Bond Convenience Yields in the Eurozone Currency Union*

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Abstract

In a monetary union, the risk-free rate cannot respond to country-level fiscal shocks, leaving only default spreads and convenience yields to respond. Empirically, we find that convenience yields play an important role as fiscal shock absorbers in the Eurozone. Consistent with downward-sloping demand for safety, Eurozone countries earn larger convenience yields after they release positive fiscal news. Since convenience yields generate substantial seigniorage revenue from debt issuance, our estimates imply economically large fiscal costs from low convenience yields for peripheral countries in the Eurozone.

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

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1 Introduction

Government bonds of fiscally strong countries provide safety and liquidity services that investors value. To own such money-like assets, investors are willing to forgo a sizable return, called the convenience yield. The convenience yield literature has focused on the U.S. Treasury, the reserve asset *par excellence* in the international monetary system after the Second World War. Our paper studies the convenience yields in the Eurozone, and applies its results to shed light on government bond pricing in the Eurozone. This setting is interesting for two reasons. First, convenience yields on Eurozone sovereign bonds exhibit large variation in both the time series and the cross-section. Second, as nominal short-term interest rates are fixed in a currency union, convenience yields can play an important role as shock absorbers in response to country-specific fiscal shocks. We find that convenience yields drive much of the variation in Eurozone bond yields and that they respond to country-specific fiscal news.

We develop this result by characterizing the equilibrium constraints imposed by the intertemporal government budget constraint (IGBC) which equates the market value of government debt in each country to the present value of its current and future primary surpluses. Between countries with flexible interest rates, nominal interest rates can adjust to enforce the IGBC in response to a fiscal shock in each country. In contrast, in a currency union, nominal short-term interest rates have to be the same across countries despite fiscal conditions that vary across member countries. While the union-wide interest rate can adjust in response to union-wide fiscal shocks, it cannot adjust to simultaneously satisfy each country's IGBC following different country-specific fiscal shocks.

To enforce the IGBC for each member country in a currency union, sovereign bond yields have to adjust for reasons other than the movements in the common interest rate. The sovereign bond yield depends on the common nominal risk-free yield curve, the country-specific default spread, and the country-specific convenience yield. As a result, when a country experiences a higher-than-average primary surplus shock, the relative market value of its debt has to adjust either through an increase in the bond's relative convenience yield or a decrease in the bond's relative default spread. This opens up the possibility for the convenience yield to do some—or much—of the adjustment to enforce the IGBC. In fact, for a Eurozone country with low sovereign default risk like Germany, only the convenience channel remains.

We formalize this result in a variance decomposition. The conditional variance of the market's relative debt values of two member countries can be decomposed into a relative convenience yield component, given by the covariance between the relative debt valuation and the relative convenience yield on the countries' debt, and a default risk component, given by minus the covariance between the relative debt valuation and the relative default spread.

Moreover, we can obtain a stronger result if we additionally assume that the demand for sovereign bonds is downward-sloping. Then, as a country that experiences positive fiscal news needs to issue less debt over the horizon of the fiscal news, its debt supply declines and the equilibrium convenience yield on its outstanding debt increases. This leads to a positive relationship between fiscal news about current or future government surpluses and the bond convenience yield.

Finally, we note that convenience yields 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 surpluses lower bond values. In the presence of convenience yields, there is an additional stream of government revenue akin to seigniorage revenue. Since negative shocks to surpluses drive down convenience yields, they also reduce the present value of seigniorage revenues, amplifying the decline in bond values.

Guided by these theoretical results, we turn to the Eurozone sovereign debt market and examine the properties of the convenience yields. First, we find that bond convenience yields in the Eurozone exhibit economically significant fluctuations, which account for over half of the variation in the relative bond yield differentials across Eurozone countries. We measure the convenience yield differential between a Eurozone country and Germany as the difference between their sovereign bond yields with the same tenor minus these bonds' credit default spread differential, obtained from credit default swap data. It is convenient to study these convenience yield differentials as they difference out the common risk-free yield curve which is unobserved.

Figure 1 plots these convenience yield differentials for various Eurozone countries at the five-year tenor. If a country's convenience yield differential is negative, the five-year German government bond enjoys a higher convenience yield than this country's five-year government bond. This figure shows that convenience yield differentials vary substantially both across countries and over time. Notably, as Germany is the bond market's preferred safe asset supplier within the Eurozone, it has the highest convenience yield and therefore the convenience yield differentials reported in this figure are overwhelmingly negative. Convenience yield differentials peak during the Eurozone sovereign debt crisis of 2011—12. They spike again in some countries during the Covid-19 crisis in March 2020.

We conduct a variance decomposition of Eurozone sovereign bond yield differentials relative to Germany. Contrary to the popular belief that bond yield differentials in the Eurozone differ mostly due to default spread differentials between member countries, we find that the convenience yield differentials are the main driver of bond yield differentials. In the 2008—2020 subsample, in which the bond yields diverge significantly across Eurozone countries, nearly 60% of the variation in bond yield differentials is due to the convenience yields, with the remaining 40% accounted for by default spread differentials. In the 2002—2007 subsample, in which the bond yields are much more similar across Eurozone countries, 98% of the variation in bond yield differentials is due to convenience yields.

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.

Another way to quantify the economic significance of these convenience yields is to consider the heterogeneous fiscal burdens they imply. We consider a simple counterfactual in which all countries earn the same 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 this revenue at German bond yields to obtain a measure of the cumulative revenue loss that each country suffered because its bonds did not earn the same convenience yield as German bonds. We find cumulate revenue losses over the period 2003—2020 of 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 of 1% of 2020 GDP. Together, the cumulative revenue losses amount to 2.6% of the aggregate GDP in the Eurozone (including Germany's GDP), a sizeable number.

After we document the magnitude of these convenience yields, we examine their connection to government fiscal conditions. Consistent with our theory, we find a positive relationship between Eurozone governments' fiscal conditions and convenience yields. In the cross-section, countries with higher average primary surpluses earn higher convenience yields than countries with lower primary surpluses. In the time series, 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 2.5%, is associated with a 27 basis point increase in the convenience yield.

We also obtain data on forecasts of government surpluses for a set of Eurozone countries from Consensus Economics. We find that expectations of improving fiscal conditions are also associated with increases in convenience yields. The economic magnitude of this association is comparable to that based on realized fiscal shocks. This result highlights the standard asset pricing intuition—present in our model—that, as convenience yields reflect the present value of future government cash flows, they are forward-looking variables. In summary, these empirical results show that the bond convenience yields account for a large fraction of variations in bond yield differentials across Eurozone countries, and they respond positively to fiscal shocks, confirming the intuition that convenience yields play an important role as fiscal shock absorbers in a currency union.

Related Literature We measure the convenience yields as CIP deviations in the Eurozone's government bond markets (Jiang, Krishnamurthy, and Lustig, 2021). Intermediary balance sheet constraints have been noted as a key driver of CIP deviations in the Libor market in the aftermath of the Great Financial Crisis (Du, Tepper, and Verdelhan, 2018). However, CIP deviations in the government bond markets are different. First, these deviations in Treasury markets have been around long before the GFC. A synthetic U.S. Treasury constructed from a German Bund or a U.K. gilt has invariably been cheap compared to an actual U.S. Treasury. Second, the U.S. Treasury, or any other Treasury, does not adjust the supply of Treasurys to eliminate these CIP deviations in bond markets, unlike unconstrained global banks in Libor markets. Third, these CIP deviations likely reflects the demand of global investors for the safety and liquidity of U.S. Treasurys (Jiang, Krishnamurthy, and Lustig, 2021). To these investors, these CIP deviations in government bond markets do not represent an arbitrage opportunity.

In the Eurozone, Germany is the preferred safe asset supplier. Empirically, we find that the level of the convenience yield of Eurozone countries' sovereign bonds correlated with traditional flight-to-safety measures such as the U.S. Treasury basis and global stock market volatility, whereas convenience yield differentials between Eurozone countries respond to country-level differences in fiscal conditions. These results suggest that safe asset demand affects the average convenience yield, while country-specific fiscal conditions govern the differences in the convenience yield across Eurozone bond markets.

Our paper contributes to the literature on the convenience yields of government debt (Krishnamurthy and Vissing-Jorgensen, 2012; Nagel, 2016; Du, Im, and Schreger, 2018; Valchev, 2020; He, Nagel, and Song, 2022). These convenience yields are quantitatively important and time-varying. Jiang, Krishnamurthy, and Lustig (2020, 2021); Koijen and Yogo (2020) estimate that foreign investors have enjoyed convenience yields in excess of 200 bps per annum on their Treasury holdings.[1] This literature emphasizes that U.S. Treasurys occupy a special place in global financial markets.[2] In this paper, we show that convenience yields are also an important consideration in the Eurozone's sovereign bond markets, and that these convenience yields respond to fiscal shocks.

Gourinchas and Rey (2016); Farhi and Maggiori (2018); He, Krishnamurthy, and Milbradt (2019) analyze the determinants of safe asset demand in the international financial system. Their theories emphasize the importance of macro fundamentals in determining the relative safety of a country's debt. Our paper puts forth a theoretical argument that explains why fiscal fundamentals are particularly important for the convenience yields in a currency union. In related work, Chernov, Schmid, and Schneider (2020) analyze the CDS premium on U.S. Treasurys and relate it 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. Jiang (2021, 2022) studies the response of exchange rates to fiscal shocks in flexible exchange rate regimes. Croce, Nguyen, and Schmid (2012); Croce, Nguyen, Raymond, and Schmid (2019); Croce, Nguyen, and Raymond (2021) study the trade-off arising from short-run debt stabilization in models with long-run innovation risk, and characterize time-varying debt paydown rates.

In the wake of the Eurozone crisis of 2011—12, there was an extensive debate on the merits of an increased fiscal union.[3] While the Eurozone still does not produce a safe asset that can rival U.S. Treasurys, the European Union started issuing debt backed by tax revenue of each and all the EU member states in June 2021 as part of the NextGenerationEU scheme. On the one hand, our findings shed light on one potential benefit of transforming the Eurozone into a fiscal union. Such new Eurozone debt 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 would equalize convenience yields for all countries. This would lead to a revenue transfer from Germany to other Eurozone countries.

