Euro-Area Sovereign Yield Dynamics: The Role of Order Imbalance*

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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) microstructure effects. 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.

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

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Abstract

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1 Introduction

Price formation in government bond 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))[1]. 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 makers 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)). 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)). It is different from

[1] Their regressions of the daily changes in the log DM/US$ exchange rate on daily order imbalance produce R^2 statistics of over 50%.

the inventory effect, as it implies that order imbalance has a permanent effect on price. In more recent work, however, the information asymmetry argument for the permanent effect is revived (see e.g. Evans and Lyons (2005) and Pasquariello and Vega (2005)).

We explore price formation and the role of order imbalance in several countries in the Eurozone. This study is motivated by the introduction of the euro and the transition from over-the-counter trading to an electronic market, including 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[2], other factors remain, such as the lack of integration of settlement systems, different tax regimes, regulatory environment, and market conventions.

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 privatized and since then they expanded successfully abroad to other euro-denominated government bond markets.[3] 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

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

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

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[4] and a yield spread that effectively is a premium for the country's credit status[5] and the liquidity of its bond market vis-à-vis the benchmark country. We allow for 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 where we contribute to the literature: (i) 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. (ii) 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 simultaneously models the yield changes in several countries, and allows for a

[4] 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.

[5] 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.

distinction between temporary and permanent impact of order flow. These temporary effects (perhaps due to inventory considerations) 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)). On top of these modeling features, the state-space set-up deals naturally with missing observations, which is important as there are sometimes non-trading days which occur on different days across Europe. (iii) Third, we benefit from an experiment where the trading environment is controlled, as all securities trade on the same system. We use the recent and unique database with 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.[6] The sample period covers seventeen months from January 2001 through May 2002.[7]

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. We further consider the effect of ECB and FED monetary policy decisions and U.S. macro-announcements on the size of the innovations. We find that ECB policy decisions significantly increase the size of benchmark yield innovations and U.S. macro-announcements significantly increase the yield spread common factor innovation. We do not find an effect for the FED decisions, which might very well be due to the low power of the test, as we only have a few events in the

[6]Unlike many other studies that require the imperfect Lee and Ready (1991) algorithm to do this mapping.
[7]Cheung, de Jong, and Rindi (2003) contains a detailed description of the dataset.

seventeen month sample period.

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.[8] Biais, Renucci, and Saint-Paul (2004) study treasury auctions for several euro-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 3.2 explores the interaction between markets and presents the results of a multivariate model for sovereign yield dynamics. Section 4 extends the model to study the impact of order imbalance on each of the identified components of yield changes. 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.[9] 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:

[8] 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.

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

the MTS trading platforms (including 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. Order imbalance across trading venues is probably positively correlated, as investors are exposed to the same exogenous (macro) shocks and it is in the interest of investors to split orders across markets (see, e.g., Chowdhry and Nanda (1991), Menkveld (2005)). Hence, if we find a role for order imbalance, the role of "total" imbalance is likely to be even stronger

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.[10]

[insert Table 1]

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, €1.10 billion per day. The French and Belgian market follow with €171 and 135 million per day, respectively. The German market is smallest with €46 million per day. The relatively high volume in the Italian market is at least partially explained by the size of Italian public debt: €1,102 billion in July 2001 (see Blanco (2002)),

[10]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.

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.[11] 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 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 by 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. We regress yield changes on order imbalance and, in a second set of regressions,

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

on "logged" order imbalance.[12] 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)). A potential reason is these government bonds are priced in the euro-area context and we, therefore, turn to a multivariate approach.

[insert Table 2]

Although interest rates mean-revert in the long run (see, e.g., Chan et al. (1992)), we find that for a daily frequency yields are non-stationary. Figure 1 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.

[insert Table 3 and Figure 1]

Figure 1 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 established 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.

[12] 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.

