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EURO AREA SOVEREIGN YIELD DYNAMICS

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In 2004 all publications will carry a motif taken from the €100 banknote.

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CONTENTS

Abstract

We study sovereign yield dynamics and order flow in the largest euro-area treasury markets. We exploit unique transaction data to explain daily yield changes in the ten-year government bonds of Italy, France, Belgium, and Germany. We use a state space model to decompose these changes into (i) a "benchmark" yield innovation, (ii) a yield spread common factor innovation, (iii) country-specific innovations, and (iv) (transitory) noise. We relate changes in each of these factors to national order imbalance and find that Italian order imbalance impacts the common factor innovation, French and Belgian order imbalance impact country-specific innovations, and German order imbalance only changes yields temporarily. Order imbalance, however, does not have explanatory power for the most important factor: benchmark yield innovations.

JEL Classification: G10, G15, G18
Keywords: government bond, order imbalance, euro, international

Non-Technical Summary

Government bond markets have traditionally played an important role for both public and private agents. Public agents, such as governments and central banks, infer from pricing in these markets certain indicators for assessing inflation and output outlook. Private agents use these securities as a risk-free investment asset, as collateral, as a benchmark for pricing fixed-income securities and for hedging interest rate risks.

Price formation in these markets is commonly thought of as driven by public news, although we find increasing evidence that order imbalance—buy volume minus sell volume—matters as well. For the foreign exchange market, order imbalance moves prices *permanently* and has significantly more explanatory power than macro variables. Similarly, order imbalance in the U.S. treasury market correlates significantly with contemporaneous returns.

We explore price formation and the role of order imbalance in continental Europe, motivated by two recent developments: (i) the introduction of the euro, and, (ii) the transition from over-the-counter trading to an electronic market (MTS), including, not surprisingly, a pan-European trading platform. We study Italian, French, Belgian, and German yields in what is essentially a two-stage approach.

First, we decompose daily yield changes in components and estimate their size. We find that the "benchmark" (German) yield innovation is, by far, the most important component with a standard deviation of 3.61 basispoints per day. We find a strong common factor for yield spreads—national yields minus the benchmark yield—which contributes, in terms of standard deviation, 0.77, 0.30, and 0.51 basispoints for Italy, France, and Belgium, respectively. We find a country-specific innovation only for France and Belgium with standard deviations of 0.38 and 0.17, respectively. Finally, we cannot ignore transitory yield changes, as their standard deviations are 0.32, 0.58, 0.63, and 0.72 for Italy, France, Belgium, and Germany respectively.

Second, we relate each of the yield components to daily order imbalance and find that none of the national order imbalances impacts benchmark (German) yield innovations. We ascribe this to the presence of a highly liquid BUND futures market, which enables dealers to neutralize any benchmark yield exposure. This is why we do not see a "portfolio balance" effect, where market prices have to adjust to compensate dealers for not being able to diversify inventory across other dealers. For yield spreads, we find that common factor innovations are driven by Italian order imbalance. It appears that the Italian market is the "market of choice" for trading yield spread common factor exposures, arguably due to its superior liquidity. For the French and Belgian market, we find that country-specific innovations are driven by national order imbalance. All these effects are consistent with the "portfolio balance" hypothesis. Finally, national order imbalance might impact national sovereign yields temporarily to compensate dealers for inventory-holding and order-processing costs. We only find evidence of this for the German market as national order imbalance significantly impacts temporary yield changes.

1 Introduction

Government bond markets have traditionally played an important role for both public and private agents. Public agents, such as governments and central banks, infer from pricing in these markets certain indicators for assessing inflation and output outlook. Private agents use these securities as a risk-free investment asset[4], as collateral, as a benchmark for pricing corporate fixed-income securities and for hedging interest rate risks.

Price formation in these markets is commonly thought of as driven by public news, although there is increasing evidence that order imbalance matters as well. For the foreign exchange market, order imbalance moves prices *permanently* and has significantly more explanatory power than macro variables (see, e.g., Evans and Lyons (2002), Lyons (2001))[5]. We expect a similar role for order flow in government bond markets, as they are quite similar to forex markets in terms of market structure, the main players, and the type of news that is important (typically macro-economic announcements). Evidence for the U.S. treasury market shows that, indeed, order imbalance correlates significantly with contemporaneous returns (see, e.g., Fleming (2001), Brandt and Kavajecz (2004), and Green (2004)).

Theoretically, the traditional explanation for the (permanent) price impact of imbalance through privately-informed traders is hard to maintain in these markets. In the microstructure literature on equity, these traders exploit their private pay-off information strategically and hide their orders in the liquidity-motivated order flow. Rational market makers respond by updating their quotes conditional on order imbalance (see, e.g., Kyle (1985), Glosten and Milgrom (1985)). Two alternative explanations appear more promising. First, a *random* imbalance is only absorbed by market mak-

[4]Harris (2003) estimates that government bonds represent 10% of U.S. capital wealth; common stocks represent 20%.

[5]Their regressions of the daily changes in the log DM/US$ exchange rate on daily order imbalance produce R^2 statistics of over 60%.

ers if they are compensated for the risk of carrying sub-optimal inventory through time by a return premium and, thus, appropriately adjusted prices (see, e.g., Stoll (1978), Spiegel and Subramanyam (1995)). The premium and price effects are temporary, because in most markets the inventory position is shared with the wider market in subsequent transactions. This is referred to as the "inventory effect" in microstructure literature. Second, random order imbalance might impact prices permanently insofar as it cannot be completely "diversified" across all market participants. Hence, the market has to bear the risk and requires a permanent premium. In this case, (private) order imbalance information enables dealers to forecast discount factor changes. Macroeconomists call this the "portfolio balance effect" (see, e.g., Cao, Evans, and Lyons (2004) and Lyons (2001)). It is different from the inventory effect, as it implies that order imbalance has a permanent effect on price.

We explore price formation and the role of order imbalance in continental Europe, motivated by two recent developments: (i) the introduction of the euro, and, (ii) the transition from over-the-counter trading to an electronic market, including, not surprisingly, a pan-European trading platform.

The introduction of the euro has increased the degree of substitutability of euro-area government bonds. The market is increasingly regarded as a single one comparable in size to U.S. and Japanese markets. Early evidence shows that the share of stock of euro-area government bonds held by non-residents has increased by 7 percentage points between 1998 and 2000 (see Zautzik and Santorelli (2001)). Unique to the euro area, however, is the multiplicity of issuers and differences in credit ratings. Although some legal barriers to cross-border investment, such as currency matching rules, have been removed[6], other factors remain, such as the lack of integration of settlement systems, different tax regimes, regulatory environment, and market conventions.

[6]This particularly benefits pension funds and insurance companies.

Government bonds throughout Europe are increasingly traded through an electronic inter-dealer platform that originated in Italy: Mercato dei Titoli di Stato (MTS). The platform was set up in 1988 by the Bank of Italy and the Italian treasury to improve liquidity. In 1997, the "MTS group" was privatised and since then they expanded successfully abroad to other euro-denominated government bond markets.[7] In 1999, a pan-European platform was introduced, EuroMTS, that trades the benchmark bonds as well as high-quality non-government bonds. Galati and Tsatsaronis (2001) estimate its share of bond transactions at the beginning of 2000 at 40%. This new platform further reduced barriers to cross-border trading and enhanced transparency.

The advent of the euro and the (Euro)MTS trading platforms motivate an integrative approach to asset-pricing of euro-area government bonds. The elimination of exchange rate risk removed the most important source of yield differences across countries (see Blanco (2002)). For ten-year bonds, we view current yields as composed of a euro-area "benchmark" yield[8] and a yield spread that effectively is a premium for the country's credit status[9] and the liquidity of its bond market vis-à-vis the benchmark country. An appropriate asset-pricing model for sovereign yield spreads is developed in Duffie, Pedersen, and Singleton (2003), based on the Duffie and Singleton

[7] MTS is currently available in Belgium, Finland, France, Germany, Ireland, Netherlands, Portugal, and Spain.

[8] Consistent with previous literature (see, e.g., Blanco (2002) and Galati and Tsatsaronis (2001)) and with market participants' views (see Mathieson and Schinasi (2001)), we consider the ten-year German yield to be the euro-area "benchmark". This is confirmed by Dunne, Moore, and Portes (2002) who develop a methodology to study benchmark status. With today's budget deficits in Germany, the country's benchmark status might be challenged; in our sample period (2000–2001), however, this was not the case.

[9] Probability of default on government debt is often related to a country's debt level. Interesting in this respect, and relevant to the European Monetary Union (EMU), is the evidence for U.S. state governments. Bayoumi, Goldstein, and Woglom (1995) and Poterba and Rueben (1997) show that the yield of 20-year bonds of 39 U.S. states relative to New Jersey increases with the level of debt. Bernoth, von Hagen, and Schuknecht (2003) do the same for seven European countries and also find that sovereign yield spreads vis-à-vis the German yield depend on the level of debt.

(1999) framework. Inspired by this model, we consider a common factor in euro-area yield spreads, as, most likely, EMU governments are increasingly subject to common (macro) shocks. This potentially causes commonality in yield spreads, both directly and through changes in the market price of (sovereign) risk. Country-specific changes in yield spreads occur due to (idiosyncratic) changes in a country's credit status or the liquidity in its market. Favero, Pagano, and Thadden (2004) develop a sovereign yield model that includes trading and find an explicit relationship between sovereign yield, liquidity, and the market price of risk.