[1] Jiang, Richmond, and Zhang (2020) quantifies the exorbitant privilege of the U.S. as manifested in 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. Jiang, Lustig, Van Nieuwerburgh, and Xiaolan (2020) study how the exposure of convenience yields to output risk affects the trade-off between insuring bondholders and taxpayers.

[2] For example, 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).

[3] 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 (Commission, 2011; Ubide, 2015), to intermediate solutions with joint liability for some of the debt (Delpla and Von Weizsäcker, 2010; Hellwig and Philippon, 2011), to no joint liability in 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). Corsetti, Feld, Koijen, Reichlin, Reis, Rey, and di Mauro (2016) discuss reform to Eurozone institutions in the wake of the twin eurozone debt and refugee crises.

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. In related work, Bilbiie, Monacelli, and Perotti (2020) highlights the importance of fiscal policy coordination in the Eurozone, given that monetary policy tools are not available to respond to country-specific shocks. Leombroni, Vedolin, Venter, and Whelan (2021) document that the sovereign CDS premia adjust across Eurozone countries in response to the ECB's monetary policy. On the other hand, our paper shows that convenience yields and hence government funding costs can and do vary across countries, and respond to shocks to fiscal conditions, thus rewarding good fiscal stewardship at the country-level, even in a currency union. This incentive effect would disappear in a fiscal union, a potential cost of increased fiscal integration.

Textbook finance implies 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 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. Only 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) study 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. Kremens (2018) studies redenomination risk using CDS data, and interprets Germany's negative redenomination risk as a potential source of convenience yield.

Finally, there is strong evidence for our assumption of downward-sloping demand curves for safe government debt. Krishnamurthy and Vissing-Jorgensen (2012) document a negative relationship 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, Koulischer, Nguyen, and Yogo (2017, 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 develops a model of the convenience yields in a currency union. Turning to the data, Section 3 decomposes bond yields into default spreads and convenience yields and measures their relative importance. Section 4 studies the fiscal determinants of convenience yields in the data. Section 5 concludes.

2 A Model of Bond Convenience Yields in a Currency Union

In this section, we develop a model that characterizes bond convenience yields in a currency union. To make our discussion concrete, we use the Eurozone as an example of the currency union. We consider the Eurozone as a fully integrated financial market, which shares the Euro as the common numeraire, has a common yield curve for risk-free bonds that carry no convenience yield, and has a marginal investor who can trade all member countries' sovereign bonds. In practice, the Eurozone has implemented many measures to foster financial market integration.[4]

2.1 General Characterizations

Let i index the countries in the currency union. We assume governments issue nominal debt of various maturities, all denominated in the Euro. Let $P_t^{i,h}$ denote the price of the h-year bond and let $Q_t^{i,h}$ denote the book value. The market value of the bond is $Q_t^{i,h} P_t^{i,h}$. If the government does not default at time t, the intertemporal government budget condition is:

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

If the government defaults at time t, we assume all debt is wiped out with zero recovery. The government may be able to issue some new debt, in which case the intertemporal government budget condition is:

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

We use χ_t^i to indicate the event of government default at time t.

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

Sovereign bonds carry a country- and tenor-specific Euler equation wedge, $c_t^{i,h}$, which represents how much risk-adjusted return investors are willing to forgo to hold the bonds. The Euler

[4] For example, 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.

equations for bonds with maturity 1 and $h+1$ are:

$$\begin{aligned}\mathbb{E}_t[M_{t,t+1}(1-\chi^i_{t+1})]\exp(c^{i,1}_t) &= P^{i,1}_t \\ \mathbb{E}_t[M_{t,t+1}P^{i,h}_{t+1}(1-\chi^i_{t+1})]\exp(c^{i,h+1}_t) &= P^{i,h+1}_t.\end{aligned}$$

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

The following proposition characterizes the intertemporal government budget condition:

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

$$\sum_{h=0}^{H} Q^{i,h+1}_{t-1}P^{i,h}_t = \mathbb{E}_t\left[\sum_{j=0}^{\infty} M_{t,t+j}(T^i_{t+j}-G^i_{t+j})\right] + \mathbb{E}_t\left[\sum_{j=0}^{\infty} M_{t,t+j}\sum_{h=1}^{H} Q^{i,h}_{t+j}P^{i,h}_{t+j}(1-e^{-c^{i,h}_{t+j}})\right] \tag{1}$$

if the following transversality condition holds,

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

The proof is in the appendix and follows Jiang, Lustig, Van Nieuwerburgh, and Xiaolan (2019, 2020). 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 bonds with convenience yields. The bond portfolio has a higher valuation when either 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 $r^h_t = -\frac{1}{h}\log\mathbb{E}_t[M_{t,t+h}]$, a default spread component $\delta^{i,h}_t$, and a convenience yield component $\lambda^{i,h}_t$:

$$-\frac{1}{h}\log P^{i,h}_t = r^h_t + \delta^{i,h}_t - \lambda^{i,h}_t, \tag{2}$$

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

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

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 investors' Euler equation wedges $\{c_{t+j}^{i}\}$ 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), the intertemporal government budget condition, can be expressed as

$$\sum_{h=0}^{H} Q_{t-1}^{i,h+1}e^{-(r_t^h+\delta_t^{i,h}-\lambda_t^{i,h})h} = \mathbb{E}_t\left[\sum_{j=0}^{\infty}M_{t,t+j}(T_{t+j}^{i}-G_{t+j}^{i})\right]+\mathbb{E}_t\left[\sum_{j=0}^{\infty}M_{t,t+j}\sum_{h=1}^{H}Q_{t+j}^{i,h}P_{t+j}^{i,h}(1-e^{-c_{t+j}^{i,h}})\right], \quad (3)$$

which implies that 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:

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

Special case with a single debt maturity If we assume that the government debt portfolio can be approximated by a single type of zero-coupon bond with maturity h^i, then,

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

If the debt maturity h^i is the same across all Eurozone countries, since they share the same risk-free rate $r_t^{h^i}$, then, the convenience yield λ_t^{i,h^i} and the default spread δ_t^{i,h^i} have to adjust when fiscal conditions or future seigniorage revenues change. In this paper, we will investigate empirically to what extent the cross-country differences in bond yields are driven by the convenience yield and by the default spread.

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

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

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

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

Then, 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:

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

This condition implies that, if the union-level risk-free rate does not covary with the value of a claim to country i's surpluses, then, the present value of its government surpluses has to be measurable at time $t-1$, i.e., have zero conditional variance. This condition imposes a very tight constraint on the dynamics of country i's surpluses, since it has to hold for all Eurozone countries while there is only one Euro risk-free rate. So, if the Eurozone countries' debt portfolios have similar maturities, the Euro risk-free yield curve can only adjust to enforce the aggregate debt valuation equation at the union level, but not to simultaneously enforce all member countries' individual valuation equations. In other words, in a fiscal union without convenience yields and default spreads, the present values of government surpluses have to move in the same direction.

Relation to fiscal theory of price level We can rewrite Eq. (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 (the first term) or seigniorage revenues (the second term) 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 yield λ_t^i can adjust (instead of the price level) in response to the shocks to the country's future government surpluses or to shocks to future seigniorage revenues.

2.2 Variance Decomposition of Debt Valuation

Next, we build on our results above and 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:

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

We continue to assume that each country's government debt portfolio consists of zero-coupon bonds with a single maturity h^i. Then, Eq. (3) can be expressed as

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

which implies that 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:

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

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

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

Similarly, we can aggregate the surpluses and the debt portfolio at the currency union level, denoted by superscript a. We take logs of the Eurozone level expression for the valuation of the surpluses:

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

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

$$\begin{aligned}\widehat{d_t^i} &= d_t^i - d_t^a \\ &= -(r_t^{i,h^i}h^i - r_t^{h^a}h^a) + (\delta_t^{i,h^i}h^i - \delta_t^{a,h^a}h^a) - (\lambda_t^{i,h^i}h^i - \lambda_t^{a,h}h^a) + q_{t-1}^{i,h^i} - q_{t-1}^{a,h^a}.\end{aligned}$$

The innovations to $\widehat{d}_t^i$ measure country-specific fiscal news in country i, because we are comparing the valuation of the surplus for country i relative to valuation of the aggregate surplus using the same SDF.

We analyze a natural benchmark case in which all debt maturities coincide: $h^i = h^a = h$. 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 derive the following variance decomposition result for the log valuation of country i's in deviation from the Eurozone aggregate level.

Result 1. In a monetary union with integrated capital markets and equal durations for countries' outstanding debt portfolios, the variation in the log market value as a deviation from the monetary union aggregate is given by a convenience yield component and a default risk component:

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

There is no risk-free yield curve contribution because the country and the Eurozone share the same nominal pricing kernel and nominal risk-free rate. A positive variance reflects either a positive covariance of the current convenience yield (in deviation from the union-level aggregate) with the market value of debt (in deviation from the union-level aggregate), or a negative covariance of the market value with the default risk premium (in deviation from the union-level aggregate), or a combination of both.

Dividing both sides by the conditional variance, we obtain a variance decomposition formula:

$$1 \quad = \quad h\frac{\mathrm{Cov}_{t-1}\left(\widehat{\lambda}_t^{i,h}, \widehat{d}_t^i\right)}{\mathrm{Var}_{t-1}\left(\widehat{d}_t^i\right)} - h\frac{\mathrm{Cov}_{t-1}\left(\widehat{\delta}_t^{i,h}, \widehat{d}_t^i\right)}{\mathrm{Var}_{t-1}\left(\widehat{d}_t^i\right)}. \tag{4}$$

The two terms on the right-hand side have interpretations as regression coefficients. In Section 4, we estimate the regression coefficients in the data.

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:

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

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). If country i's default spread does not respond to the fiscal shock, news about higher surpluses in country i relative to the Euro-wide surpluses would have to reflected in a higher convenience yield for country i.

Next, we describe the economic mechanism that links convenience yields to fiscal news.