[insert Table 4]

For yield spreads, a similar analysis reveals that they too are non-stationary. This is suggested by the yield spread plot in Figure 2 and confirmed by the Dickey-Fuller tests in Table 3.[13] 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)).[14] 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.[15] 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[16], or the risk of EMU failure and the return of exchange rate risk prior to redemption of the bond.

[insert Figure 2]

3 A Multivariate Model

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

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

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

[15] 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.

[16] 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.

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.

3.1 Sampling Issues

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.[17] 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:

⟵ day t ⟶		⟵ day t+1 ⟶	
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})

[insert Table 5]

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

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

time, leads to more missing values for daily 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.

3.2 Decomposition of Sovereign Yield Changes

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), 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.[18]

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

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

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 (transitory) 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:

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

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

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[19], respectively; the associated scaling factors 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 microstructure effect (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.

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 $\Delta\underline{y}_t$:[20]

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

[20]With these expressions, it is immediately evident that all parameters are identified: the microstructure

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

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

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

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

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

with $\Omega = \sigma_{BY}^2 + \sigma_{YS}^2$, and BY, YS, CS, and ME indicate the various components of sovereign yield changes: benchmark yield innovations, yield spread innovations, country-specific innovations, and microstructure effects, 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.

[insert Table 6 and Figure 3]

effect variances through the diagonal of $\text{cov}(\Delta \underline{y}_t, \Delta \underline{y}_{t-1})$; the benchmark yield innovation variance through the fourth row, fourth column element of $\text{var}(\Delta \underline{y}_t)$; the yield spread innovation variance through the off-diagonal elements of $\text{var}(\Delta \underline{y}_t)$; and, finally, the country-specific innovations through the diagonal elements of $\text{var}(\Delta \underline{y}_t)$.

The model estimates are tabulated in Table 6 and depicted in Figure 3. 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 microstructure effect (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. Microstructure effects (σ^{ME}) or, in other words, 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.[21]

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 microstructure effects. 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. In this section, we extend the dynamic model developed in section 3.2 to

[21] Interestingly, our estimates for the microstructure effect 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 microstructure effect, which supports the "inventory effect" explanation. In terms of size, they are smaller, which reflects the existence of an informational ("portfolio balance") component in bid-ask spreads.

include order flow.

4.1 Empirical Results for Euro-Area Order Flow

We start with a preliminary analysis of euro-area order flow. Given the 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 by splitting orders across markets (see, e.g., Chowdhry and Nanda (1991)). 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. Important, however, in view of our objectives, is that we cannot, ex-ante, aggregate order imbalance across countries, as each country's imbalance carries a significant idiosyncratic component.

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

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

$$\Sigma^{CS} = \text{diag}((\sigma_{CS}^{IT})^2, \ldots, (\sigma_{CS}^{DE})^2),$$
$$\Sigma^{ME} = \text{diag}((\sigma_{ME}^{IT})^2, \ldots, (\sigma_{ME}^{DE})^2),$$
$$B^{CS} = \text{diag}(\beta_{CS}^{IT}, \ldots, \beta_{CS}^{DE}),$$

$$B^{ME} = \text{diag}(\beta_{ME}^{IT}, \ldots, \beta_{ME}^{DE}),$$
$$\sigma_{CS}^{DE} = \sigma_{YS}^{DE} = 0,$$
$$\beta_{YS}^{DE} = \beta_{CS}^{DE} = 0,$$
$$\underline{\iota} = (1, \ldots, 1)',$$

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.

[insert Table 7]

Table 7 presents the model estimates that allow us to study the role of order imbalance. 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 microstructure effect ($\underline{\beta}^{ME}$). In other words, 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. It is not surprising that these costs show up significantly only in the most illiquid market as dealers in such market spread their cost over fewer transactions.

For benchmark yield innovations, we do not find a significant role of any of the national order imbalances ($\underline{\beta}^{BY}$). This is most likely the result of low market share of (Euro)MTS in Germany. We, nevertheless, do not want to exclude the alternative explanation based on a *highly* liquid BUND futures market. In the presence of such market, we do not expect a strong "portfolio balance" effect in the underlying market, as dealers can diversify through off-setting positions in the derivatives market.[22]

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

For country-specific yield innovations, we find a significant negative impact of order imbalance in the French and Belgian market ($\underline{\beta}^{CS}$). This is consistent with the "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.[23] 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.[24]

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 effectively serves as the market for the yield spread common factor. 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.