In this paper, we study daily changes in euro-area ten-year sovereign yields by decomposing them into benchmark yield changes, yield spread common factor changes, country-specific changes, and temporary changes. We relate each component to national and international order imbalance and interpret the findings based on existing theory. We see three areas in which we contribute to the literature. First, we extend the well-established single market analyses on the role of imbalance to a multiple market analysis. We are the first to study the role of national order imbalance for international sovereign yields within a single monetary system, i.e. the euro-area government debt market. Second, we use a state-space model to identify and estimate the importance of the proposed yield change components. The innovative feature of this model compared to a standard regression model is that it (i) deals naturally with missing observations due to non-synchronicity in non-trading days across Europe and (ii) it accommodates temporary changes in prices due to microstructure effects ("inventory"). These temporary effects are oftentimes ignored in daily analyses, but should not be as is evident from equity studies (see, e.g., George and Hwang (2001), Menkveld, Koopman, and Lucas (2003)). Third, we use a recent and unique database of all MTS and EuroMTS transactions in ten-year Italian, French, Belgian, and German government bonds. For each transaction, we have an exact time-stamp and we know whether it was buyer- or seller-initiated and can thus perfectly map transactions into daily order imbalance.[10] The sample period covers seventeen months from January 2001 through May 2002.[11]

Our empirical results demonstrate the importance of the integrative approach, as national order imbalance affects international sovereign yields. We find that none of the European order flow impacts "benchmark" yield changes, which contrasts findings for the U.S. markets. We attribute this to the presence of a highly liquid derivatives market in the "benchmark" security, i.e. the BUND future. Additionally, we find that Italian order imbalance affects not only Italian sovereign yields, but also Belgian and French yields, as it impacts the strong common factor in sovereign yield spreads. Finally, in a univariate analysis Belgian and French order imbalance do not affect yield changes, but in our multivariate set-up—where we control for temporary effects and innovations in the benchmark yield and the yield spread common factor—they do affect national yields. All these results are robust to controlling for macro-economic announcements that appear to impact short-term yields rather than ten-year yields.

Our findings add to two contemporary papers on the topic, as we consider the role of order imbalance. Favero, Pagano, and Thadden (2004) study euro-zone yield spreads and also find a strong common factor. They find that this factor is due to the market price of risk rather than to liquidity. Our results show that this factor is only driven by order imbalance in the most liquid of the non-benchmark markets: the Italian market.[12] Biais, Renucci, and Saint-Paul (2004) study treasury auctions for several euro-

[10]Unlike many other studies that require the imperfect Lee and Ready (1991) algorithm to do this mapping.

[11]Cheung, de Jong, and Rindi (2003) contains a detailed description of the dataset and documents that signed orders impact bond prices.

[12]Favero, Pagano, and Thadden (2004) develop a model for sovereign yields that includes trading rounds for investors. However, in their set-up order imbalance does not depend on model parameters and, therefore, the model is silent on the role of order imbalance in the market.

zone countries and find that macro-economic variables (e.g. public deficits) and microstructure variables (e.g. the availability of an electronic trading platform) matter for the auction price and, therefore, determine sovereign yields.

The remainder of the paper is organized as follows. Section 2 briefly describes the institutional setting and presents summary statistics and a preliminary, univariate analysis. Section 3 explores the interaction between markets and presents the results of a multivariate model for sovereign yield dynamics. Section 4 reviews the microstructure literature to develop predictions on the role of order imbalance for euro-area yields and extends the model to study the impact of order imbalance empirically. Section 5 summarizes the main findings.

2 Data, Statistics, and Preliminary Analysis

We explore a recent and unique dataset of all MTS and EuroMTS transactions in the ten-year government bond markets of Italy, France, Belgium, and Germany.[13] These countries represent 75% of the European market for public debt (see Mathieson and Schinasi (2001)). The sample covers trading from January 2001 through May 2002. The data enable us to build clean measures of daily order imbalance, as all transactions are identified as buyer- or seller-initiated. We are careful to note that this does not represent total order imbalance, as MTS and EuroMTS have an important and increasing share of the market, but they are not the only trading venue. Galati and Tsatsaronis (2001) estimate its share of bond transactions at the beginning of 2000 at 40%. We are not overly worried, though, as our analysis of yield dynamics is not affected and the role of order imbalance in causing this dynamics is probably underestimated, i.e. if we find a role for order imbalance,

[13] In this study we focus on bonds with the expiration date in 2011, as these are the most liquid securities in the dataset.

the role of "total" imbalance is likely to be even stronger. The reason is that order imbalance across trading venues is probably positively correlated, as (i) investors are exposed to the same exogenous (macro) shocks and (ii) it is in the interest of investors to split orders across markets (see, e.g., Chowdhry and Nanda (1991), Menkveld (2003)).

2.1 Setting and Summary Statistics

The MTS and EuroMTS systems are electronic markets in which mainly investment banks participate, who are either market makers with a quote obligation or price takers. The main difference between the two systems is that the first is national and the second is pan-European. Most of the market makers are active on both platforms. Cheung, de Jong, and Rindi (2003) study trades and quotes in both systems and find that they are similar in many respects. We, therefore, decide to aggregate transactions across both systems for the remainder of the paper.[14]

In Table 1, we report daily averages of volume, the number of transactions, the absolute value of order imbalance, and the ten-year yield. We find that, by far, the Italian market generates most volume, EUR 1.10 billion per day. The French and Belgian market follow with EUR 171 and 135 million per day, respectively. The German market is smallest with EUR 46 million per day. The relatively high volume in the Italian market is at least partially explained by the size of Italian public debt: EUR 1,102 billion in July 2001 (see Blanco (2002)), which is roughly twice as high as French or German debt at that time. And, the local MTS trading system has the largest market share in Italy, as it originated there.[15] On the other end, German volume is relatively low for two main reasons. First, a highly liquid BUND futures index provides an alternative venue to build exposure to German ten-year

[14] For an elaborate description of the microstructure of these markets we refer to Cheung, de Jong, and Rindi (2003) as it is beyond the scope of this paper.

[15] The Italian debt office estimates this market share at 65% in its Quarterly Bulletin, 3rd Quarter 2002.

yields. Second, MTS-Germany fiercely competes for order flow with a local competitor: the Eurex Bond trading platform. If, instead of volume, we compare the euro-area markets in terms of the number of transactions or absolute order imbalance, we find similar results. To put these numbers into perspective, Fleming (2001) reports for ten-year U.S. treasury notes in the period 1996 through 2000 an average daily volume of $3.81 billion and an average number of transactions of 593.

The average ten-year yield in our sample period is lowest for Germany and highest for Belgium and Italy. The German yield is 4.77%. The French yield is 13 basispoints higher; Belgian and Italian yields are 25 basispoints higher. The German yield is lowest as it has become the ten-year "benchmark" yield in the euro area (see, e.g., Blanco (2002), Galati and Tsatsaronis (2001), and Mathieson and Schinasi (2001)). Concurrently, in the futures market on euro-area government bonds, the (ten-year) BUND futures gained market share from 57% in 1996 to 84% in 2001 (see Blanco (2002)). Higher yields for the other countries are primarily explained through a difference in credit status and liquidity vis-à-vis the German bond. In 2001, the sovereign credit ratings (Moody's/ Standard&Poor's) for Italy, France, Belgium, and Germany were Aa3/AA, Aaa/AAA, Aa1/AA+, and Aaa/AAA, respectively (see Mathieson and Schinasi (2001)). Hence, the higher yields for Italy and Belgium are most likely due to their lower credit status.

2.2 Univariate Analysis of Yields and Order Flow

As a preliminary analysis, we relate daily yield changes to order imbalance on a country-by-country basis. The scatter plots in Figure 1 reveal that (i) it is not immediately evident that such relationship exists and (ii) that there exist a few days with extraordinary imbalances.[16] To further explore

[16] We studied the news items for these days and altough we find some evidence of imbalances being driven by public news, we believe that they are primarily driven by liquidity needs of investors. For example, we do not find extraordinary imbalances around arguably the most important event in our sample period: the terrorist attack of September 11, 2001.

this relationship, we regress yield changes on order imbalance and, in a second set of regressions, on "logged" order imbalance.[17] The logarithmic transformation neutralizes the influence of extreme imbalance days in the regressions. The results in Table 2 show a significant role for order imbalance in the Italian and German market, but not in the French and Belgian market. The coefficient is negative, consistent with higher prices when buy volume exceeds sell volume on a particular day. The explanatory power of order imbalance is, however, relatively low in comparison to similar analyses for the U.S. treasury market; we find R^2 to be less than 5%, whereas U.S. studies find it to be around 20% (see Brandt and Kavajecz (2004) and Fleming (2001)). One of the reasons might be that euro-area government debt is priced collectively and we therefore turn to a multivariate approach.

2.3 Preparing for a Multivariate Model

Although interest rates mean-revert in the long run (see, e.g., Chan et al. (1992), Brenner, Harjes, and Kroner (1996), and Amin and Ng (1997)), we find that for a daily frequency yields are non-stationary. Figure 2 plots the Italian, French, Belgian, and German yields for the entire sample period. They appear to be non-stationary and Dickey-Fuller tests, reported in Table 3, confirm this, as for none of the countries we reject the null hypothesis of a unit root ($\xi = 0$).[18]

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[17] Logged order imbalance is defined as sign(order imbalance)*log(1+|order imbalance|). One step further is to ignore trade size and define order imbalance as the number of buys minus the number of sells. Fleming (2001) uses this definition in a similar study for the U.S. treasury market. We also use this alternative definition for our models and find qualitatively similar results.

[18] As the figure suggests, our data period does not include monetary announcements with strong impact on the ten-year yield. We have screened all ECB announcements in this period and the most important one is the 0.5% cut in the main refinancing rate, announced on September 17, 2001. That day, the ten-year German yield dropped by 17 basispoints, which is, by no means, extraordinary. For this study we decided to present all our results without controlling for macro-announcements, as we find that they do not change if we do control for such annoucements.