2.3 Fiscal News Channel for Convenience Yields

Negative short-run fiscal news (i.e., a larger deficit) implies an increase in government bond supply to finance the deficit. If the demand curve for safe assets is downward-sloping, then the increase in bond supply results in lower convenience yields. Hence, we expect to see a positive time-series covariance between innovations to the surplus process in the short run and convenience yield innovations.

To formalize this result, let $\kappa^i_{t+j} D^i_{t+j} = \sum_{h=1}^{H} Q^{i,h}_{t+j} P^{i,h}_{t+j} (1 - e^{-c^{i,h}_{t+j}})$ denote the seigniorage revenue at time $t + j$. The relationship between fiscal news at horizon h, debt supply h periods from now, and the returns today:

$$
\begin{aligned}
(\mathbb{E}_t - \mathbb{E}_{t-1}) \sum_{j=0}^{h} M_{t,t+j} (T^i_{t+j} - G^i_{t+j} + \kappa^i_{t+j} D^i_{t+j}) &= -(\mathbb{E}_t - \mathbb{E}_{t-1}) \left[M_{t,t+h} D_{t+h} \right] \\
&+ D_t (\mathbb{E}_t - \mathbb{E}_{t-1}) [R^D_t].
\end{aligned} \tag{5}
$$

This expression follows from Proposition 1. If the debt is risk-free, then $(\mathbb{E}_t - \mathbb{E}_{t-1})[R^D_t] = 0$. A negative fiscal shock over horizon h, measured by

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

will then raise the risk-neutral expectation of debt supply h periods from now, i.e.,

$$
(\mathbb{E}_t - \mathbb{E}_{t-1}) \left[M_{t,t+h} D_{t+h} \right] > 0.
$$

Given that demand for safe assets is downward-sloping, we assume that the expected future convenience yield $\mathbb{E}_t[\lambda^1_{t+h}]$ on 1-period debt will tend to decline in the expected future supply (Krishnamurthy and Vissing-Jorgensen, 2012; Koijen and Yogo, 2020):

Assumption 1. Downward-sloping demand curves:

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

In addition, we assume that a version of the expectations hypothesis holds for the convenience yields:

Assumption 2. 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 following prediction for the relationship between short-run fiscal shocks and convenience yields:

Result 2. In the presence of downward-sloping demand curves for safe asset, and if the expectations hypothesis holds for convenience yields, then for any $h \leq H$, where H denotes the longest outstanding maturity in the government's debt portfolio, the covariance between fiscal news at horizon h and the convenience yield is positive:

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

To show this result, we use Eq. (5) to obtain that the covariance between fiscal news and convenience yields for any $h \leq H$ can be decomposed as follows:

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

The first term on the right-hand side is positive because of the downward-sloping demand curves (Assumption 1). The second covariance is positive because higher future convenience yields imply higher bond prices and returns on the debt outstanding today. Finally, an increase in λ^h_t results from an increase in the expected convenience yield h years from now, λ^1_{t+h}, by Assumption 2.[5]

This result implies that the reaction of bond convenience yields to fiscal news should have a clear positive sign. This fiscal channel is operative even if there is no long-run fiscal news ($h = \infty$), 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 for Result 2 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

We provide a numerical example to illustrate the positive relationship between fiscal news and the convenience yield. For simplicity, this example abstracts from output growth and default. Investors are risk-neutral and have a constant discount rate: $M_{t,t+h} = \exp(-rh)$. Government debt has an exponential maturity structure parameterized by ν:

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

[5] This is true as long as $h < H$. Once the horizon exceeds the maturity of the longest maturity bond, this result breaks down because it relies on the short-run supply effects of fiscal innovations on the convenience yield of outstanding debt.

We also assume the Euler equation wedge is the same for debt of different maturities: $c^{i,h}_{t+k} = c^{i}_{t+k}$.

We begin by deriving the relationship between the convenience yield and the surplus in steady state. In steady state, the surplus $S^i_t = \bar{S}^i$ and the Euler equation wedge $c^i_t = \bar{c}^i$. 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 approximately equals:

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

In 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 surplus $\bar{S}^i$. To understand this negative relationship between long-run surplus and long-run convenience yield, 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 debt.

Next, we show that the relationship between government surplus and convenience yield can turn positive in the short run, consistent with the prediction of Result 2. We assume that the log government debt follows an AR(1) process:

$$\log Q^i_{t+1} \quad = \quad \phi \log Q^i_t + (1-\phi) \log \bar{Q}^i + \sigma \varepsilon^i_{t+1}. \tag{6}$$

Following Assumption 1, the Euler equation wedge is a decreasing in the quantity of government debt outstanding:

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

Then, the convenience yield in period t is:

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

where the first equality follows from risk neutrality, and the last equation expresses the convenience yield as the sum of expected future Euler equation wedges and a Jensen term. If the expectation hypothesis for convenience yields holds (Assumption 2), the Jensen term equals 0.[6]

[6] In this example, although investors are risk-neutral, the Jensen term reflects higher-order terms from the expecta-

To show some qualitative results, we parameterize the model at the annual frequency. We set the risk-free rate $r = 5\%$, the steady-state Euler equation wedge $\bar{c}^i = 0.5\%$, and the steady-state debt market value to be 50% of the GDP. We set the convenience yield's loading on the log debt quantity at $\beta = 1.8$, so that if the debt/GDP ratio goes from 50% to 60% of the GDP, then the convenience yield goes from 0.5% to 0.36%.[7] We set $\nu = 0.12$ which governs how fast the amount of government debt declines as a function of maturity, targeting an average maturity of the aggregate debt portfolio of 6.8 years in the steady state. In comparison, Germany's average government debt maturity is 6.9 years as of May 2022 (Source: Bloomberg DDIS). As for the debt quantity dynamics Eq. (6), it has a persistence of $\phi = 0.6$ and a volatility of $\sigma = 5\%$.

Now consider a negative two-standard-deviation shock to government debt quantity, i.e., $\varepsilon_t = -2$. This means the government surplus will go up upon the shock arrival and reduce the quantity of outstanding government debt by $2 \times 5\% = 10\%$ on the log scale. We compute the responses of surpluses, debt, and convenience yields assuming future shocks to government debt are all zero. The law of motion for the 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 the impulse responses. The fiscal shock arrives in period 0, raising the government surplus from the steady-state value of 2.3% to 7% of the GDP (left panel) and hence lowering

tion of exponentials. We ignore variation in the higher-order terms, effectively taking a first-order approximation.

[7] Krishnamurthy and Vissing-Jorgensen (2012) report that a 1 unit increase in log debt/GDP is associated with a 0.75% decline in the convenience yield level, which is measured by the Aaa-Treasury spread. This implies that, if the debt/gdp ratio goes from 50% to 60% of GDP, then the convenience yield goes from 0.5% to 0.36%. This implies a β of 1.8.

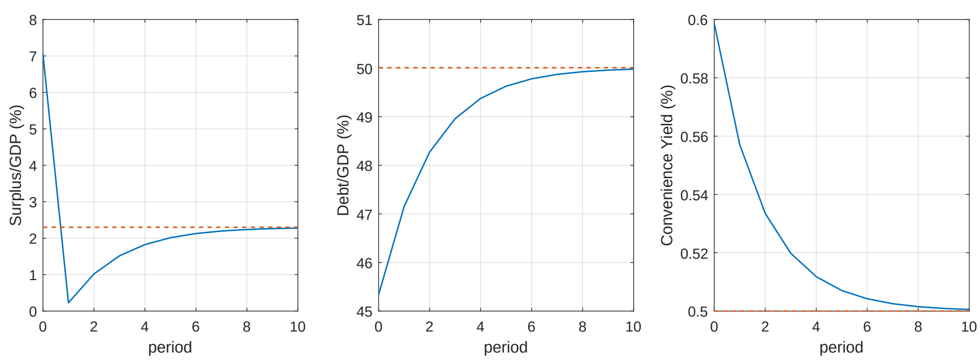

Figure 2: Numerical Example: Impulse-Response to a Fiscal Shock

Notes: This figure reports the impulse responses of government surplus (as % of GDP), bond quantity (as % of GDP), and bond convenience yield (in %) after a positive shock to government surplus.

the outstanding quantity of government debt (middle panel).[8] By Assumption 1, a lower debt supply raises the convenience yield from the steady-state value of 0.5% to 0.6% (right panel). In sum, there is a positive correlation between the bond convenience yield and the government surplus in the short run, consistent with Result 2.

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 elevated but slowly returns to its steady-state value. Surpluses in future periods decline below the steady-state level, because a higher convenience yield leads to a higher seigniorage revenue and allows the government to raise less surplus for debt payments.

3 Convenience Yields in Eurozone Sovereign Bonds

3.1 Data and Measurement

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 country (denoted by i) and Germany (denoted by DE), we can difference out the common nominal risk-free rate, and obtain a measure of the convenience yield differential from bond yields and CDS spreads:

$$(\lambda_t^i - \lambda_t^{DE}) \equiv \tilde{\lambda}_t^i = \tilde{\delta}_t^i - \tilde{y}_t^i \equiv (\delta_t^i - \delta_t^{DE}) - (y_t^i - y_t^{DE}), \tag{7}$$

where the tilde sign denotes the differential between country i and Germany. A higher $\tilde{\lambda}_t^i$ means country i's sovereign bond has a higher convenience yield relative to German sovereign bond. When the government bond yields and CDS spreads are correctly measured, convenience yield differentials represent deviations from covered interest rate parity.

Our sample is from 2002-07 to 2020-12 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. Our preferred tenor is 5 years because the 5-year CDS contracts are the most liquid. We use the CDS spreads from the CR contracts before 2014 and we use the CR14 contracts as they become available from 2014. The government bond yields are par yields from Bloomberg and the CDS spreads are from Markit; both are Euro-denominated. Appendix Figure A.1, Figure A.2 and Figure A.3 report the time series of yields, CDS spreads, and convenience yields for each country and tenor.

