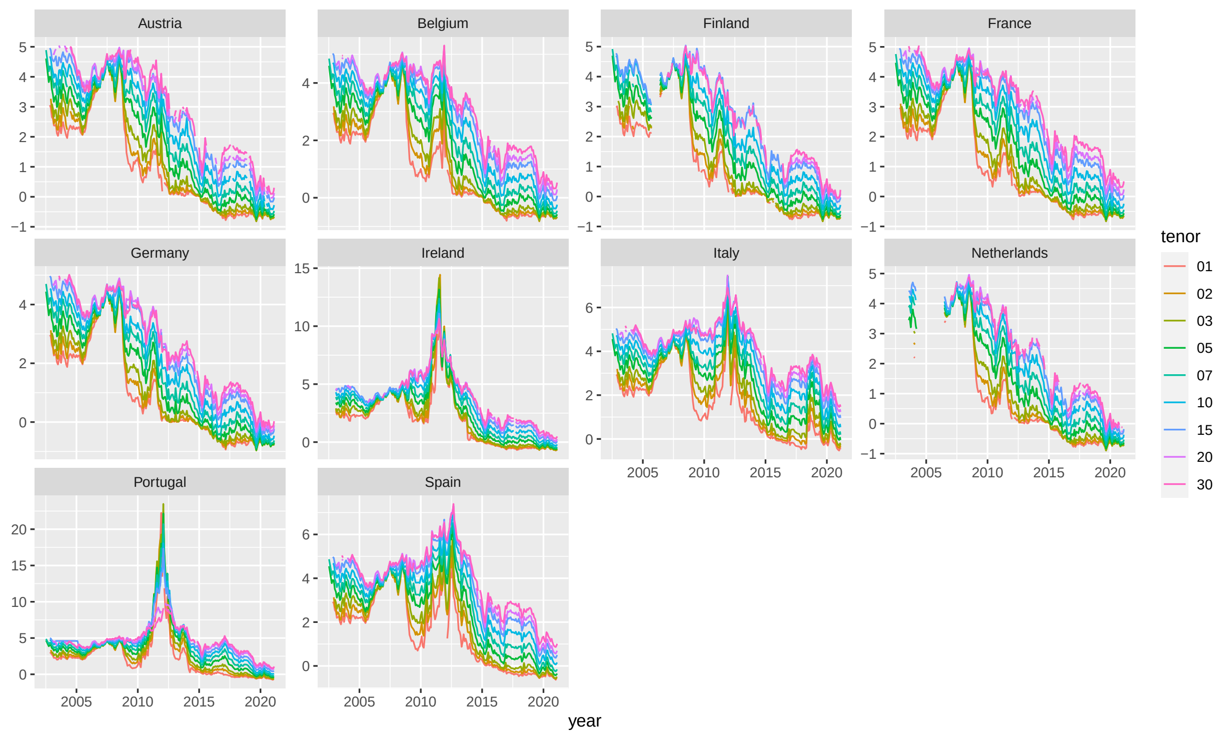
$$\begin{aligned} \sum_{h=0}^{\infty} Q^{i,h+1}_{t-1} P^{i,h}_t &= \mathbb{E}_t \left[\sum_{j=0}^{\infty} M_{t,t+j}(T^i_{t+j} - G^i_{t+j}) \right] + \mathbb{E}_t \left[\sum_{j=0}^{\infty} M_{t,t+j} \sum_{h=1}^{\infty} Q^{i,h}_{t+j} P^{i,h}_{t+j} (1 - e^{-c^{i,h}_{t+j}}) \right] \\ \frac{\bar{Q}^i}{1 - e^{-(r+\bar{\omega}^i+\nu-\bar{c}^i)}} &= \mathbb{E}_t \left[\sum_{j=0}^{\infty} M_{t,t+j}(T^i_{t+j} - G^i_{t+j}) \right] + \frac{(1 - e^{-\bar{c}^i}) \exp(-(r + \bar{\omega}^i - \bar{c}^i))}{1 - e^{-r}} \frac{\bar{Q}^i}{1 - e^{-(r+\bar{\omega}^i+\nu-\bar{c}^i)}}. \end{aligned}$$