Figure 2 further suggests a strong common factor in yield changes for the major euro-zone issuers. Cross-country correlations, reported in Panel A of Table 4, range from 0.92 (Belgium-Germany) to 0.97 (Italy-France). Panel B of the same table presents the factor structure, which is establised through principal components analysis. We sort the factors according to the percentage of total variance explained and find that the first factor contributes 96%. These results are consistent with the view that non-German sovereign yields are the sum of the German "benchmark" yield and a so-called yield spread that compensates investors for potentially higher sovereign risk or worse liquidity.

For yield spreads, a similar analysis reveals that they too are non-stationary. This is suggested by the yield spread plot in Figure 3 and confirmed by the Dickey-Fuller tests in Table 3.[19] It is tempting to view the decrease as a result of the introduction of the euro, but one has bear in mind that yield spreads increased in the first months after the euro came into existence on January 1, 1999 (see, e.g., Bernoth, von Hagen, and Schuknecht (2003)).[20] The figure again suggests a strong common factor and Panel A of Table 4 reports high and significant correlations in yield spreads ranging from 0.68 (France-Belgium) to 0.76 (Italy-France). Economically, there appears to be a common risk factor for the non-benchmark countries.[21] This could be due to commonality in liquidity for these countries, common (macro) shocks that impact the probability of default for the non-benchmark countries[22], or the risk of EMU failure and the return of exchange rate risk prior to redemption of the bond.

[19] These tests are, essentially, a test on (economically motivated) co-integration.

[20] A thorough discussion of the economic forces driving the yield spread change is beyond the scope of the current paper.

[21] Geyer, Kossmeier, and Pichler (2004) are the first to report a strong common factor in euro-area yield spreads. Their data sample runs from January 1999 through April 2000.

[22] The likelihood of multiple governments defaulting on their debt at the same time is non-negligible, not only due to common shocks to their economies, but also because default is essentially a political decision. Governments trade off the cost of making debt payments against reputation costs, the costs of having assets abroad seized, and the costs of having international trade impeded (see Eaton and Gersovitz (1981), Bulow and Rogoff (1989), and Gibson and Sundaresan (1999)) Its political nature makes it easier for governments to default when neighbors have done so.

For the remainder of the paper, we suggest a multivariate model that captures both the "asset-pricing" features of sovereign yields (non-stationarity and commonality) and potential "microstructure" effects, such as the impact of order imbalance on yield changes.

The multivariate nature of the model motivates a sampling scheme that accounts for a potential non-synchronicity bias. Traditionally, end-of-day prices are used to relate log price changes to order imbalance (see, e.g., Evans and Lyons (2002)). In a multivariate setting, however, this approach might lead to biased estimates of yield change components if trading frequency significantly differs across markets. In that case, the average time stamp of the final quote or trade in the day differs across markets, and, therefore, time intervals do not fully overlap.[23] Inspired by Brandt and Kavajecz (2004), we decide to measure our variables over separate and disjoint intervals. For each security and each day in our sample, we aggregate signed transactions from the market open to 15:00 to find daily order imbalance. In contrast, yields are averaged from 15:00 to the market close. The sampling scheme is summarized as:

$\longleftarrow$ day t $\longrightarrow$		$\longleftarrow$ day t+1 $\longrightarrow$	
Open - 15:00	15:00 - Close	Open - 15:00	15:00 - Close
Order Imbalance (x_t)	Yield (y_t)	Order Imbalance (x_{t+1})	Yield (y_{t+1})

The choice of 15:00 is the result of a trade-off: a later time in the day improves the quality of the calculated order imbalance as a measure of *daily* order imbalance, but, at the same time, leads to more missing values for daily

[23]We will come back to this issue later, as in Appendix B we will show that ignoring non-synchronicity leads to biased estimates.

yields and vice versa for an earlier time. Table 5 reveals that the number of days with no trades ranges from 0.7% for Italy to 24.8% for Germany. This is the benchmark for the number of days with missing values for the yield after 15:00. Hence, the table shows that by only considering observations after 15:00, we lose, relative to the benchmark, 0.9% of the days for Italy and 20.3%, 21.2%, and 26.7% for France, Belgium, and Germany, respectively. The order imbalance measure, on the other hand, covers between 75.5% and 78.9% of the number of daily transactions as is evident from the same table.

3 Decomposition of Sovereign Yield Changes

In this section, we construct and estimate a multivariate model to decompose daily sovereign yield changes into benchmark (German) yield innovations, yield spread common factor innovations, country-specific innovations, and temporary deviations. A natural extension to include order imbalance is left for the next section. We choose to capture yield dynamics through a state space model for four reasons. First, we do not, ex-ante, want to rule out temporary yield changes due to microstructure effects. In the equity literature, these effects were proven to be significant (see George and Hwang (2001), de Jong, Mahieu, and Schotman (1998), and Menkveld, Koopman, and Lucas (2003)). Second, we want to exploit the full sample period, even though some 2011 issues did not exist yet in January 2001. The Kalman filtering and smoothing that comes with estimating state space models deals with missing values in a natural way. Third, the same goes for missing values due to the proposed sampling scheme of yields after 15:00. Fourth, state space models allow for estimating latent factors, which appear to be driving euro-area sovereign yields.[24]

[24]We refer to Durbin and Koopman (2001) for a discussion of state space models.

To introduce the model, we first present a univariate version of a state space model for yields:

$$\begin{aligned} v_t &= v_{t-1} + \sigma^{SI} z_{1,t}, \\ y_t &= v_t + \sigma^{ME} z_{2,t}, \end{aligned} \tag{1}$$

where, in state space terms, the first equation is the state equation that specifies the dynamics in the unobserved state variable and the second is the observation equation that sets the observed variable equal to the state variable plus some measurement error. $z_{i,t}$ are independent and standard normal distributed random variables and σ^{SI} and σ^{SE} represent the standard deviations of the state innovation (SI) and the measurement error (ME). For our application, we interpret this model as: y_t, the observed yield, is equal to a noise-free or "true" yield (v_t) plus a potential temporary deviation due to microstructure effects.

We generalize this model to a multivariate model, including common factors:

$$\begin{aligned} \underline{v}_t &= \underline{v}_{t-1} + \underline{c} + f_t^{BY} \sigma^{BY} \underline{\iota} + f_t^{YS} \underline{\sigma}^{YS} + \Sigma^{CS} \underline{z}_{1,t} \\ f_t^{BY} &= z_{2,t} \\ f_t^{YS} &= z_{3,t} \\ \underline{y}_t &= \underline{v}_t + \Sigma^{ME} \underline{z}_{4,t} \end{aligned} \tag{2}$$

$$\begin{gathered} \Sigma^{CS} = \mathrm{diag}((\sigma_{CS}^{IT})^2, \ldots, (\sigma_{CS}^{DE})^2), \\ \Sigma^{ME} = \mathrm{diag}((\sigma_{ME}^{IT})^2, \ldots, (\sigma_{ME}^{DE})^2), \\ \sigma_{CS}^{DE} = \sigma_{YS}^{DE} = 0, \\ \underline{\iota} = (1, \ldots, 1)', \end{gathered}$$

where the underlined variables are vectors in $\mathbb{R}^4$ that contain values for Italy (IT), France, Belgium, and Germany (DE); f_t^{BY} and f_t^{YS} are unobserved factors to pick up the "benchmark" yield (BY) change and commonality in the yield spread (YS) change[25], respectively; the associated scaling factors

[25] Note that yield spreads are defined as yield premiums vis-à-vis the German yield.

σ^{BY} and $\underline{\sigma}^{YS}$ measure their importance in total yield change; Σ^{CS} and Σ^{ME} are diagonal matrices with scaling parameters that capture the importance of country-specific (CS) yield innovations and the measurement error (ME), respectively; $\underline{c}$ is the intercept term. To identify the "benchmark" yield as the German one, we set σ^{DE}_{CS} and σ^{DE}_{YS} equal to zero.

To establish identification and to gain further insight into the model, we develop the reduced form of equation (2), by calculation of the variance and autocovariances of $\Delta\underline{y}_t$:[26]

$$\mathrm{var}(\Delta\underline{y}_t) =$$

$$\begin{pmatrix} \Omega+(\sigma^{IT}_{CS})^2+(\sigma^{IT}_{ME})^2 & \Omega & \Omega & \sigma^2_{BY} \\ \Omega & \Omega+(\sigma^{FR}_{CS})^2+(\sigma^{FR}_{ME})^2 & \Omega & \sigma^2_{BY} \\ \Omega & \Omega & \Omega+(\sigma^{BE}_{CS})^2+(\sigma^{BE}_{ME})^2 & \sigma^2_{BY} \\ \sigma^2_{BY} & \sigma^2_{BY} & \sigma^2_{BY} & \sigma^2_{BY}+(\sigma^{DE}_{ME})^2 \end{pmatrix}$$

$$\mathrm{cov}(\Delta\underline{y}_t, \Delta\underline{y}_{t-1}) =$$

$$\begin{pmatrix} -(\sigma^{IT}_{ME})^2 & 0 & 0 & 0 \\ 0 & -(\sigma^{FR}_{ME})^2 & 0 & 0 \\ 0 & 0 & -(\sigma^{BE}_{ME})^2 & 0 \\ 0 & 0 & 0 & -(\sigma^{DE}_{ME})^2 \end{pmatrix}$$

$$\mathrm{cov}(\Delta\underline{y}_t, \Delta\underline{y}_{t-k}) = 0 \text{ for } k \geq 1,$$

with $\Omega = \sigma^2_{BY} + \sigma^2_{YS}$, and BY, YS, CS, and ME indicate the various components of sovereign yield changes: benchmark yield innovations, yield spread innovations, country-specific innovations, and measurement errors,

[26] With these expressions, it is immediately evident that all parameters are identified: the measurement error variances through the diagonal of $\mathrm{cov}(\Delta\underline{y}_t, \Delta\underline{y}_{t-1})$; the benchmark yield innovation variance through the fourth row, fourth column element of $\mathrm{var}(\Delta\underline{y}_t)$; the yield spread innovation variance through the off-diagonal elements of $\mathrm{var}(\Delta\underline{y}_t)$; and, finally, the country-specific innovations throught the diagonal elements of $\mathrm{var}(\Delta\underline{y}_t)$.

respectively. IT, FR, BE, DE are country indices: Italy, France, Belgium, and Germany, respectively.