4.2 The Role of Announcements

Finally, we analyze the effect of ECB and FED monetary decisions and U.S. macro-announcements on the size of yield innovations through the model's estimates (see equation (3)). We use the Kalman smoother to estimate each day's (unobserved) benchmark yield innovation (f_t^{BS}) and yield spread common factor innovation (f_t^{CS}) conditional on all observations (see Durbin and Koopman (2001) for details). We calculate the correlation of the squared factor estimates with several dummies for announcement days. We study (i) ECB monetary policy decisions, (ii) FED monetary policy decisions, and (iii) several U.S. macro-announcements. We find a significant positive correlation for ECB monetary decisions and the benchmark

[23]We expect a negative sign for yields as yields are inversely related to prices.

[24]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, $0.27 = \frac{0.03 \cdot 3.68}{\sqrt{(0.03 \cdot 3.68)^2 + 0.38^2}}$.

yield innovations. We also find that a significant positive correlation between U.S. macro-announcements and the yield spread common factor innovation. News on the state of the U.S. economy, therefore, seems to affect European yield spreads. We do not find an effect for FED decisions, but are careful to note that this could be due to the low power of these tests as we do not have many event days in the sample period of seventeen months.

5 Conclusion

We study euro-area ten-year sovereign yields from Jan 1, 2001, through May 31, 2002, 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 attribute this to a relatively low market share of the system that we have data for, but also entertain the alternative explanation that this is due to the presence of a highly liquid BUND futures market. We might not see a "portfolio balance" effect in this case, as dealers can diversify positions in the derivatives market (see also Naik and Yadav (2003)). For yield spreads, we find that common factor innovations are driven only by Italian order imbalance. Trading in the Italian market seems to drive price discovery of the common factor in yield spreads, arguably due to its superior liquidity among all non-benchmark markets. The impact of Italian order imbalance is also economically significant as the standard deviation of its contribution is 25% compared to total standard deviation. 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.

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.

[insert Table 8]

If we disregard non-synchronicity, we find significantly higher microstructure effects. 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 microstructure effects increase dramatically, from the range of 0.32 to 0.72 to a range of 0.95 to 1.21.

[insert Table 9]

If, in addition to disregarding non-synchronicity, we also do not allow for microstructure effects, 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 microstructure effects. 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.

References

Bayoumi, T.A., M. Goldstein, and G. Woglom. 1995. "Do Credit Markets Discipline Sovereign Borrowers: Evidence from U.S. States." Technical Report 5-28, CEPR Discussion Paper.

Bernoth, K., J. von Hagen, and L. Schuknecht. 2003. "The Determinants of the Yield Differential in the EU Government Bond Market." Technical Report, University of Bonn: Center for European Integration Studies.

Biais, B., A. Renucci, and G. Saint-Paul. 2004. "Liquidity and the Cost of Funds in the European Treasury Bills Market." Technical Report, IDEI Working Paper.

Blanco, R. 2002. "Euro Area Government Securities Markets: Recent Developments and Implications for Market Functioning." Technical Report 12(4), Bank for International Settlements (BIS).

Brandt, M.W., and K.A. Kavajecz. 2004. "Price Discovery in the U.S. Treasury Market: The Impact of Orderflow and Liquidity on the Yield Curve." *Journal of Finance*, no. 59:2623–2654.

Bulow, J., and K. Rogoff. 1989. "Sovereign Debt: Is to Forgive to Forget?" *American Economic Review* 79:43–50.

Cao, H.H., M.D.D. Evans, and R.K. Lyons. 2004. "Inventory Information." *Journal of Business (Forthcoming).*

Chan, K.C., A. Karolyi, F.A. Longstaff, and A.B. Sanders. 1992. "An Empirical Comparison of Alternative Models of the Short-Term Interest Rate." *Journal of Finance* 47:1209–1227.