When convenience yield is sufficiently smaller than the discount rate, $(1 - e^{-\bar{c}^i}) \exp(-(r + \bar{\omega}^i - \bar{c}^i)) < r$, then the bond valuation $\frac{\bar{Q}^i}{1-e^{-(r+\bar{\omega}^i+\nu-\bar{c}^i)}}$ is greater than the present value of seigniorage revenue $\frac{(1-e^{-\bar{c}^i})\exp(-(r+\bar{w}^i-\bar{c}^i))}{1-e^{-r}}\frac{\bar{Q}^i}{1-e^{-(r+\bar{w}^i+\nu-\bar{c}^i)}}$. We can express the budget condition as

$$\frac{1-\frac{(1-e^{-\bar{c}^i})\exp(-(r+\bar{w}^i-\bar{c}^i))}{1-e^{-r}}}{1-e^{-(r+\bar{w}^i+\nu-\bar{c}^i)}}\bar{Q}^i = \mathbb{E}_t\left[\sum_{j=0}^{\infty} M_{t,t+j}(T^i_{t+j}-G^i_{t+j})\right]. \tag{A.1}$$

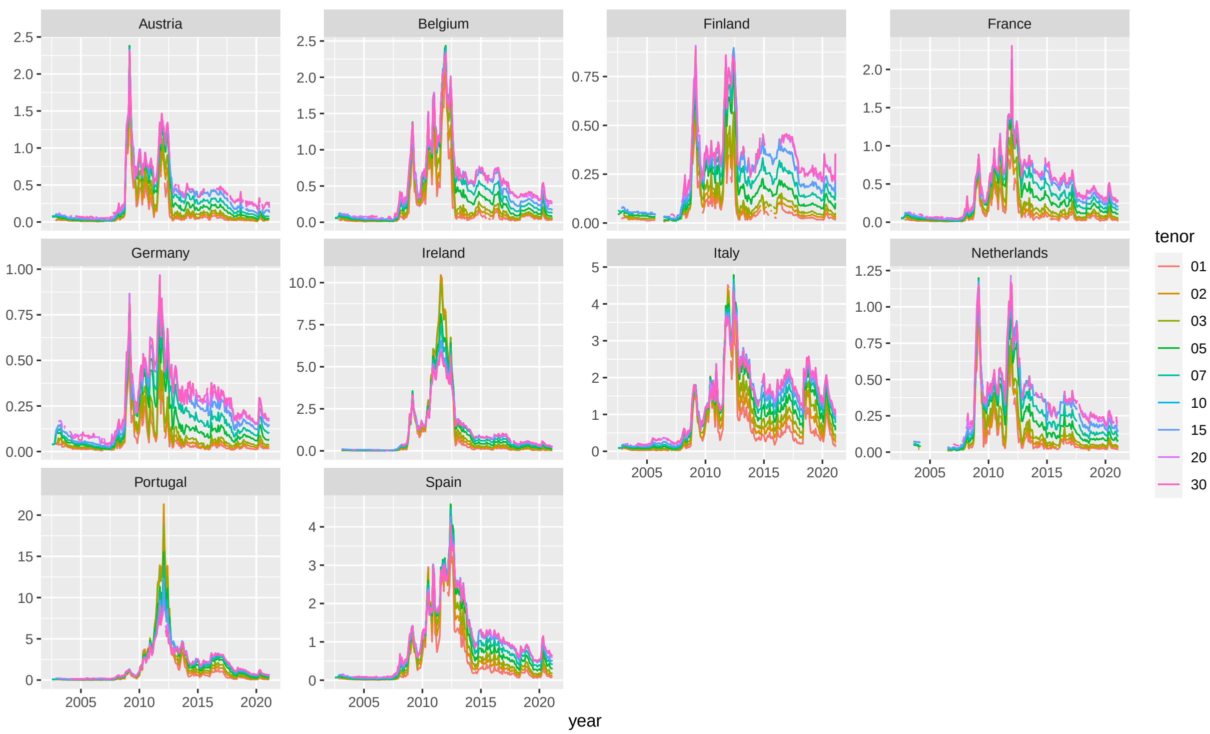
B Additional Empirical Results

Figure A.1: The Time Series of Yields



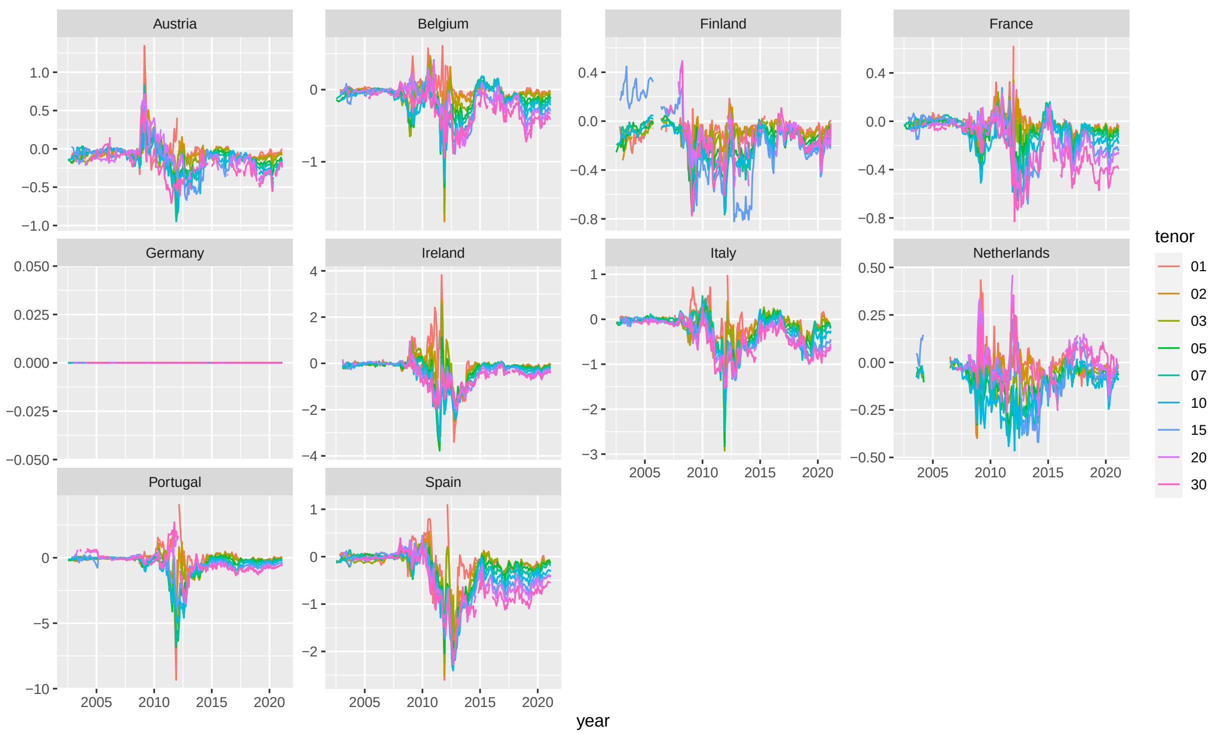
Notes: The yields are in percentage points.