One 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 their

[8] The actual market value of government debt is not exactly 100% in the long run due to the Jensen's term.

bonds in a different currency. Depending on the relative value of the new currency, the redenomination may lead to either a capital loss or gain for the bondholders, called positive and negative redenomination risk, respectively. The CDS CR contracts we use do not protect against the event of redenomination without default for France, Germany and Italy (but do pay off for the other countries in our sample). Thus, the positive redenomination risk in the absence of default affects our measure of the convenience yield for these three countries before 2014. However, we think this event is unlikely since countries that redenominate their debt when they exit the Eurozone are more likely to simultaneously default. We are also missing the negative redenomination risk. Specifically, if the German government were to redenominate its debt back to the Deutsche Mark if Germany leaves the Euro Area on a future date, and the Mark is stronger than the Euro, then the German sovereign bond yield may be lower today to reflect this effect. Moreover, as no German CDS contracts have negative payoff in this event, the valuation manifests itself as a convenience yield on the German bond. Given limited information on the rare event of Germany leaving the Eurozone, we cannot isolate the negative redenomination risk component in our convenience yield measure. Our convenience yield has a broader interpretation that includes this negative redenomination component.

3.2 Summary Statistics

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

On average, the convenience yield differentials against German bonds are negative, which means the German bonds enjoy higher convenience yields than any other countries. This gap widens since 2008, averaging to 28 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, which means that there are occasions in which the convenience yield gap between German bonds and other countries' bonds widen dramatically. Moreover, the convenience yield differentials are relatively persistent at monthly frequency. The average autocorrelation is 0.87 before 2008 and 0.84 since 2008.

How large are the convenience yield differentials between each country and Germany relative to the level of each country's convenience yield? This requires an estimate of Germany's convenience yield level. For this purpose, we assume that the Euro OIS rate is a good proxy for the benchmark nominal risk-free rate r_t^h that carries no convenience yield.[9] Combined with the CDS

[9] OIS rates with maturity beyond two years are not available before 2005/06. For the earlier subsample, we use the

rate and the bond yield, we then obtain the convenience yield level $\lambda_t^{i,h}$ from:

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

We report the German convenience yield level in the last row of Table 1. Before 2008, the German convenience yield level averaged 16 basis points. This is larger than the average convenience yield differential between other countries and Germany. So, all countries' bonds enjoy a similar level of convenience yield before 2008. After 2008, the German convenience yield level is 33 basis points on average, which is similar in magnitude to the average convenience yield differential between other countries and Germany. This implies that the average country's convenience yield level is around zero.

We also calculate the convenience yield differential for different tenors. Figure 3 reports the average term structure of convenience yield differentials for each country. For most countries, the

zero-coupon curve derived from the OIS.

Table 1: Summary Statistics of Convenience Yield Differentials

Notes: This table reports the convenience yield differentials $\tilde{\lambda}_t^i = \lambda_t^i - \lambda_t^{DE}$ with 5-year tenor, annualized and reported in percentage points. The last row reports the German convenience yield level, using the OIS rate as a proxy for the benchmark risk-free rate. The data are at monthly frequency.

Panel (a) 2002—2007							
Country	Mean	Std Dev	10th Pct	50th Pct	90th Pct	Skewness	Autocorr
France	−0.02	0.03	−0.06	−0.02	0.01	−0.36	0.83
Netherlands	−0.03	0.03	−0.06	−0.03	−0.00	−0.92	0.42
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
Italy	−0.02	0.05	−0.08	−0.03	0.04	−0.05	0.82
Ireland	−0.05	0.06	−0.12	−0.03	0.02	−0.59	0.60
Spain	−0.02	0.06	−0.09	−0.02	0.04	−0.92	0.85
Portugal	−0.06	0.06	−0.14	−0.04	−0.00	−1.13	0.84
Average	−0.04	0.05	−0.11	−0.03	0.01	−0.75	0.77
Germany Level	0.16	0.08	0.06	0.16	0.29	0.26	0.87
Panel (b) 2008—2020							
Country	Mean	Std Dev	10th Pct	50th Pct	90th Pct	Skewness	Autocorr
France	−0.10	0.12	−0.26	−0.08	0.04	−0.98	0.60
Netherlands	−0.12	0.09	−0.25	−0.10	−0.04	−1.15	0.72
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	−1.73	0.85
Finland	−0.19	0.14	−0.35	−0.16	−0.06	−1.56	0.82
Italy	−0.30	0.42	−0.72	−0.19	0.11	−2.02	0.82
Ireland	−0.38	0.69	−1.28	−0.15	0.08	−2.20	0.79
Spain	−0.39	0.49	−1.02	−0.24	0.07	−1.67	0.91
Portugal	−0.70	1.20	−2.02	−0.24	0.05	−2.77	0.91
Average	−0.28	0.39	−0.74	−0.16	0.04	−1.61	0.81
Germany Level	0.33	0.17	0.15	0.30	0.50	1.07	0.84

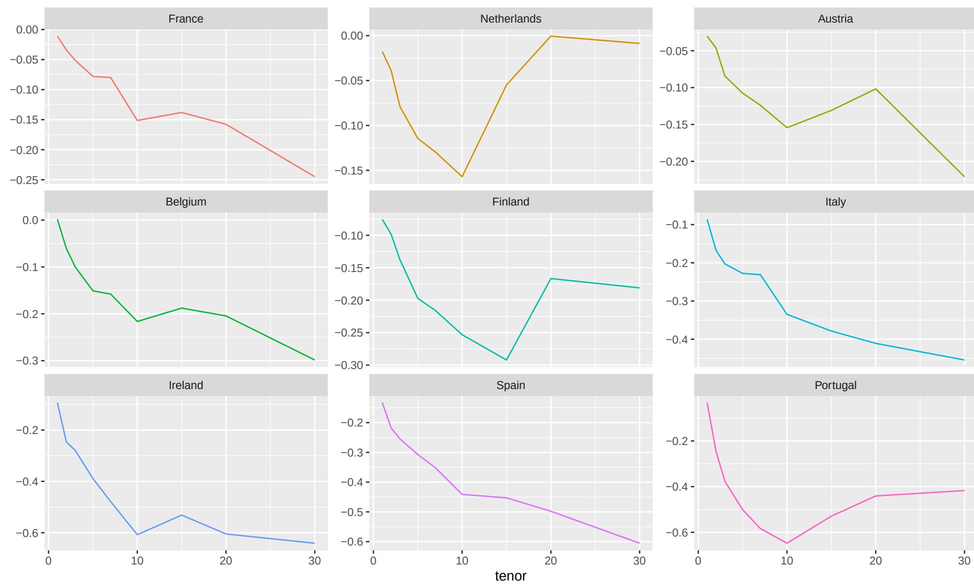

Figure 3: The Term Structure of Average Convenience Yields

Notes: This figure reports the average convenience yield differentials $\tilde{\lambda}_t^i = \lambda_t^i - \lambda_t^{DE}$ across different tenors. The convenience yield differentials are annualized and reported in percentage points, 2002—2020.

term structure is downward-sloping, suggesting that long-term German bonds enjoy relatively higher convenience yield advantages relative to other Eurozone sovereign bonds than short-term German bonds. Notable exceptions include Finland and the Netherlands.[10]

3.3 How Much Variation of Bond Yields Is Due To Convenience Yields?

We consider two ways to decompose the variance of bond yield differential. By Eq. (7),

$$\begin{aligned}\mathrm{Var}(\Delta\tilde{y}_t^i) &= \mathrm{Var}(\Delta\tilde{\delta}_t^i) + \mathrm{Var}(\Delta\tilde{\lambda}_t^i) - 2\mathrm{Cov}(\Delta\tilde{\delta}_t^i, \Delta\tilde{\lambda}_t^i) \\ &= \mathrm{Cov}(\Delta\tilde{y}_t^i, \Delta\tilde{\delta}_t^i) - \mathrm{Cov}(\Delta\tilde{y}_t^i, \Delta\tilde{\lambda}_t^i).\end{aligned}$$

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

Table 2 reports the results from both decomposition methods for the 5-year tenor. Before 2008, the bond yield differential fluctuations are small with a mean standard deviation of 3 basis points per month. The convenience yield component accounts for the majority of the yield differential

[10]This might be related to their pension funds buying the long-term bonds issued by their own governments.

Table 2: Variance Decomposition of Convenience Yield Differential Movement

Notes: This figure reports the variance decomposition of bond yield variations into convenience yield differentials and default spreads. The yields are annualized and reported in percentage points. The data are at monthly frequency, 2002—2020.

Panel (a) 2002—2007						
Country	$sd(\Delta\tilde{y}^i_t)$	$\frac{\mathrm{Var}(\Delta\tilde{\delta}^i_t)}{\mathrm{Var}(\Delta\tilde{y}^i_t)}$	$\frac{\mathrm{Var}(\Delta\tilde{\lambda}^i_t)}{\mathrm{Var}(\Delta\tilde{y}^i_t)}$	$\frac{-2\mathrm{Cov}(\Delta\tilde{\delta}^i_t,\Delta\tilde{\lambda}^i_t)}{\mathrm{Var}(\Delta\tilde{y}^i_t)}$	$\frac{\mathrm{Cov}(\Delta\tilde{y}^i_t,\Delta\tilde{\delta}^i_t)}{\mathrm{Var}(\Delta\tilde{y}^i_t)}$	$\frac{-\mathrm{Cov}(\Delta\tilde{y}^i_t,\Delta\tilde{\lambda}^i_t)}{\mathrm{Var}(\Delta\tilde{y}^i_t)}$
France	0.01	0.07	1.08	−0.15	−0.00	1.00
Netherlands	0.02	0.06	1.15	−0.21	−0.05	1.05
Austria	0.03	0.07	0.97	−0.04	0.05	0.95
Belgium	0.02	0.14	0.94	−0.08	0.10	0.90
Finland	0.03	0.08	1.14	−0.21	−0.03	1.03
Italy	0.03	0.25	1.09	−0.34	0.08	0.92
Ireland	0.05	0.02	0.99	−0.00	0.01	0.99
Spain	0.03	0.11	1.09	−0.20	0.01	0.99
Portugal	0.02	0.13	1.12	−0.25	0.00	1.00
Average	0.03	0.10	1.06	−0.16	0.02	0.98
Panel (b) 2008—2020						
Country	$sd(\Delta\tilde{y}^i_t)$	$\frac{\mathrm{Var}(\Delta\tilde{\delta}^i_t)}{\mathrm{Var}(\Delta\tilde{y}^i_t)}$	$\frac{\mathrm{Var}(\Delta\tilde{\lambda}^i_t)}{\mathrm{Var}(\Delta\tilde{y}^i_t)}$	$\frac{-2\mathrm{Cov}(\Delta\tilde{\delta}^i_t,\Delta\tilde{\lambda}^i_t)}{\mathrm{Var}(\Delta\tilde{y}^i_t)}$	$\frac{\mathrm{Cov}(\Delta\tilde{y}^i_t,\Delta\tilde{\delta}^i_t)}{\mathrm{Var}(\Delta\tilde{y}^i_t)}$	$\frac{-\mathrm{Cov}(\Delta\tilde{y}^i_t,\Delta\tilde{\lambda}^i_t)}{\mathrm{Var}(\Delta\tilde{y}^i_t)}$
France	0.08	1.53	1.68	−2.21	0.43	0.57
Netherlands	0.06	0.73	1.35	−1.08	0.19	0.81
Austria	0.10	0.94	0.94	−0.87	0.50	0.50
Belgium	0.16	0.50	0.51	−0.01	0.50	0.50
Finland	0.07	0.23	1.25	−0.48	−0.01	1.01
Italy	0.41	0.50	0.36	0.14	0.57	0.43
Ireland	0.61	0.35	0.53	0.12	0.41	0.59
Spain	0.36	0.45	0.32	0.23	0.56	0.44
Portugal	1.05	0.54	0.24	0.23	0.65	0.35
Average	0.32	0.64	0.80	−0.44	0.42	0.58

variability in both decompositions.