We use maximum likelihood to estimate the parameters. In each step of the optimization we use Kalman filtering and smoothing techniques to calculate the likelihood. We use appropriate algorithms for inference and signal extraction (see, e.g., Durbin and Koopman (2001)). The estimation was done in Ox using SsfPack software (see Doornik (2001) and Koopman, Shephard, and Doornik (1999)).

The model estimates are tabulated in Table 6 and depicted in Figure 4. A nice feature of the model set-up is that all σ coefficients are, effectively, standard deviations of the various components of yield change. Hence, the analysis, essentially, can be interpreted as "variance decomposition" of the yield change into: a benchmark yield innovation (BY), a yield spread common factor innovation (YS), a country-specific innovation (CS), and measurement error (ME). The results reveal that the daily benchmark yield innovation (σ^{BY}), by far, dominates all other components with an estimated standard deviation of 3.61 basispoints. The yield spread common factor is significant for all three countries and factor loadings (σ^{YS}) are 0.77, 0.30, and 0.51 basispoints for Italy, France, and Belgium, respectively. Interestingly, for Italy this factor makes up the entire yield spread innovation, as we cannot reject the null hypothesis of no country-specific innovation (σ^{CS}). For France and Belgium, however, we do find significant country-specific innovations with standard deviations of 0.38 and 0.17 basispoints, respectively. Measurement error (σ^{ME}) or, in microstructure terms, temporary inventory effects due to market making activity, cannot be ignored for daily changes in the yield, as they are economically and statistically significant with a standard deviation in the range of 0.32 for Italy to 0.72 for Germany.[27]

[27]Interestingly, our estimates for the measurement error match up quite well with reported bid-ask spreads (see Cheung, de Jong, and Rindi (2003)) in terms of cross-sectional ranking. High spreads coincide with high measurement error, which supports the "inventory effect" explanation. In terms of size, they are smaller, which reflects the existence of

In the Appendix, we explore the merits of the proposed methodology. We compare our parameter estimates with those of conventional analyses that ignore non-synchronicity and measurement error. We find significant differences and conclude that the traditional approach leads to biased estimates.

4 Sovereign Yield Changes and Order Imbalance

The interesting and new issue in our paper is how national order imbalance affects euro-area sovereign yields, which, in a single market, are priced collectively. In this section, we use the microstructure literature to develop predictions for the role of daily order imbalance in the euro-area sovereign debt market. We then extend the dynamic model developed in section 3 to include order flow.

4.1 Related Literature: What do we Expect for Order Flow?

To discuss the role of order imbalance in a multiple security setting, we review the microstructure literature developed for a single security.[28] The early literature focuses on equity trading, where order imbalance has a permanent impact on prices, as it contains orders from investors with private information on future cash flows. For exchange rates and government bonds, all future cash flow related information is public and it was therefore quite unexpected that order imbalance also permanently moves prices in these markets (see, e.g., Evans and Lyons (2002), Fleming (2001), Brandt and Kavajecz (2004), and Green (2004)).[29] A common explanation builds on the structure of these markets, as liquidity providers, i.e. dealers, often take

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an informational ("portfolio balance") component in bid-ask spreads.

[28]For an extensive survey on the microstrcuture literature, we refer to Madhavan (2000)

[29]Fleming and Remolona (1999) show, for the U.S. treasury market, that price response to public news announcements happens through bid and ask quote adjustments rather than through actual trades.

on large positions by trading with investors and subsequently neutralize these by trading with other dealers in the market ("hot potato trading"). If this position cannot be fully "diversified" across all dealers, prices will have to adjust to make the market bear the remaining inventory (see, e.g., Lyons (1997), Evans and Lyons (2002)). Macroeconomists call this the "portfolio balance" effect (see Lyons (2001)). This effect is different from what microstructure ecnonomists call the "inventory effect," which predicts that order imbalance has a *temporary* effect on prices, since dealers need to be compensated for temporarily keeping a sub-optimal inventory position (Stoll (1978) and Spiegel and Subramanyam (1995)). Such temporary effect also compensates dealers for order-processing costs (see, e.g., Copeland and Stoll (1990)).

In the remainder, we discuss the role of daily order imbalance for each of the four components of sovereign yield changes as captured by $\underline{z}_1$ through $\underline{z}_4$ in equation (2).

Temporary deviations ($\underline{z}_4$)

To start with the temporary effect of order imbalance, we expect temporary deviations in the national sovereign yield to be negatively related to national order imbalance. In other words, we expect temporary *price* changes to be *positively* related to imbalance. That is, prices "overreact" to order imbalance, which is in the interest of quote-setting "national" dealers who need to be compensated for the inventory-holding and order-processing costs of providing liquidity.

Benchmark yield innovations (z_2)

In the presence of a highly liquid derivatives market (BUND future), we do not expect order imbalance to impact benchmark yield innovations. That is, any exposure of dealers to the benchmark yield can easily be hedged through an offsetting position in the BUND future market and therefore we do not expect a "portfolio balance" effect.[30]

Country-specific yield innovations ($\underline{z}_1$)

Country-specific innovations cannot be hedged and we therefore expect these innovations to be negatively related to national order imbalance, due to the "portfolio balance" effect.

Yield spread common factor innovations (z_2)

There is no ex-ante reason to expect a role of order imbalance for yield spread common factor innovations. If, however, one of the non-German markets is highly liquid, this market might become the "market of choice" for dealers who want to neutralize an exposure to yield spread common factor innovations. These dealers, however, will only do so if the country-specific innovations in this market are small vis-à-vis the yield spread common factor innovations, as this is the extra risk they take on. In this case, the "portfolio balance" effect predicts the most liquid market's order imbalance to negatively impact yield spread common factor innovations.

4.2 Empirical Results for Euro-Area Order Flow

We relate the various components of yield change to order imbalance to screen the predictions based on the order imbalance literature. But, before we estimate the impact of order imbalance, we start with a preliminary analysis of euro-area order flow. Given our result that benchmark yield innovations are the most important factor that drives euro-area sovereign yields, we might expect investors to regard the four bonds as perfect substitutes. In this case, theory predicts that investors minimize price concession

[30] Naik and Yadav (2003) provide evidence on how U.K. government bond dealers use the futures market to manage their risk.

by splitting orders across markets (see, e.g., Chowdhry and Nanda (1991), Biais, Martimort, and Rochet (2000)). Indicative evidence is in Panel A of Table 4 as it reports cross-country correlations in volume and order imbalance. For volume, four out of six correlations are significantly positive, ranging from 0.11 for Italy-Germany to 0.26 for Italy-Belgium. Days of high volume apparently coincide for these markets. More important, however, is whether trading is in the same direction. Order imbalance correlations are all positive, but only significant for two out of six pairs: 0.11 for Italy-Belgium and 0.16 for France-Belgium. The factor structures for volume and order imbalance, reported in Panel B, show that the first factor accounts for less than 40% of total variation. Hence, evidence of order-splitting behavior is thin. These effects are more likely to be due to common exogenous shocks that make investors in these countries rebalance their portfolios. Important, however, in view of our objectives, is that we cannot, ex-ante, aggregate order imbalance across countries, as each country's imbalance potentially adds information as its correlation with other countries' imbalance is relatively low.

To study the role of national order imbalance for euro-area sovereign yield we extend the model presented in equation (2) in a very natural way:

$$\begin{aligned} \underline{v}_t &= \underline{v}_{t-1} + \underline{c} + f_t^{BY}\sigma^{BY}\underline{\iota} + f_t^{YS}\underline{\sigma}^{YS} + B^{CS}\underline{x}_t + \Sigma^{CS}\underline{z}_{1,t} \\ f_t^{BY} &= (\underline{\beta}^{BY})'\underline{x}_t + z_{2,t} \\ f_t^{YS} &= (\underline{\beta}^{YS})'\underline{x}_t + z_{3,t} \\ \underline{y}_t &= \underline{v}_t + B^{ME}\underline{x}_t + \Sigma^{ME}\underline{z}_{4,t} \end{aligned} \tag{3}$$

$$\begin{aligned} \Sigma^{CS} &= \text{diag}((\sigma_{CS}^{IT})^2, \ldots, (\sigma_{CS}^{DE})^2), \\ \Sigma^{ME} &= \text{diag}((\sigma_{ME}^{IT})^2, \ldots, (\sigma_{ME}^{DE})^2), \\ B^{CS} &= \text{diag}(\beta_{CS}^{IT}, \ldots, \beta_{CS}^{DE}), \\ B^{ME} &= \text{diag}(\beta_{ME}^{IT}, \ldots, \beta_{ME}^{DE}), \\ \sigma_{CS}^{DE} &= \sigma_{YS}^{DE} = 0, \end{aligned}$$

$$\beta_{YS}^{DE} = \beta_{CS}^{DE} = 0,$$
$$\underline{\iota} = (1, \ldots, 1)',$$

where, in addition to equation (2), $\underline{x}_t$ denotes order imbalance before 15:00 and, essentially, shows up as explanatory factor in each of the yield change components; β_{CS}, β_{BY}, β_{YL}, and β_{ME} represent its coefficients for each of the components. Consistent with the role of the German yield as the benchmark yield, we introduce the additional restrictions: $\beta_{CS}^{DE} = \beta_{YS}^{DE} = 0$. Note that this does not exclude a country-specific impact for German order imbalance as it shows up in the benchmark yield innovation equation.