Figure A.2: The Time Series of CDS Spread



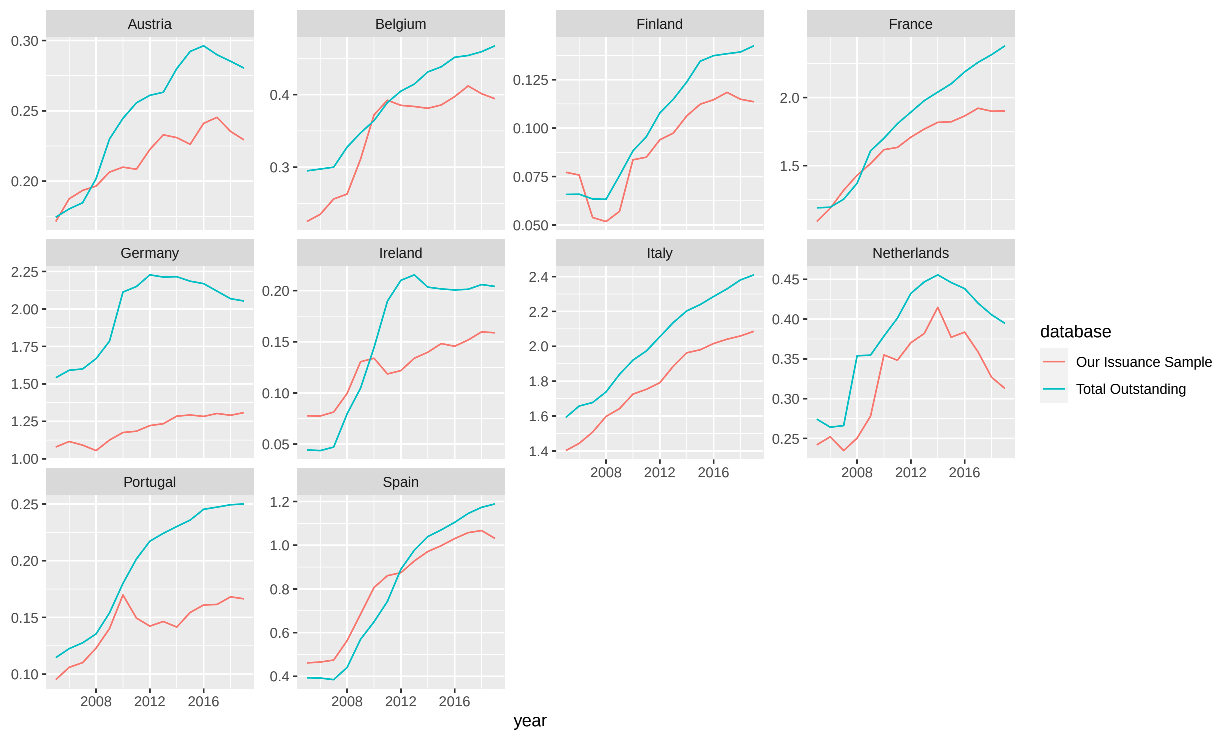
Notes: The CDS spreads are in percentage points.

Figure A.3: The Time Series of Convenience Yields



Notes: The convenience yields are in percentage points.

Figure A.4: Coverage of Bond Issuance Database



Notes: We report the total amount of sovereign debt in our issuance database that contains information about bond issuance, and compare it with the total amount of outstanding debt. In trillion Euro.

Table A.1: Average Convenience Yield vs. Fiscal Conditions, Controlling for Bond Bid-Ask Spread.

	(1)	(2)	(3)	(4)	(5)
Panel (a) Panel with Tenor Fixed Effects					
Surplus/GDP (%)	0.05***			0.06***	0.04***
	(0.01)			(0.01)	(0.01)
Debt/GDP (%)		−0.003***		−0.004***	−0.004***
		(0.001)		(0.001)	(0.001)
Surplus Cyclicality			−0.20***		−0.14***
			(0.04)		(0.05)
Bid Ask Spread	−0.80**	−1.15***	−0.63*	−0.49	−0.23
	(0.36)	(0.37)	(0.36)	(0.32)	(0.31)
Observations	88	88	88	88	88
Adjusted R^2	0.41	0.32	0.42	0.54	0.59
Panel (b) 5-Year Tenor Only					
	(1)	(2)	(3)	(4)	(5)
Surplus/GDP (%)	0.01			0.02	0.02
	(0.02)			(0.02)	(0.02)
Debt/GDP (%)		−0.001		−0.002	−0.002
		(0.001)		(0.001)	(0.001)
Surplus Cyclicality			0.01		−0.02
			(0.10)		(0.12)
Bid Ask Spread	−4.49***	−4.67***	−4.86***	−4.16***	−4.05**
	(0.90)	(0.68)	(1.19)	(0.83)	(1.24)
Observations	10	10	10	10	10
Adjusted R^2	0.82	0.85	0.80	0.85	0.82
Notes:			*p<0.1; **p<0.05; ***p<0.01		