Cheung, Y.C., F. de Jong, and B. Rindi. 2003. "Trading European Sovereign Bonds: The Microstructure of the MTS Trading Platforms." Technical Report, EFA 2003 Annual Conference Paper `www.ssrn.com/abstract=424936`.

Chowdhry, B., and V. Nanda. 1991. "Multimarket Trading and Market Liquidity." *Review of Financial Studies* 4:483–511.

Dunne, P.G., M.J. Moore, and R. Portes. 2002. "Defining Benchmark Status: An Application using Euro-Area Bonds." Technical Report 9087, National Bureau of Economic Research (NBER).

Durbin, J., and S.J. Koopman. 2001. *Time Series Analysis by State Space Models.* Oxford: Oxford University Press.

Eaton, J., and M. Gersovitz. 1981. "Debt with Potential Repudiation: Theoretical and Empirical Analysis." *Review of Economic Studies* 48:289–309.

Evans, M.D.D., and R.K. Lyons. 2002. "Orderflow and Exchange Rate Dynamics." *Journal of Political Economy* 110:170–180.

———. 2005. "Exchange Rate Fundamentals and Order Flow." Technical Report, U.C. Berkeley.

Favero, C., M. Pagano, and E.-L. Von Thadden. 2004. "Valuation, Liquidity, and Risk in Government Bond Markets." Technical Report, Università di Napoli Federico II Working Paper.

Fleming, M.J. 2001. "Measuring Treasury Market Liquidity." Technical Report, Federal Reserve Bank of New York.

Galati, G., and K. Tsatsaronis. 2001. "The Impact of the Euro on Europe's Financial Markets." Technical Report 100, Bank for International Settlements.

George, T.J., and C.Y. Hwang. 2001. "Information Flow and Pricing Errors: A Unified Approach to Estimation and Testing." *Review of Financial Studies* 14 (4): 979–1020.

Geyer, A., S. Kossmeier, and S. Pichler. 2004. "Empirical Analysis of European Government Yield Spreads." *Review of Finance*, vol. 1(2).

Gibson, R., and S.M. Sundaresan. 1999. "A Model of Sovereign Borrowing and Sovereign Yield Spreads." Technical Report, Graduate School of Business, Columbia University.

Glosten, L., and P. Milgrom. 1985. "Bid, Ask, and Transaction Prices in a Specialist Market with Heterogeneously Informed Agents." *Journal of Financial Economics* 14:71–100.

Green, T.C. 2004. "Economic News and the Impact of Trading on Bond Prices." *Journal of Finance*, no. 59:1201–1233.

Kyle, A. 1985. "Continuous Auctions and Insider Trading." *Econometrica* 53:1315–1335.

Lee, C., and M. Ready. 1991. "Inferring Trade Direction from Intraday Data." *Journal of Finance*, no. 46:733–746.

Mathieson, D.J., and G.J. Schinasi. 2001. "The Changing Structure of the Major Government Securities Markets: Implications for Private Financial Markets and Key Policy Issues." Technical Report, Chapter IV in IMF Report "International Capital Markets: Developments, Prospects, and Key Policy Issues".

Menkveld, A.J. 2005. "Splitting Orders in Overlapping Markets: Theory and U.S.-Dutch Evidence." Technical Report, AFA 2002 Annual Conference Paper www.ssrn.com/abstract=286986.

Menkveld, A.J., S.J. Koopman, and A. Lucas. 2003. "Modelling Round-the-Clock Price Discovery for Cross-Listed Stocks using State Space Methods." Technical Report, EFA 2003 Annual Conference Paper No. 472. www.ssrn.com/abstract=424522.

Naik, N.Y., and P.K. Yadav. 2003. "Risk Management with Derivatives by Dealers and Market Quality in Government Bond Markets." *Journal of Finance* 58(5):1873–1904.