Table 7 presents the model estimates that allow us to screen the predictions on the role of order imbalance presented in Section 4.1. We will discuss its role for each of the four components of sovereign yield change.

For temporary deviations, we find evidence only for the German market, where order imbalance negatively affects yield through the measurement error ($\underline{\beta}^{ME}$). This is consistent with the hypothesis that dealers need to be compensated for the costs of providing liquidity, i.e. inventory-holding and order-processing costs.

For benchmark yield innovations, we do not find a significant role of any of the national order imbalances ($\underline{\beta}^{BY}$). This is consistent our hypothesis; the presence of a highly liquid derivates market—the BUND futures market—enables dealers to neutralize any benchmark yield exposure.

For country-specific yield innovations, we find a significant negative impact of order imbalance only in the French and Belgian market ($\underline{\beta}^{CS}$). This is consistent with the hypothesized "portfolio balance" effect i.e. if this risk factor cannot be diversified by offloading an inventory position across dealers, prices have to adjust for the market to bear this risk. Evidently, other euro-area markets cannot be used to neutralize an exposure to country-specific innovations. And, the order imbalance effect is economically significant as the standard deviation of its contribution to the common factor is

27% and 52%, respectively, relative to the total standard deviation of this factor.[31]

For yield spread common factor innovations, we find a significant impact of order imbalance in the Italian market ($\underline{\beta}^{YS}$). As we could not reject the null hypothesis of no Italian country-specific innovations, this market appears to serve as the "market of choice" for yield spread common factor exposures. Dealers can thus neutralize such exposure through the Italian market as they do not take on country-specific risk. This is consistent with the significantly negative effect of Italian order imbalance on yield spread common factor innovations. And, its effect is economically significant as the standard deviation of its contribution to the common factor is 25% of the total standard deviation.

5 Conclusion

We study euro-area ten-year sovereign yields in what is essentially a two-stage approach.

First, we decompose daily yield changes in components and estimate their size. We find that the "benchmark" (German) yield innovation is, by far, the most important component with a standard deviation of 3.61 basispoints per day. We find a strong common factor for yield spreads—national yields minus the benchmark yield—which contributes, in terms of standard deviation, 0.77, 0.30, and 0.51 basispoints for Italy, France, and Belgium, respectively. We find a country-specific innovation only for France and Belgium with standard deviations of 0.38 and 0.17, respectively. Finally, we cannot ignore transitory yield changes, as their standard deviations are 0.32, 0.58, 0.63, and 0.72 for Italy, France, Belgium, and Germany, respectively.

[31] The calculation that leads to this result is, in case of the French market, based on a coefficient of 0.03 and a standard deviation of order imbalance of 3.68 and a total standard deviation of the country-specific factor of 0.38 (see Table 6). Hence, $0.27 = \frac{0.03 \cdot 3.68}{\sqrt{(0.03 \cdot 3.68)^2 + 0.38^2}}$.

Second, we relate each of the yield components to daily order imbalance and find that none of the national order imbalances impacts benchmark (German) yield innovations. We ascribe this to the presence of a highly liquid BUND futures market, which enables dealers to neutralize any benchmark yield exposure. This is why we do not see a "portfolio balance" effect, where market prices have to adjust to compensate dealers for not being able to diversify inventory across other dealers (see, e.g., Evans and Lyons (2002)). For yield spreads, we find that common factor innovations are driven by Italian order imbalance. It appears that the Italian market is the "market of choice" for trading yield spread common factor exposures, arguably due to its superior liquidity. This impact is also economically significant as the standard deviation of its contribution compared to total standard deviation is 25%. For the French and Belgian market, we find that country-specific innovations are driven by national order imbalance. Again, contributions are economically significant, 27% and 52%, respectively, relative to total standard deviation. All these effects are consistent with the "portfolio balance" hypothesis. Finally, national order imbalance might impact national sovereign yields temporarily to compensate dealers for inventory-holding and order-processing costs. We only find evidence of this for the German market as national order imbalance significantly impacts temporary yield changes.

The merits of the proposed methodology based on a state space model become particularly clear when comparing results with conventional univariate analysis. In the latter case, we find a significant role for Italian and German imbalance, but not for French and Belgian imbalance. Our model reveals that French and Belgian imbalance do have a significant effect, but only on yield innovation when we control for the benchmark yield innovation, the yield spread common factor innovation, and (temporary) noise.

Appendix: Merits of the Proposed Methodology

We motivated our sampling scheme and the state space approach for a number of reasons, in particular, to circumvent non-synchronicity and to account for potential temporary microstructure effects. In this section, we illustrate the merits of this methodology by comparing our results with the results of more conventional analyses that ignore these issues. Any difference in parameter estimates indicates how biased the results of conventional analyses are.

If we disregard non-synchronicity, we find significantly higher measurement errors. A conventional approach is to take the last transaction price in the day in order to calculate yield changes. The reason for this is that it is the only information available in standard databases. In a multivariate set-up, this means that yield changes are not synchronized, particularly in our case where the number of observations for the Italian market far exceeds the other markets. Table 8 contains the model estimates based on the conventional sampling scheme. We see that, consistent with non-synchronicity, the size of common factor innovations is underestimated (σ^{BY} and σ^{YS}). More important, however, is the finding that measurement errors increase dramatically, from the range of 0.32 to 0.72 to a range of 0.95 to 1.21.

If, in addition to disregarding non-synchronicity, we also do not allow for measurement errors, we find significantly different results. This traditional approach assumes transaction prices are equal to efficient prices and considers temporary deviations, therefore, negligible. For changes at a daily level, these temporary effects cannot be ignored, as we documented significant measurement errors. If we, nevertheless, disregard these effects, Table 9 shows that the estimates significantly change. Particularly, the size of common spread and country-specific innovations is overestimated (σ^{YS} and σ^{CS}).

These findings reconfirm the value of the proposed sampling scheme and the state space model.

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Table 1: Summary Statistics

This table presents trading statistics on ten-year government bonds. They are based on all MTS and EuroMTS transactions for the period from January 1, 2001, through May 31, 2002.

(Daily Averages)	Italy	France	Belgium	Germany
Volume[a]	1095.85	171.10	134.58	46.42
	(661.55)	(127.95)	(113.38)	(63.76)
#Transactions	164.02	12.74	14.93	7.62
	(124.63)	(18.46)	(12.50)	(11.08)
|Order Imbalance|[b]	115.15	34.60	52.02	17.87
	(174.42)	(60.77)	(57.74)	(30.29)
Yield[c]	5.02	4.90	5.02	4.77
	(0.22)	(0.24)	(0.23)	(0.27)

[a] In million Euro face value.

[b] In 1,000 bonds.

[c] Based on days with observations for all markets to ensure meaningful comparisons across markets.

Table 2: Yield Change and Order Imbalance: Univariate Results

This table reports the results of country-by-country regressions of daily yield changes on order imbalance. Yield (in basispoints) is calculated from the last transaction price in the day; order imbalance is calculated based on all transactions.

Panel A: Standard Order Imbalance

	Italy	France	Belgium	Germany
Intercept	0.119	0.130	0.051	0.157
	(0.56)	(0.39)	(0.24)	(0.58)
Order Imbalance	**−0.003**	0.003	−0.003	**−0.012**
	(−2.87)	(0.80)	(−1.10)	(−1.97)
R^2	0.03	0.00	0.00	0.02
N	300	173	331	222

Panel B: Logged Order Imbalance[b]

	Italy	France	Belgium	Germany
Intercept	0.209	0.124	0.042	0.127
	(0.97)	(0.37)	(0.19)	(0.48)
Logged Order Imbalance[b]	**−0.169**	0.028	−0.057	**−0.264**
	(−3.51)	(0.33)	(−0.96)	(−2.66)
R^2	0.04	0.00	0.00	0.03
N	300	173	331	222

[a]Bold face is used to indicate 90% significant estimates.

[b]Defined as: sign(Order Imbalance)*log(1+|Order Imbalance|).

Table 3: Unit Root Tests for Sovereign Yields and Yield Spreads

This table contains the results of Dickey-Fuller tests to trace unit roots in sovereign yields and sovereign yield spreads, defined as a country's yield minus the German yield. The tests are based on all MTS and EuroMTS transactions for the period from January 1, 2001, through May 31, 2002. We estimate the model:

$$\begin{aligned} \Delta y_t &= \alpha + \phi y_{t-1} + \varepsilon_t, \quad \varepsilon_t \sim \mathrm{N}(0, \sigma^2), \\ \mathrm{H}_0 &: \phi = 0, \quad \text{(series contains unit root)} \end{aligned}$$

where y_t is the average yield on day t and ε_t is an i.i.d. random variable. The Dickey-Fuller test statistic (DF) is the estimated ϕ divided by its standard error.

Panel A: Sovereign Yields

	Italy	France	Belgium	Germany
α	0.101	0.073	0.109	0.134
	(0.054)	(0.068)	(0.054)	(0.060)
ϕ	−0.020	−0.015	−0.021	−0.027
	(0.011)	(0.014)	(0.010)	(0.012)
DF^a	−1.86	−1.07	−2.00	−2.20
Reject H_0?	No	No	No	No
N	299	172	332	221

Panel B: Sovereign Yield Spreads

	Italy	France	Belgium
α	0.005	−0.002	0.005
	(0.006)	(0.006)	(0.007)
ϕ	−0.022	0.010	−0.018
	(0.018)	(0.042)	(0.021)
DF^a	−1.19	0.23	−0.85
Reject H_0?	No	No	No
N	167	69	205

[a]The 95% critical value is -2.86.