After 2008, the bond yield differentials are much more volatile with a mean standard deviation of 32 basis points per month. The first method implies that the convenience yield component is slightly more volatile than the default spread. Convenience yield differentials and default spreads are positively correlated on average across countries. The second method implies that the convenience yield component explains 58% of the variation in the yield differential, whereas the default spread component explains the remaining 42%. In other words, the convenience yield component accounts for the larger fraction of variation in bond yields.

3.4 The Fiscal Costs of Convenience Yields

Another way to quantify the economic significance of the convenience yields is to consider their implications for government revenue from bond issuances. We compute each country's revenue loss from having to issue bonds at a convenience yield that is 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 $\tilde{\lambda}_t^i$:

$$\mathcal{L}_t^i \quad = \quad I_t^i \cdot \tau_t^i \cdot \tilde{\lambda}_t^i. \tag{8}$$

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

We report two estimates of the revenue loss. 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 implied convenience yield differential at that tenor to the entire term structure. Second, we use the tenor-specific convenience yield differentials. At each date t, we interpolate the convenience yield differentials using a cubic spline fit to the available tenors (1, 2, 3, 5, 7, 10, 20, and 30 years).

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.[11]

Figure 4 plots the annual revenue loss as a fraction of current GDP, measured in the year of issuance, under both assumptions on the convenience yield differentials. For countries like Italy, Portugal and Spain, the revenue loss is as high as 0.75%—1.5% of GDP per year in the depth of the Eurozone sovereign bond crisis.

Figure 5 reports the cumulative revenue loss for each issuer. Our first measure compounds the annual revenue loss using the German 5-year bond yield. It scales the lost revenue in euros by 2020 GDP of the issuing country. Using the 5-year convenience yield differentials to calculate the revenue loss, Ireland, Italy, Portugal and Spain have lost from 3% to 6% of their 2020 GDP due to their lower convenience yields than Germany. Even for core countries like Austria, France, and the Netherlands, cumulative revenue losses amount to 1% of 2020 GDP. Using the term structure of convenience yield differentials, the revenue losses become larger because the average term structure of convenience yield differentials is downward-sloping, as shown earlier in 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 over the past two decades had all countries benefited from the same convenience yields as Germany. This number provides an indication

[11] 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 are likely to 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 plus the number of years between the issuance date and the first day of available data.

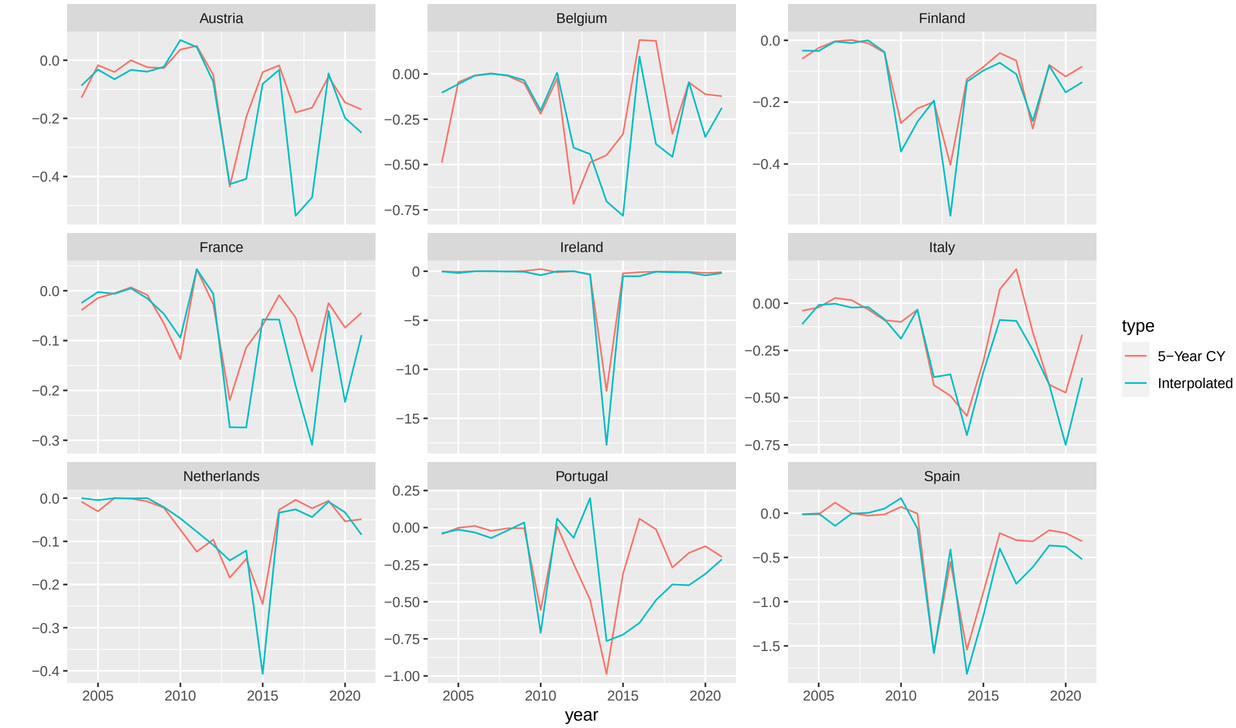

Figure 4: Annual Revenue Loss due to Convenience Yield Differentials

Notes: This figure plots each country's annual revenue loss $\mathcal{L}_t^i$ defined in Eq. (8), normalized by the concurrent national GDP.

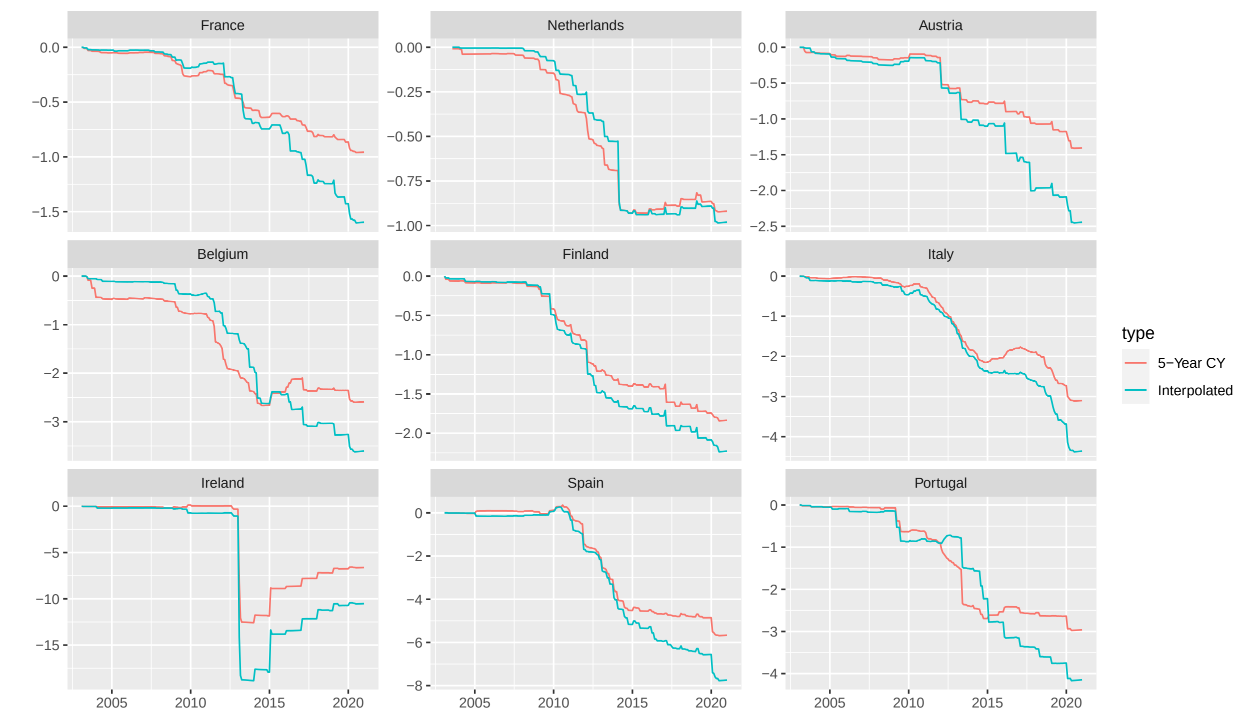

Figure 5: Cumulative Loss due to Convenience Yield Differentials

Notes: This figure plots each country's cumulative revenue loss, normalized by the concurrent national GDP.

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 an increase in the level of the convenience yield of a eurobond.