Pasquariello, P., and C. Vega. 2005. "Informed and Strategic Order Flow in the Bond Market." Technical Report, University of Rochester.

Poterba, J., and K. Rueben. 1997. "State Fiscal Institutions and the U.S. Municipal Bond Market." Technical Report 6237, NBER Working Paper.

Stoll, H. 1978. "The Supply of Dealer Services in Securities Markets." *Journal of Finance* 33:1133–1151.

Zautzik, E., and A. Santorelli. 2001. "The Eurobond Market." Technical Report, European Central Bank.

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 Jan 1, 2001, through May 31, 2002.

(Daily Averages)	Italy	France	Belgium	Germany
Volume (in €mio face value)	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| (in 1,000 bonds)	115.15	34.60	52.02	17.87
	(174.42)	(60.77)	(57.74)	(30.29)
Yield[a] (in %-age)	5.02	4.90	5.02	4.77
	(0.22)	(0.24)	(0.23)	(0.27)

[a]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. t-values are in parentheses.

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 95% 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. We estimate the model:

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

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 ϕ estimate divided by its standard error. The tests are based on all MTS and EuroMTS transactions for the period from January 1, 2001, through May 31, 2002.

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 percentage 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. Standard errors are in parentheses.

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 95% 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) the number of transactions before 15:00 relative to the total number of transactions to gauge how much of daily volume 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

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

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

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 microstructure effect (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 errors 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)	
Microstructure Effect ($\underline{\sigma}^{ME}$)		0.32	0.58	0.63	0.72
		(0.11)	(0.11)	(0.05)	(0.10)

Panel B: Other Parameters

	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.

Table 7: Sovereign Yield Model Estimates with Order Imbalance

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

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

$$B^{CS} = \mathrm{diag}(\beta_{CS}^{IT}, \ldots, \beta_{CS}^{DE});\ B^{ME} = \mathrm{diag}(\beta_{ME}^{IT}, \ldots, \beta_{ME}^{DE});$$
$$\beta_{CS}^{DE} = 0;\ \beta_{YS}^{DE} = 0;\ \sigma_{CS}^{DE} = 0;\ \underline{\iota} = (1, \ldots, 1)';$$

where, in addition to 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 errors 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)	
Microstructure Effect ($\underline{\sigma}^{ME}$)		0.35	0.56	0.62	0.73
		(0.10)	(0.10)	(0.05)	(0.10)

Panel B: Order Imbalance Impact[b]

	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)	
Microstructure Effect ($\underline{\beta}^{ME}$)	−0.01	0.03	0.01	**-0.08**
	(0.01)	(0.02)	(0.01)	(0.03)

Panel C: Other Parameters

	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 of no country-specific innovation for Italy at a 95% 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 errors 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)	
Microstructure Effect ($\underline{\sigma}^{ME}$)		1.13	1.12	0.95	1.21
		(0.08)	(0.10)	(0.08)	(0.10)

Panel B: Other Parameters

	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.

Table 9: Are Transitory 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 microstructure effects, which oftentimes are not considered in studies based on daily price series. By comparing these results with those of Table 6 and Table 8, we find to what extent transitory microstructure effects matter. Standard errors 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)	
Microstructure Effect ($\underline{\sigma}^{ME}$)		0.00[b]	0.00[b]	0.00[b]	0.00[b]

Panel B: Other Parameters

	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 microstructure effect variance at zero.