Table 4: Commonality

This table presents inter-market correlations and a factor decomposition based on these correlations using principal components analysis. We study ten-year yields, yield spreads, volume, and order imbalance. The yield spread is defined only for the Italian, French, and Belgian bonds as the yield difference with "benchmark" German yield. Panel A presents inter-market correlations. Panel B presents the factor structures, which are ordered by the percent of total variation explained by each factor. The estimates are based on MTS and EuroMTS transactions for the period from January 1, 2001, through May 31, 2002.

Panel A: Correlation[a] (Daily Values)

	Yield Level Changes			Yield Spread Changes		Volume			Order Imbalance		
	France	Belgium	Germany	France	Belgium	France	Belgium	Germany	France	Belgium	Germany
Italy	**0.97**	**0.96**	**0.94**	**0.76**	**0.69**	0.12	**0.26**	**0.11**	0.06	**0.11**	0.05
	(0.08)	(0.06)	(0.08)	(0.12)	(0.08)	(0.07)	(0.06)	(0.06)	(0.07)	(0.06)	(0.06)
France		**0.95**	**0.95**		**0.68**		**0.20**	**0.22**		**0.16**	0.09
		(0.08)	(0.12)		(0.12)		(0.07)	(0.07)		(0.07)	(0.07)
Belgium			**0.92**					−0.05			0.03
			(0.07)					(0.05)			(0.05)

Panel B: Factor Structures[b] (Daily Values)

	Factors Yield Level Changes				Factors Volume				Factors Order Imbalance			
	1^{st}	2^{nd}	3^{rd}	4^{th}	1^{st}	2^{nd}	3^{rd}	4^{th}	1^{st}	2^{nd}	3^{rd}	4^{th}
Italy	0.51	-0.18	0.23	0.81	0.61	0.31	-0.13	-0.72	0.48	0.29	-0.82	0.08
France	0.50	0.17	-0.85	-0.04	0.36	-0.64	0.67	-0.09	0.47	-0.73	-0.03	-0.50
Belgium	0.50	-0.68	0.18	-0.51	0.56	0.48	0.24	0.64	0.56	-0.16	0.34	0.73
Germany	0.49	0.69	0.45	-0.29	0.43	-0.51	-0.69	0.27	0.48	0.60	0.45	-0.45
R^2	0.96	0.03	0.01	0.00	0.39	0.25	0.21	0.15	0.32	0.24	0.23	0.21

[a] Bold face is used to indicate 90% significant estimates.
[b] We do not report the factor structure for yield spreads changes as we have too few observations.

Table 5: Missing Values and Coverage Order Imbalance

This table presents (i) the number of days with missing values relative to the total number of days that the bond was available for trade and (ii) it presents the number of transactions before 15:00 relative to the total number of transactions to gauge how much of daily transactions the before-15:00 order imbalance measure covers.

Panel A: Missing Values

(%)	Italy	France	Belgium	Germany
Transactions	0.7	2.2	2.3	24.8
Yield after 15:00	1.6	22.5	23.5	51.5
Order Imbalance before 15:00	0.7	3.3	4.3	30.1

Panel B: Coverage Order Imbalance

(%)	Italy	France	Belgium	Germany
Order Imbalance before 15:00[a]	76.4	78.9	78.0	75.5

[a]The number of transactions before 15:00 as a percentage of the total number of transactions.

Table 6: Sovereign Yield Model Estimates

This table contains maximum likelihood estimates of a state space model for ten-year European sovereign yields based on transaction prices for the period from January 1, 2001, through May 31, 2002. The model definition is

$$\begin{aligned}
\underline{v}_t &= \underline{v}_{t-1} + \underline{c} + f_t^{BY}\sigma^{BY}\underline{\iota} + f_t^{YS}\underline{\sigma}^{YS} + \Sigma^{CS}\underline{z}_{1,t} & (1)\\
f_t^{BY} &= z_{2,t} & (2)\\
f_t^{YS} &= z_{3,t} & (3)\\
\underline{y}_t &= \underline{v}_t + \Sigma^{ME}\underline{z}_{4,t} & (4)
\end{aligned}$$

$$\Sigma^{CS} = \text{diag}((\sigma_{CS}^{IT})^2, \ldots, (\sigma_{CS}^{DE})^2);\ \Sigma^{ME} = \text{diag}((\sigma_{ME}^{IT})^2, \ldots, (\sigma_{ME}^{DE})^2);$$
$$\sigma_{CS}^{DE} = 0;\ \underline{\iota} = (1, \ldots, 1)';$$

where (1)-(3) are the state equations and (4) is the observation equation. Underlined variables are vectors in $\mathbb{R}^4$ that contain values for Italy (IT), France, Belgium, and Germany (DE); $\underline{y}_t$ contains the average yield after 15:00 (in basispoints); $\underline{v}_t$ is the noise-free "true" yield; f_t^{BY} and f_t^{YS} are unobserved factors to pick up the "benchmark" yield (BY) innovation and commonality in yield spread (YS) innovations, respectively; the associated scaling factors σ^{BY} and $\underline{\sigma}^{YS}$ measure their importance for total yield change; Σ^{CS} and Σ^{ME} are diagonal matrices with scaling parameters that capture the importance of country-specific (CS) yield innovations and the measurement error (ME), respectively; $\underline{c}$ is the intercept term. To identify the "benchmark" yield as the German one, we set σ_{CS}^{DE} and σ_{YS}^{DE} equal to zero. Standard deviations are in parentheses.

Panel A: Yield Change Decomposition (basispoints)

	All	Italy	France	Belgium	Germany
Yield Level (σ^{BY})	3.61				
	(0.15)				
Yield Spread ($\underline{\sigma}^{YS}$)		0.77	0.30	0.51	
		(0.09)	(0.13)	(0.08)	
Country-Specific ($\underline{\sigma}^{CS}$)		0.00[a]	0.38	0.17	
			(0.13)	(0.05)	
Measurement Error ($\underline{\sigma}^{ME}$)		0.32	0.58	0.63	0.72
		(0.11)	(0.11)	(0.05)	(0.10)

Panel B: Other Parameters[b]

	Italy	France	Belgium	Germany
Intercept ($\underline{c}$)	0.05	0.09	0.06	0.10
	(2.37)	(2.08)	(2.28)	(1.97)

[a]We cannot reject the null hypothesis of no country-specific innovation for Italy at a 95% significance level.

[b]Bold face is used to indicate 95% significant estimates.

Table 7: Sovereign Yield Model Estimates with Order Imbalance

This table, essentially, extends Table 6 to include order imbalance. The model is

$$\begin{aligned} \underline{v}_t &= \underline{v}_{t-1} + \underline{c} + f_t^{BY}\sigma^{BY}\underline{\iota} + f_t^{YS}\underline{\sigma}^{YS} + B^{CS}\underline{x}_t + \Sigma^{CS}\underline{z}_{1,t} \\ f_t^{BY} &= (\underline{\beta}^{BY})'\underline{x}_t + z_{2,t} \\ f_t^{YS} &= (\underline{\beta}^{YS})'\underline{x}_t + z_{3,t} \\ \underline{y}_t &= \underline{v}_t + B^{ME}\underline{x}_t + \Sigma^{ME}\underline{z}_{4,t} \end{aligned}$$

$$\begin{aligned} &B^{CS} = \text{diag}(\beta_{CS}^{IT}, \ldots, \beta_{CS}^{DE});\ B^{ME} = \text{diag}(\beta_{ME}^{IT}, \ldots, \beta_{ME}^{DE}); \\ &\Sigma^{CS} = \text{diag}((\sigma_{CS}^{IT})^2, \ldots, (\sigma_{CS}^{DE})^2);\ \Sigma^{ME} = \text{diag}((\sigma_{ME}^{IT})^2, \ldots, (\sigma_{ME}^{DE})^2); \\ &\beta_{CS}^{DE} = 0;\ \beta_{YS}^{DE} = 0;\ \sigma_{CS}^{DE} = 0;\ \underline{\iota} = (1, \ldots, 1)'; \end{aligned}$$

where, in addition to the notation in Table 6, $\underline{x}_t$ denotes order imbalance before 15:00 and, essentially, shows up as explanatory factor for each of the yield change components; β^{CS}, β^{BY}, β^{BY}, and β^{ME} are the associated coefficients. Consistent with the German yield being the benchmark yield, we need the additional restrictions: $\beta_{CS}^{DE} = \beta_{YS}^{DE} = 0$. Standard deviations are in parentheses.

Panel A: Yield Change Decomposition (basispoints)

	All	Italy	France	Belgium	Germany
Yield Level (σ^{BY})	3.59				
	(0.15)				
Yield Spread ($\underline{\sigma}^{YS}$)		0.71	0.25	0.44	
		(0.10)	(0.13)	(0.11)	
Country-Specific ($\underline{\sigma}^{CS}$)		0.00[a]	0.36	0.16	
			(0.13)	(0.05)	
Measurement Error ($\underline{\sigma}^{ME}$)		0.35	0.56	0.62	0.73
		(0.10)	(0.10)	(0.05)	(0.10)

Panel B: Order Imbalance Impact[a]

	Italy	France	Belgium	Germany
Yield Level ($\underline{\beta}^{BY}$)	0.00	−0.03	0.00	−0.01
	(0.01)	(0.02)	(0.02)	(0.02)
Yield Spread ($\underline{\beta}^{YS}$)	**-0.06**	0.03	−0.03	
	(0.03)	(0.04)	(0.03)	
Country-Specific ($\underline{\beta}^{CS}$)	0.01	**-0.03**	**-0.03**	
	(0.01)	(0.02)	(0.01)	
Measurement Error ($\underline{\beta}^{ME}$)	−0.01	0.03	0.01	**-0.08**
	(0.01)	(0.02)	(0.01)	(0.03)

Panel C: Other Parameters[b]

	Italy	France	Belgium	Germany
Intercept ($\underline{c}$)	0.05	0.07	0.07	0.08
	(2.39)	(2.25)	(2.24)	(2.21)

[a]We cannot reject the null hypothesis of no country-specific innovation for Italy at a 95% significance level.