3.5 Global Flight To Safety

Convenience yield differentials do not capture global flight to safety dynamics. German convenience yield levels, and hence the baseline level in all Eurozone convenience yields, do. To see this, we study the relationship between convenience yield levels and convenience yield differentials on the one hand, and two indicators of the global flight to safety on the other hand. The indicators are (i) the 1-year U.S. Treasury basis against other G10 countries' government debt, and (ii) the monthly realized global equity volatility constructed from daily cum-dividend returns on the MSCI World Equity Index. We regress the monthly changes in the convenience yield measures on the monthly changes in these indicators.

Columns (1) and (4) of Table 3 show that the average convenience yield differential between other Eurozone countries and Germany is unrelated to the flight-to-safety measures. In contrast, columns (2) and (5) show that the German convenience yield level comoves with the flight-to-safety measures. The same is true for the average convenience yield level across Eurozone countries (excluding Germany), as shown in columns (3) and (6). So, while German and other Eurozone countries' convenience yield levels comove with flight-to-safety indicators, this comovement effect differences out once we study convenience yield differentials. In the next section, we will show that convenience yield differentials are closely related to relative fiscal conditions. This re-

Table 3: Convenience Yield Levels and Differentials and Flight to Safety

Notes: The dependent variables are the changes in the average convenience yield differential between Germany and other countries, the Germany convenience yield level, and the average convenience yield level across all countries. The sample is 2002—2020. *p<0.1; **p<0.05; ***p<0.01.

	$\Delta\overline{\lambda_t^i - \lambda_t^{DE}}$	$\Delta\lambda_t^{DE}$	$\Delta\overline{\lambda_t^i}$	$\Delta\overline{\lambda_t^i - \lambda_t^{DE}}$	$\Delta\lambda_t^{DE}$	$\Delta\overline{\lambda_t^i}$
	(1)	(2)	(3)	(4)	(5)	(6)
ΔUS Treasury basis (bps)	0.04	0.19***	0.22**			
	(0.09)	(0.06)	(0.10)			
ΔWorld Equity Vol (%)				-0.39	4.69***	4.34**
				(1.73)	(1.12)	(1.93)
Observations	213	213	213	213	213	213
Adjusted R^2	-0.004	0.04	0.02	-0.005	0.07	0.02

sult is consistent with our model's implication that convenience yield differentials adjust to absorb country-specific fiscal shocks within the currency union.

This comparison demonstrates that convenience yield levels and differentials play different roles in a currency union. Like other measures of flight-to-safety, the convenience yield increase during global flight-to-safety episodes marked by increases in volatility and larger Treasury bases. In contrast, the convenience yield differentials between member countries within the currency union adjust in response to country-specific fiscal shocks to clear the bond markets. In sum, these two channels are not mutually exclusive.

Furthermore, convenience yield levels (and differentials) are connected through a factor structure. To examine the common movements in countries' convenience yields, we regress each country's convenience yield level on Germany's convenience yield level:

$$\lambda_t^{i,h} \quad = \quad \alpha^i + \beta^i \lambda_t^{DE,h} + \varepsilon_t^i. \tag{9}$$

Table 4(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. As safe assets, the government bonds issued by the Netherlands and Austria are perceived to be close substitutes for German bonds. The debt of peripheral countries is perceived to be a poor substitute. None of the β^i coefficient is above 1, which suggests that when Germany's convenience

Table 4: Loadings on Convenience Yield Levels

Notes: Panel (a) reports the results of the regression (9) 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. The sample is 2002—2020. *p<0.1; **p<0.05; ***p<0.01.

	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

yield is higher, it rises above other countries' convenience yields. In other words, the convenience yield differential $\lambda_t^{DE,h} - \lambda_t^{i,h}$ should widen with an average coefficient of $1 - \beta^i > 0$. Moreover, the R^2s are substantial for several countries, suggesting that Germany's convenience yield represents a common factor in the cross-section of convenience yields.

Table 4(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.

4 Convenience Yields and Fiscal Conditions

In this section, we test our model's main prediction that the convenience yield differentials reflect the relative fiscal conditions of member countries. In particular, Result 2 implies that a country has a higher convenience yield relative to other countries in the currency union if its current and expected future government surpluses increase. 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.

4.1 Explaining Cross-Country Variation in Convenience Yield Differentials

First, we examine this relationship in the cross-section by comparing the average convenience yield differentials and the average government surplus-to-GDP or debt-to-GDP ratios across countries. Figure 6 plots these cross-sectional comparisons for 5-year bonds. On average, Germany has a low government deficit-to-GDP ratio (deficit is minus the surplus) and a low debt-to-GDP ratio, and it earns the highest average convenience yield among the Eurozone countries. In comparison, Portugal has high deficits and high debt, and it earns the lowest convenience yields relative to Germany. These cross-sectional findings are consistent with downward-sloping demand for sovereign debt by a given issuer within the Eurozone. As countries issue more debt, 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 Eurozone country's debt benefits from more safe asset demand.

Table 5 reports these results in linear regressions. We estimate two specifications. In Panel (a), we estimate a panel regression by pooling all tenors and then control for tenor fixed effects. The multivariate regression results in Column (3) imply that a one-standard-deviation increase in the average surplus-to-GDP ratio (which is 1.8%) increases the average convenience yield differential by 11 basis points. Similarly, a one-standard-deviation increase in the average debt-to-GDP ratio (which is 22%) decreases the average convenience yield differential by more than 7 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 (3), is 44 basis points. This is close to the observed difference in average convenience yields between Germany

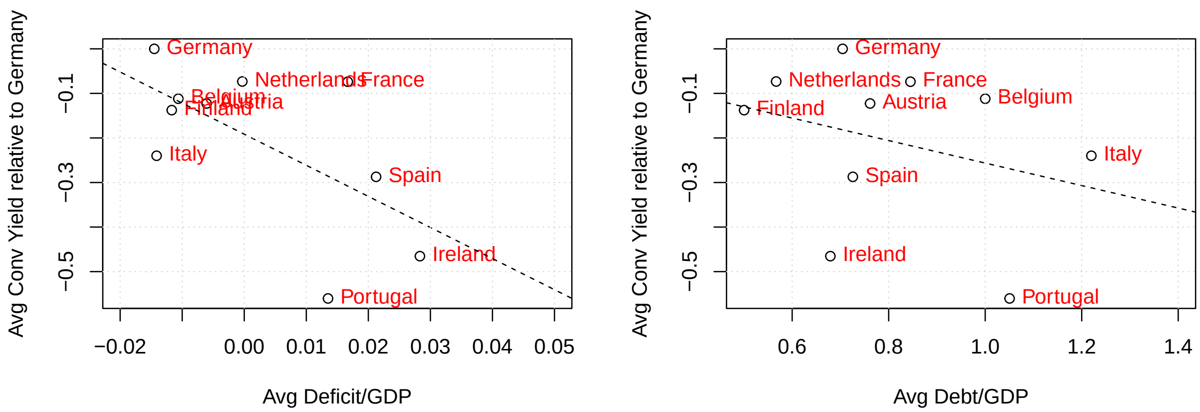

Figure 6: The Cross-Section of Convenience Yields and Fiscal Status

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

Table 5: Average Convenience Yield Differentials vs. Average Fiscal Conditions.

Notes: We take the average of the convenience yield differentials 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 differential 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.

Panel (a) Panel with Tenor Fixed Effects			
	(1)	(2)	(3)
Surplus/GDP	6.22^{***}		6.78^{***}
	(1.06)		(0.93)
Debt/GDP		-0.33^{***}	-0.39^{***}
		(0.10)	(0.08)
Observations	90	90	90
Adjusted R^2	0.39	0.24	0.54
Panel (b) 5-Year Tenor Only			
	(1)	(2)	(3)
Surplus/GDP	6.98^{*}		7.50^{**}
	(3.12)		(2.92)
Debt/GDP		-0.25	-0.32
		(0.27)	(0.21)
Observations	10	10	10
Adjusted R^2	0.31	-0.02	0.40

and Portugal, which is 51 basis points.

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

In Table A.1, we repeat these regressions additionally controlling for the bonds' liquidity, as measured by the average bid-ask spread. We show that the coefficients for the fiscal variables remain similar.

4.2 Explaining the Time-Series Variation in Convenience Yield Differentials

Fiscal condition also helps explain the variation in convenience yield differentials across time. We investigate how a country's bond yield, convenience yield, and the CDS spread change when its surplus-to-debt ratio changes. The regression specification is as follows:

$$\Delta\tilde{y}_t^i \text{ or } \Delta\tilde{\lambda}_t^i \text{ or } \Delta\tilde{\delta}_t^i = \alpha + \beta\Delta\tilde{s}_t^i + \varepsilon_t^i \tag{10}$$

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

While the government surplus data are annual from Eurostat, the asset price data are daily. We take a stance on the timing of these asset prices. Specifically, 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 six months' time for the fiscal information to affect the debt market.

Table 6(a) reports the regression results for the 5-year tenor. As shown in Column (2), higher government surpluses are associated with higher convenience yield differentials in the time series. The point estimate suggests that a one-standard-deviation increase in the government surplus/GDP ratio (about 2.5%) is associated with a 27 basis point increase in the convenience yield differential. Given this regression does not include any fixed effects, the R^2 of 31% is also notable. Column (3) shows that higher government surpluses are also associated with lower default spreads. Both effects combine to lead to lower bond yield differentials.

Panels (b) and (c) control for the bonds' bid-ask spreads and the countries' GDP growth. The coefficient of interest remains economically and statistically significant. Appendix Table A.2 repeats the regressions for the sample that combines all tenors, with similar results.

Returning to our relative variance decomposition in Eq. (4), repeated below for convenience, we can use the change in the surplus/GDP ratio as a proxy for fiscal news $\widehat{d}_t^i$. If the Eurozone countries have the same duration of debt h, then the implied duration would be $\frac{1}{0.11+0.22} = 3.03$

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

Notes: Results for the regression Eq. (10). The sample is 2002—2020 at annual frequency. Rates and surplus-to-GDP ratios are differenced by their German counterparts. 5-year tenor only. *p<0.1; **p<0.05; ***p<0.01.