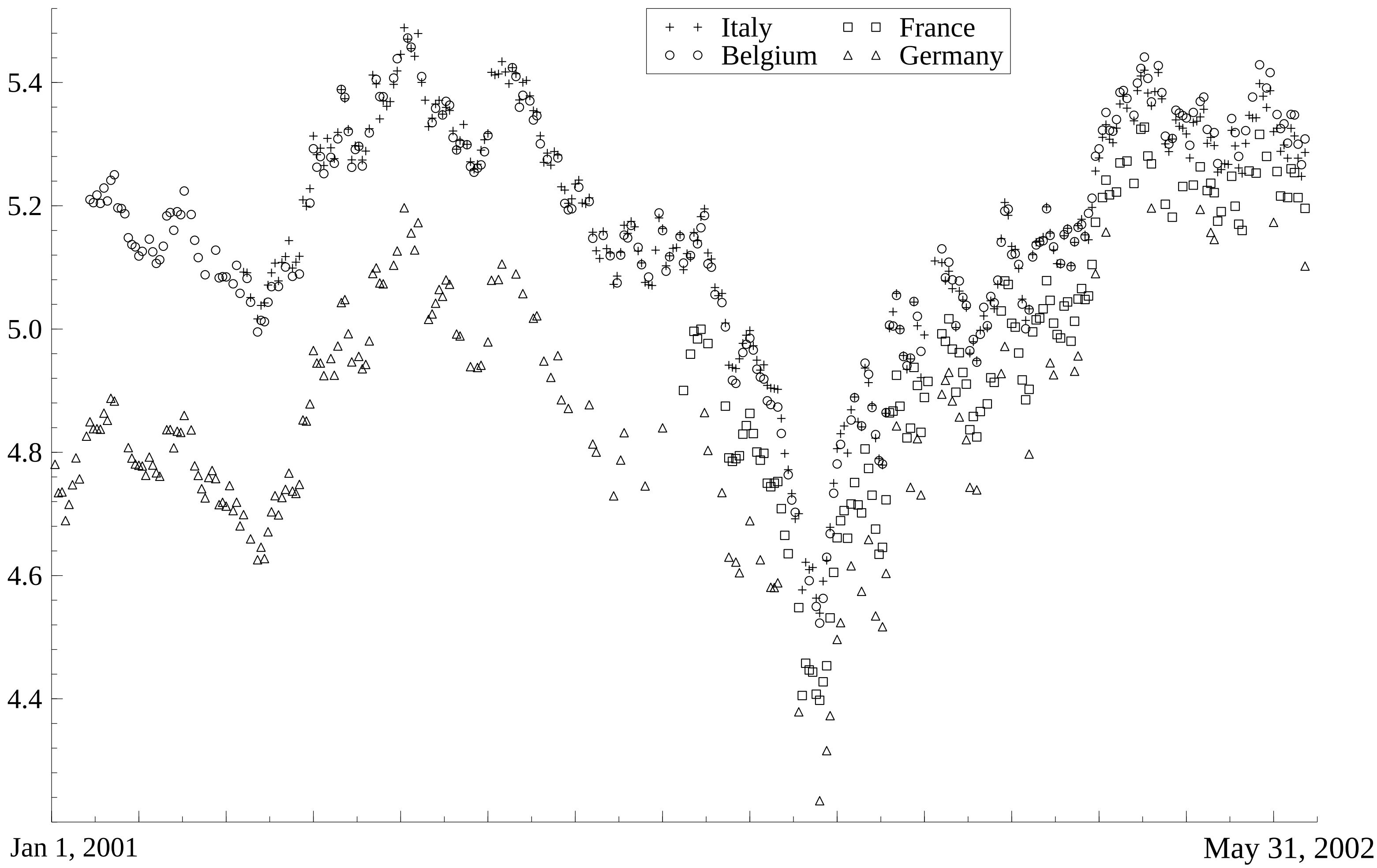

Figure 1: **Sovereign Yields**. This figure presents sovereign yields (in %-age) of Italian, French, Belgian, and German government bonds. Yields are calculated on a daily basis based on all transactions after 15:00 in the MTS and EuroMTS market. These series are input to the state space model that captures 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.