[b]Bold face is used to indicate 95% significant estimates.

Table 8: Is Non-Synchronicity an Issue?

This table contains estimates of the sovereign yield model presented in Table 6; this time, however, we do not control for non-synchronicity by averaging prices after 15:00. Instead, yields are based on the last transaction price, which is often reported in standard financial databases. By comparing these results with those of Table 6, we find to what extent non-synchronicity matters. Standard deviations are in parentheses.

Panel A: Yield Change Decomposition (basispoints)

	All	Italy	France	Belgium	Germany
Yield Level (σ^{BY})	3.51				
	(0.15)				
Yield Spread ($\underline{\sigma}^{YS}$)		0.77	0.37	0.58	
		(0.12)	(0.15)	(0.10)	
Country-Specific ($\underline{\sigma}^{CS}$)		0.00[a]	0.31	0.16	
			(0.11)	(0.06)	
Measurement Error ($\underline{\sigma}^{ME}$)		1.13	1.12	0.95	1.21
		(0.08)	(0.10)	(0.08)	(0.10)

Panel B: Other Parameters[b]

	Italy	France	Belgium	Germany
Intercept ($\underline{c}$)	0.04	0.08	0.05	0.11
	(2.38)	(2.07)	(2.25)	(1.92)

[a]We cannot reject the null hypothesis of no country-specific innovation for Italy at a 95% significance level.

[b]Bold face is used to indicate 95% significant estimates.

Table 9: Are Temporary Microstructure Effects an Issue?

This table contains estimates of the sovereign yield model presented in Table 6; this time, however, we do not control for non-synchronicity by averaging prices after 15:00. Instead, yields are based on the last transaction price, which is often reported in standard financial databases. And, we do not allow for measurement error, which oftentimes is not considered in day-over-day studies. By comparing these results with those of Table 6, we find to what extent measurement matters. Standard deviations are in parentheses.

Panel A: Yield Change Decomposition (basispoints)

	All	Italy	France	Belgium	Germany
Yield Level (σ^{BY})	3.76				
	(0.15)				
Yield Spread ($\underline{\sigma}^{YS}$)		2.49	1.34	1.03	
		(0.12)	(0.16)	(0.12)	
Country-Specific ($\underline{\sigma}^{CS}$)		0.00[a]	1.67	1.65	
			(0.10)	(0.07)	
Measurement Error ($\underline{\sigma}^{ME}$)		0.00[b]	0.00[b]	0.00[b]	0.00[b]

Panel B: Other Parameters[c]

	Italy	France	Belgium	Germany
Intercept ($\underline{c}$)	0.04	0.07	0.05	0.10
	(2.80)	(2.59)	(2.54)	(2.04)

[a]We cannot reject the null hypothesis of no country-specific innovation for Italy at a 95% significance level.

[b]We fixed measurement error variance at zero.

[c]Bold face is used to indicate 95% significant estimates.

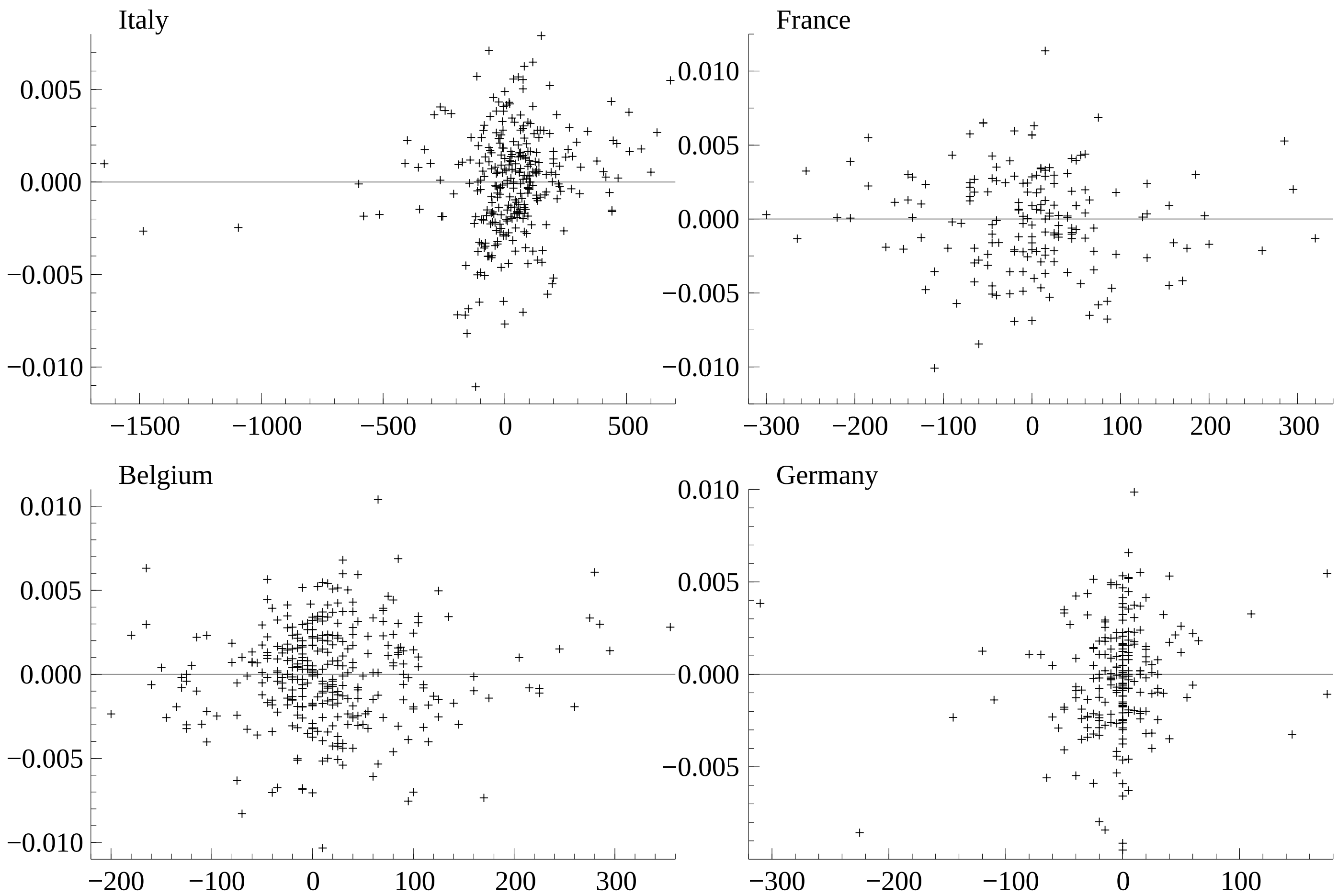

Figure 1: **Scatter Plot of Log Price Change and Order Imbalance**. This figure presents a scatter plot of the daily log price change and order imbalance (in 1,000 contracts) for all four countries. Daily prices are based on the last transaction in the day; order imbalance is the daily aggregate of signed transaction volume.