Panel (a): Surplus Alone			
	(1)	(2)	(3)
	$\Delta\tilde{y}$	$\Delta\tilde{\lambda}$	$\Delta\tilde{\delta}$
ΔSurplus/GDP (%)	-0.33^{***}	0.11^{***}	-0.22^{***}
	(0.03)	(0.01)	(0.02)
Observations	151	151	151
Adjusted R^2	0.42	0.31	0.37
Panel (b): Control for Change in Bid-Ask Spread			
	(1)	(2)	(3)
	$\Delta\tilde{y}$	$\Delta\tilde{\lambda}$	$\Delta\tilde{\delta}$
ΔSurplus/GDP (%)	-0.15^{***}	0.06^{***}	-0.09^{***}
	(0.02)	(0.01)	(0.02)
ΔBid Ask Spread	9.85^{***}	-2.90^{***}	6.94^{***}
	(0.66)	(0.37)	(0.51)
Observations	151	151	151
Adjusted R^2	0.77	0.51	0.72
Panel (c): Control for GDP Growth			
	(1)	(2)	(3)
	$\Delta\tilde{y}$	$\Delta\tilde{\lambda}$	$\Delta\tilde{\delta}$
ΔSurplus/GDP (%)	-0.33^{***}	0.11^{***}	-0.22^{***}
	(0.03)	(0.01)	(0.02)
Log GDP Growth	0.33	0.32	0.65
	(2.31)	(0.97)	(1.70)
Observations	151	151	151
Adjusted R^2	0.42	0.31	0.37

years.

$$1 = h\frac{\mathrm{Cov}_{t-1}\left(\widehat{\lambda}_t^{i,h}, \widehat{d}_t^i\right)}{\mathrm{Var}_{t-1}\left(\widehat{d}_t^i\right)} - h\frac{\mathrm{Cov}_{t-1}\left(\widehat{\delta}_t^{i,h}, \widehat{d}_t^i\right)}{\mathrm{Var}_{t-1}\left(\widehat{d}_t^i\right)} = 3.03 \times (0.11 - (-0.22)). \tag{11}$$

The convenience yield channel accounts for 0.11×3.03 or 33% of the variance in fiscal news (debt valuations), while the default risk channel accounts for the remaining 67%.

4.3 The Explanatory Power of Fiscal Forecasts

Proposition 1 suggests that the convenience yield, like any other asset price, is forward-looking. Not only current realized fiscal conditions but also forecasts of future fiscal conditions affect current convenience yields.

For a subsample of Eurozone countries (Germany, France, Italy, the Netherlands, and Spain), we obtain median forecasts of budget deficits in the current year and in the next year. The data is from Consensus Economics and available monthly. Since not every country's deficit forecast is sampled on the same day of the month, we aggregate to quarterly frequency and take the last observation in the quarter. We normalize the median forecast of the budget deficit by the GDP in the year prior to the year for which the forecast is produced.

Table 7 reports the regression results for five-year bonds. As with the realized surplus, a higher forecasted surplus-to-GDP ratio is associated with a higher convenience yield differential. The economic magnitude is comparable to the results using realized surpluses in the previous section. A 1% point increase in the forecasted government surplus-to-GDP ratio in the current year is associated with a 7 basis points increase in the convenience yield differential. Appendix Table A.3 repeats these regressions controlling for changes in bid-ask spreads.

Returning to our relative variance decomposition in Eq. (4), the change in the forecasted surplus is a plausible proxy for fiscal news $\widehat{d}_t^i$. If the Eurozone countries have the same duration of debt h, then the implied duration would be $\frac{1}{0.07+0.05} = 8.3$ years.

$$1 \quad = \quad h\frac{\mathrm{Cov}_{t-1}\left(\widehat{\lambda}_t^{i,h}, \widehat{d}_t^i\right)}{\mathrm{Var}_{t-1}\left(\widehat{d}_t^i\right)} - h\frac{\mathrm{Cov}_{t-1}\left(\widehat{\delta}_t^{i,h}, \widehat{d}_t^i\right)}{\mathrm{Var}_{t-1}\left(\widehat{d}_t^i\right)} = 8.3 \times (0.07 - (-0.05)) \,. \tag{12}$$

When we use survey data, the convenience yield channel accounts for 0.07×8.3 or 58% of the

Table 7: Time-Series Change in Convenience Yield vs. Change in Fiscal Forecasts.

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.

Panel (a): Forecast of Current Year Surplus			
	(1)	(2)	(3)
	$\Delta\tilde{y}$	$\Delta\tilde{\lambda}$	$\Delta\tilde{\delta}$
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

variance in fiscal conditions (debt valuations), while the default risk channel accounts for the remaining 42%. These results show that fiscal news is an important driver of convenience yields.

5 Conclusion

We develop a theoretical framework to study the convenience yields countries earn on their bond issuance in a currency union. Consistent with our model, convenience yields are a major determinant of sovereign bond yield differentials in the Eurozone as they absorb country-specific fiscal shocks. Convenience yields, or the lack thereof, imply large fiscal costs for the peripheral countries, which can be mitigated through responsible fiscal stewardship. Our findings speak to the costs and benefits of deepening the fiscal union in the Eurozone.

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Appendix

A Proof

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:

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

and

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

So

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

Combine with the period-t constraint, the sum is

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

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

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

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

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

$\square$

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

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

Then, the market value of outstanding government debt is

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

Similarly,

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

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 $\frac{(1-e^{-\bar{c}^i})\exp(-(r+\bar{\omega}^i-\bar{c}^i))}{1-e^{-r}}\frac{\bar{Q}^i}{1-e^{-(r+\bar{\omega}^i+\nu-\bar{c}^i)}}$. We can express the budget condition as

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

B Additional Empirical Results

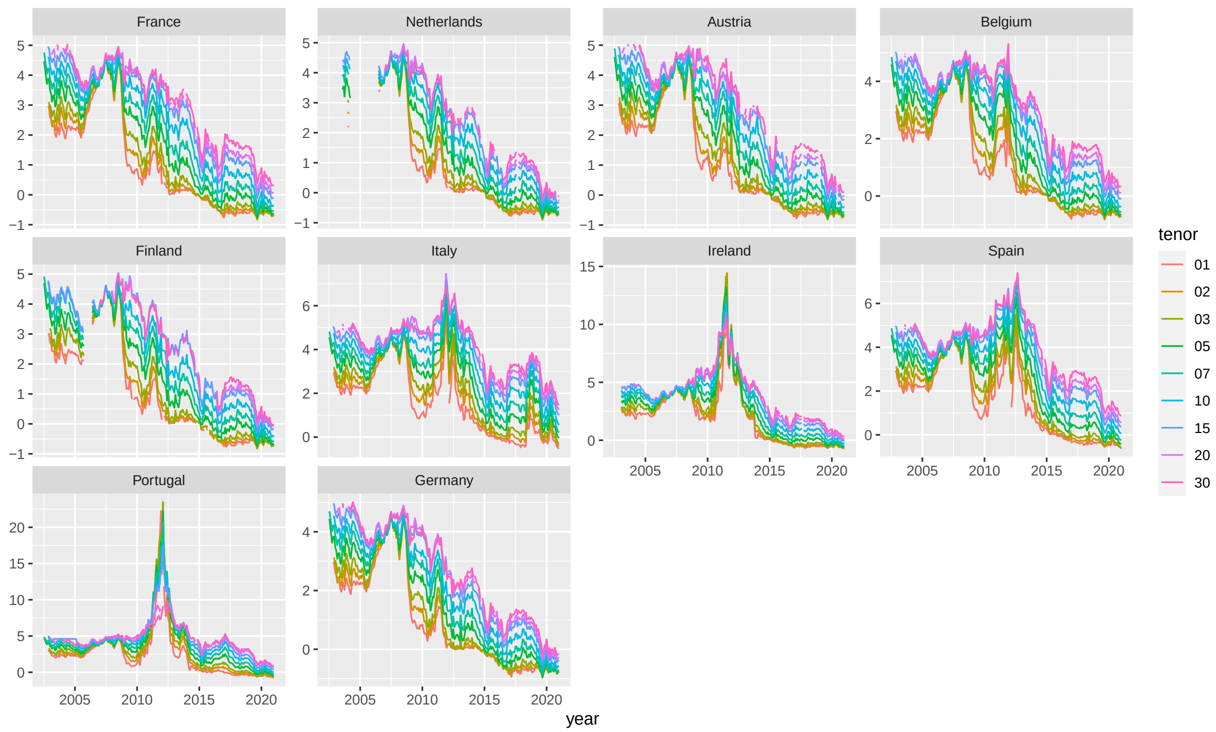

Figure A.1: The Time Series of Yields

Notes: The yields are in percentage points.

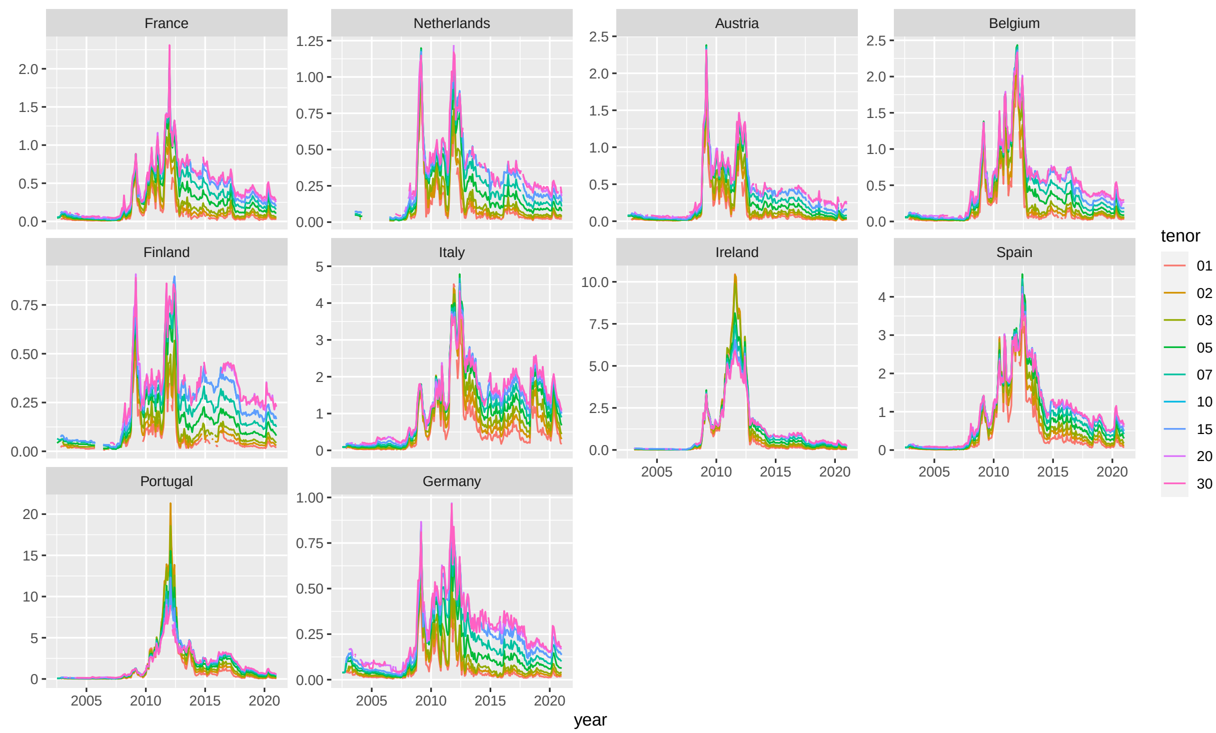

Figure A.2: The Time Series of CDS Spread

Notes: The CDS spreads are in percentage points.