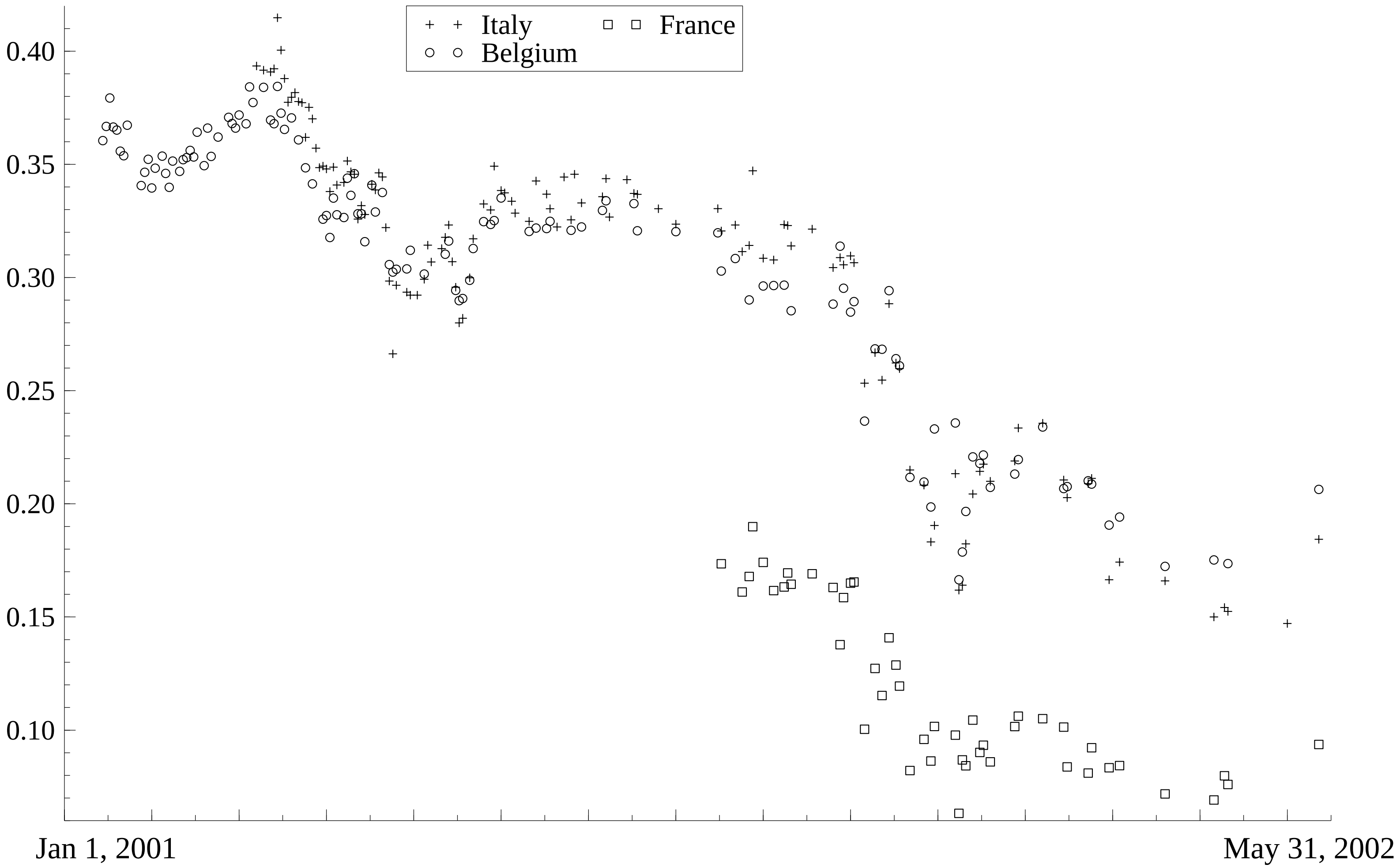

Figure 2: **Sovereign Yield Spreads**. This figure presents sovereign yield spreads (in %-age) of Italian, French, and Belgian government bonds. They are defined as the bond's yield minus the "benchmark" German yield. Yields are calculated on daily basis based on all transactions after 15:00 in the MTS and EuroMTS market. They are reported for all business days from January 1, 2001, through May 31, 2002.