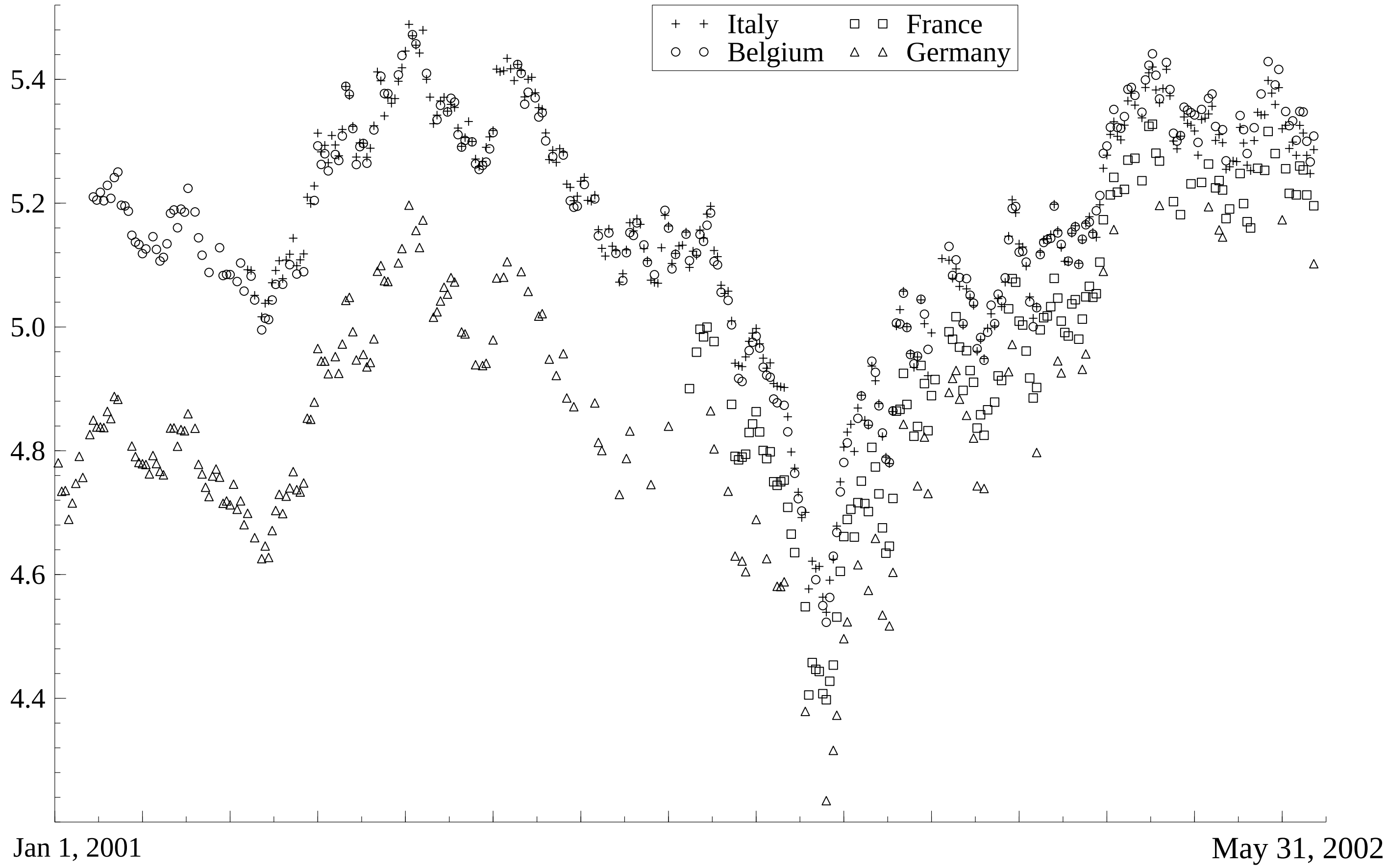

Figure 2: **Sovereign Yields**. This figure presents sovereign yields of Italian, French, Belgian, and German government bonds. Yields are calculated on a daily basis based on all transactions after 15:00 in the MTS and EuroMTS market. These series are input to the state space model that captures the yields dynamics and the impact of order imbalance (see Tables 6 and 7). The yields are reported for all business days from January 1, 2001, through May 31, 2002.

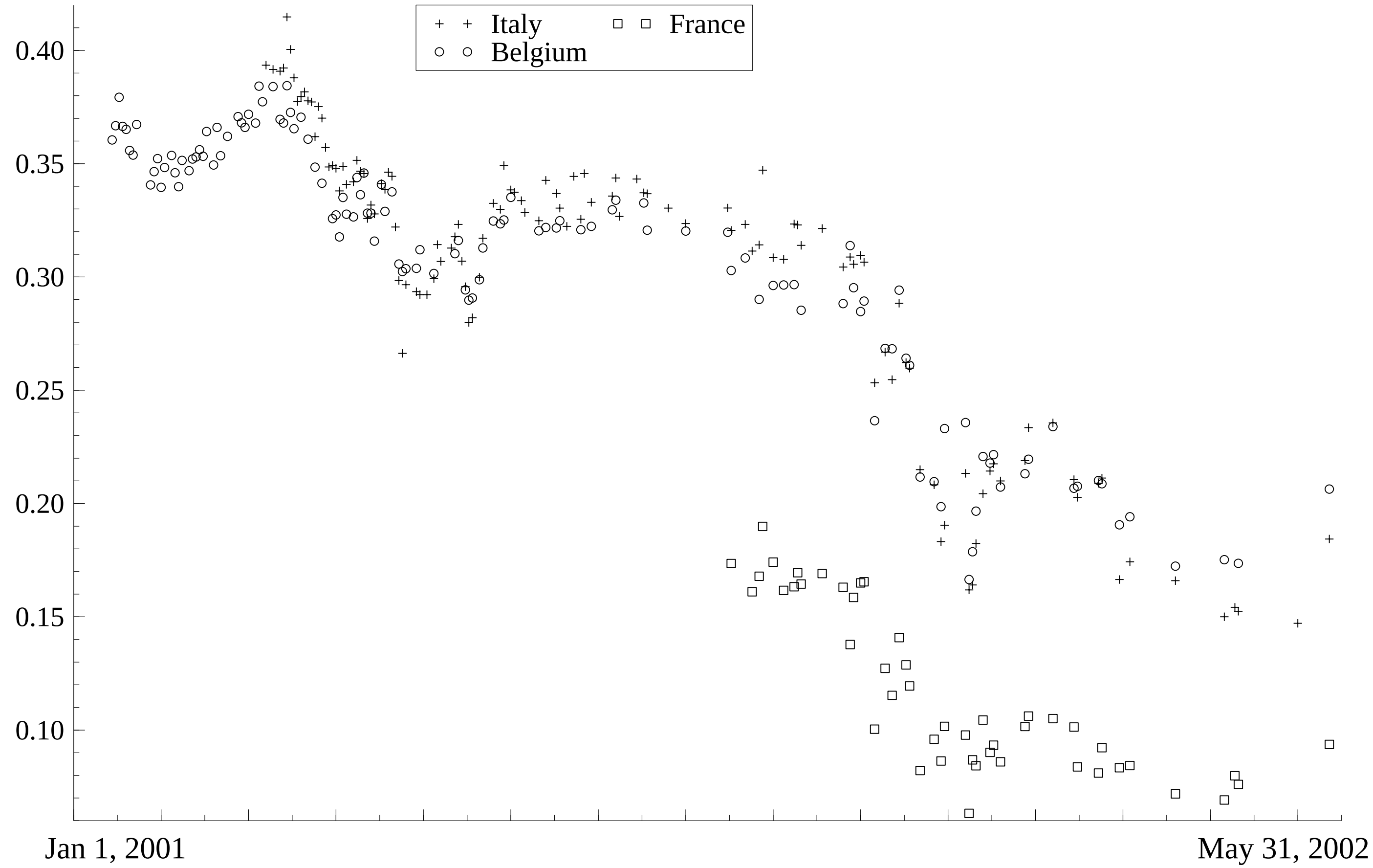

Figure 3: **Sovereign Yield Spreads**. This figure presents sovereign yield spreads of Italian, French, and Belgian government bonds. They are defined as the bond's yield minus the "benchmark" German yield. Yields are calculated on daily basis based on all transactions after 15:00 in the MTS and EuroMTS market. They are reported for all business days from January 1, 2001, through May 31, 2002.

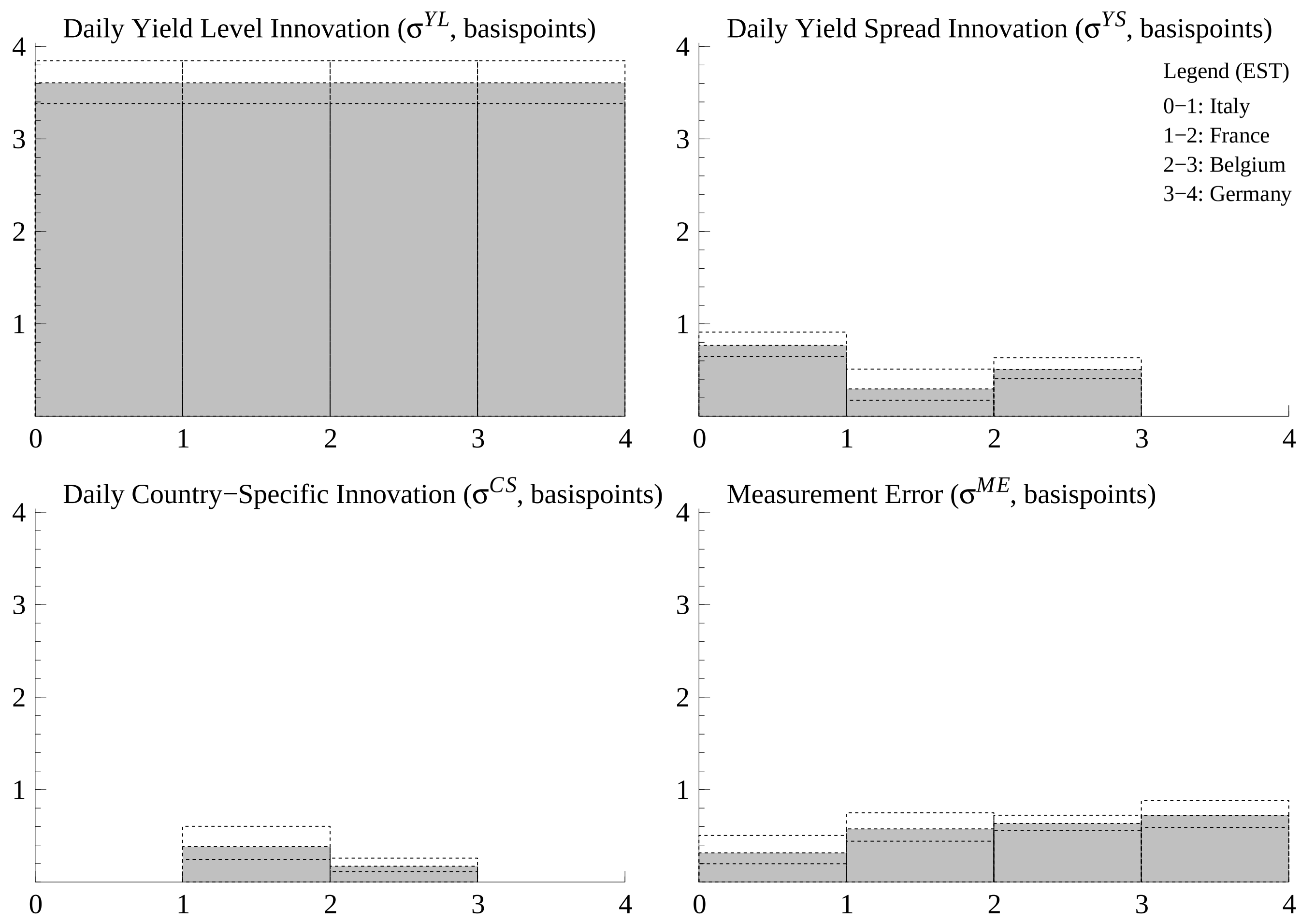

Figure 4: **Yield Model Estimates**. This figure depicts the estimates based on the yield model presented in Table 6.

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