Notes: We take the average of the convenience yields and fiscal variables across time for each country and each tenor. In Panel (a), we run the panel regression and control for the tenor fixed effects. In Panel (b) we run the cross-sectional regression using 5-year bonds only. The dependent variable is the convenience yield spread relative to Germany, in percentage points. The tenors are 1, 2, 3, 5, 7, 10, 20, and 30 years.

Table A.2: Time-Series Change in Convenience Yield vs. Change in Fiscal Conditions.

Panel (a): Surplus Alone			
	(1)	(2)	(3)
	$\Delta\tilde{y}$	$\Delta\tilde{\lambda}$	$\Delta\tilde{\delta}$
ΔSurplus/GDP (%)	-0.26^{***}	0.06^{***}	-0.21^{***}
	(0.04)	(0.02)	(0.03)
Observations	1,404	1,290	1,332
Adjusted R^2	0.35	0.08	0.36
Panel (b): Control for Change in Bid-Ask Spread			
	(1)	(2)	(3)
	$\Delta\tilde{y}$	$\Delta\tilde{\lambda}$	$\Delta\tilde{\delta}$
ΔSurplus/GDP (%)	-0.21^{***}	0.05^{**}	-0.17^{***}
	(0.03)	(0.02)	(0.02)
ΔBid Ask Spread	3.35^{***}	-0.54^{***}	2.79^{***}
	(0.56)	(0.20)	(0.49)
Observations	1,341	1,248	1,265
Adjusted R^2	0.56	0.12	0.58
Panel (c): Control for GDP Growth			
	(1)	(2)	(3)
	$\Delta\tilde{y}$	$\Delta\tilde{\lambda}$	$\Delta\tilde{\delta}$
ΔSurplus/GDP (%)	-0.26^{***}	0.06^{**}	-0.21^{***}
	(0.04)	(0.02)	(0.03)
Log GDP Growth	0.92	0.59	1.36
	(2.12)	(0.79)	(1.57)
Observations	1,404	1,290	1,332
Adjusted R^2	0.35	0.09	0.36

Notes: Regression Results 2001—2020 at annual frequency. Rates and surpluses differenced by German counterparts. Rates and Surplus-to-GDP are in percentage points. All tenors are pooled. We control for tenor fixed effects and cluster the errors by country-year. *p<0.1; **p<0.05; ***p<0.01

Table A.3: Time-Series Change in Convenience Yield vs. Change in Fiscal Forecasts.

Panel (a): Forecast of Current Year Surplus			
	(1)	(2)	(3)
	$\Delta\tilde{y}$	$\Delta\tilde{\lambda}$	$\Delta\tilde{\delta}$
ΔSurplus Forecast/GDP (%)	-0.11^{**}	0.06^{***}	-0.04
	(0.05)	(0.02)	(0.05)
ΔBid Ask Spread	15.81^{***}	-7.02^{***}	8.79^{***}
	(1.90)	(0.80)	(1.74)
Observations	230	230	230
Adjusted R^2	0.24	0.27	0.10

Panel (b): Forecast of Next Year Surplus			
	(1)	(2)	(3)
	$\Delta\tilde{y}$	$\Delta\tilde{\lambda}$	$\Delta\tilde{\delta}$
ΔSurplus Forecast/GDP (%)	-0.05	0.05^{*}	-0.01
	(0.06)	(0.02)	(0.05)
ΔBid Ask Spread	15.99^{***}	-7.12^{***}	8.87^{***}
	(1.91)	(0.81)	(1.74)
Observations	230	230	230
Adjusted R^2	0.23	0.26	0.09

Notes: Regression Results 2002—2020 at quarterly frequency. Rates and surplus forecasts differenced by German counterparts. Rates and Surplus-to-GDP are in percentage points. 5-year tenor only. $^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$.