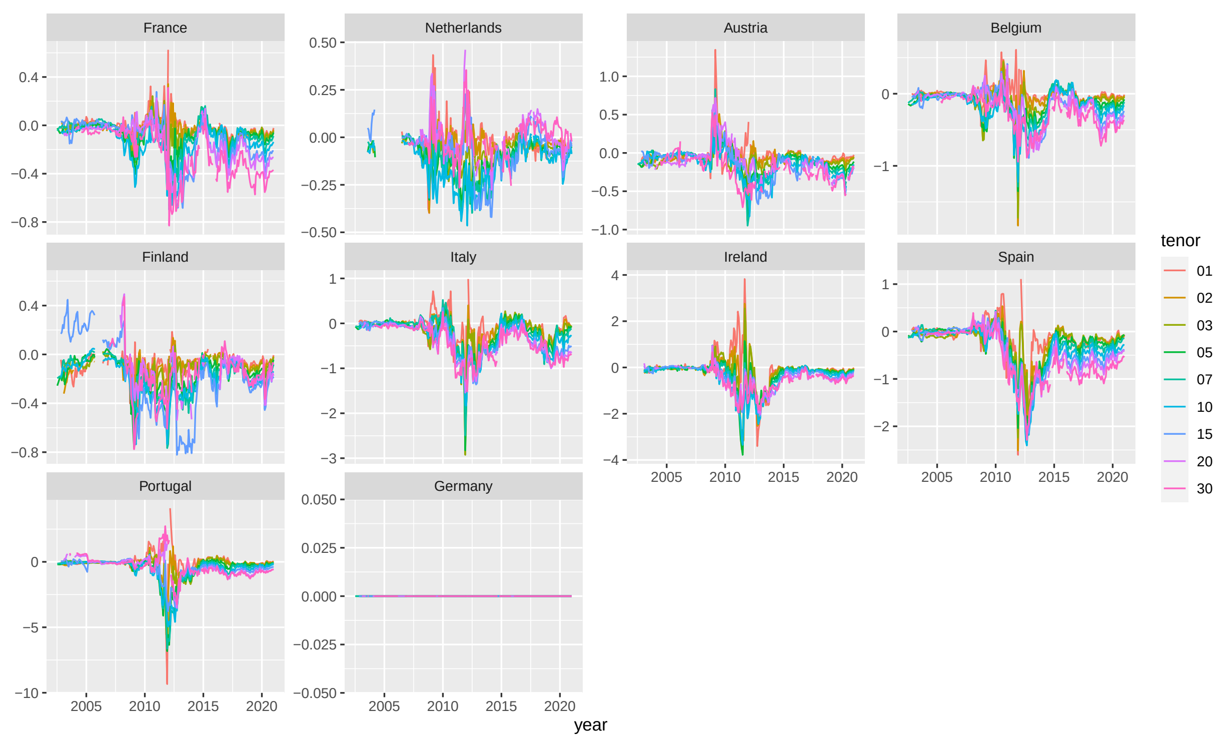

Figure A.3: The Time Series of Convenience Yields

Notes: The convenience yields are in percentage points.

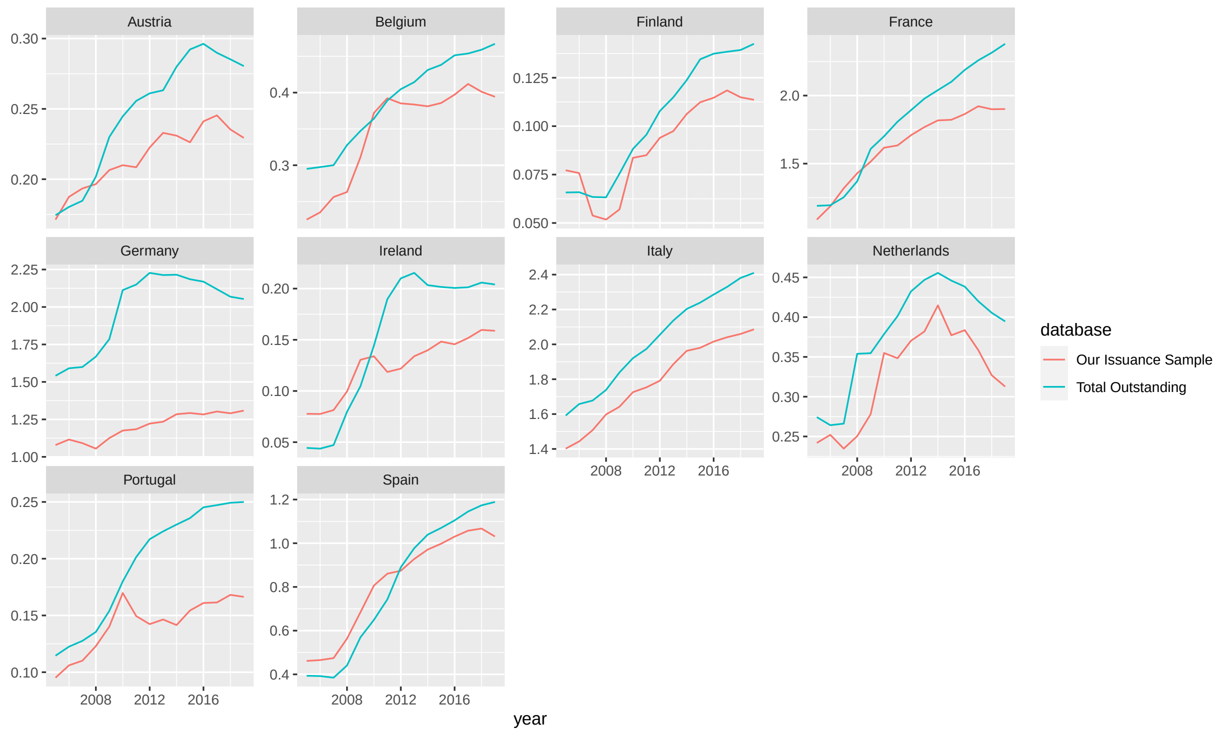

Figure A.4: Coverage of Bond Issuance Database

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.

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.

Panel (a) Panel with Tenor Fixed Effects			
	(1)	(2)	(3)
Surplus/GDP	5.38^{***}		6.44^{***}
	(1.13)		(1.01)
Debt/GDP		-0.28^{***}	-0.39^{***}
		(0.10)	(0.08)
Bid Ask Spread	-0.74^{**}	-1.14^{***}	-0.38
	(0.35)	(0.36)	(0.31)
Observations	88	88	88
Adjusted R^2	0.41	0.31	0.55

Panel (b) 5-Year Tenor Only			
	(1)	(2)	(3)
Surplus/GDP	1.04		1.82
	(1.98)		(1.90)
Debt/GDP		-0.13	-0.16
		(0.11)	(0.11)
Bid Ask Spread	-4.51^{***}	-4.66^{***}	-4.12^{***}
	(0.91)	(0.67)	(0.88)
Observations	10	10	10
Adjusted R^2	0.82	0.85	0.85

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

Notes: Results for the regression Eq. (10). The sample is 2002—2020 at annual frequency. Rates and surplus-to-GDP ratios are differenced by their German counterparts. 5-year tenor only. *p<0.1; **p<0.05; ***p<0.01.

Panel (a): Surplus Alone			
	(1)	(2)	(3)
	$\Delta\tilde{y}$	$\Delta\tilde{\lambda}$	$\Delta\tilde{\delta}$
ΔSurplus/GDP (%)	-0.27^{***}	0.06^{***}	-0.22^{***}
	(0.04)	(0.02)	(0.03)
Observations	1,325	1,213	1,251
Adjusted R^2	0.37	0.09	0.38
Panel (b): Control for Change in Bid-Ask Spread			
	(1)	(2)	(3)
	$\Delta\tilde{y}$	$\Delta\tilde{\lambda}$	$\Delta\tilde{\delta}$
ΔSurplus/GDP (%)	-0.22^{***}	0.05^{**}	-0.17^{***}
	(0.03)	(0.02)	(0.02)
ΔBid Ask Spread	3.33^{***}	-0.54^{***}	2.77^{***}
	(0.57)	(0.20)	(0.49)
Observations	1,263	1,172	1,186
Adjusted R^2	0.57	0.13	0.60
Panel (c): Control for GDP Growth			
	(1)	(2)	(3)
	$\Delta\tilde{y}$	$\Delta\tilde{\lambda}$	$\Delta\tilde{\delta}$
ΔSurplus/GDP (%)	-0.27^{***}	0.06^{***}	-0.22^{***}
	(0.04)	(0.02)	(0.03)
Log GDP Growth	0.05	0.80	0.65
	(2.26)	(0.86)	(1.65)
Observations	1,325	1,213	1,251
Adjusted R^2	0.37	0.09	0.38

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

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.

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