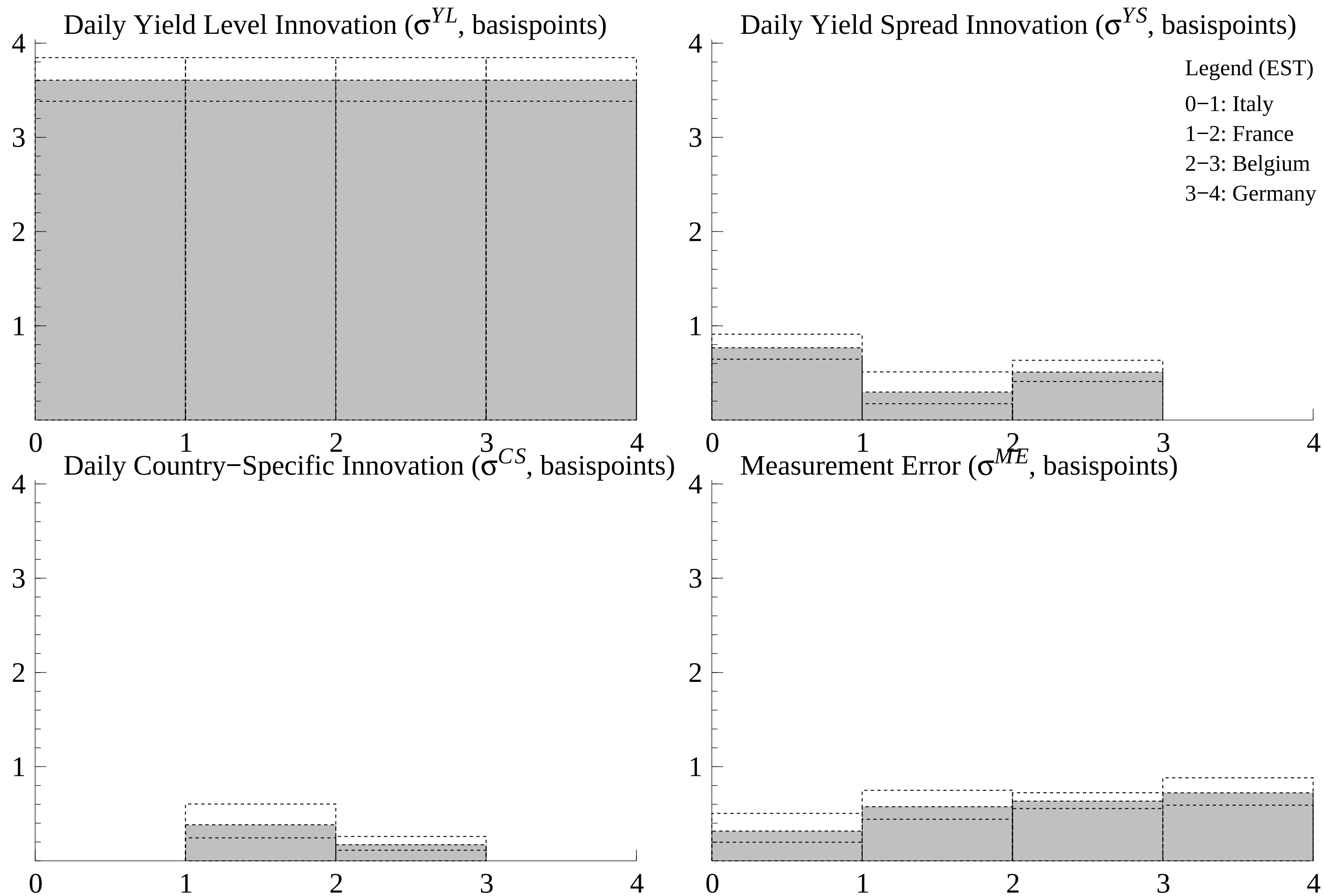

Figure 3: **Yield Model Estimates**. This figure depicts the estimates based on the yield model presented in Table 6.