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Benchmark Yield Undershooting in the E.M.U.

Angelos A. Antzoulatos*

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Hamburgisches Welt-Wirtschafts-Archiv (HWWA)
Hamburg Institute of International Economics

Öffentlichkeitsarbeit
Neuer Jungfernstieg 21 – 20347 Hamburg
Telefon: 040/428 34 355
Telefax: 040/428 34 451
E-mail: hwwa@hwwa.de
Internet: http://www.hwwa.de/

Angelos A. Antzoulatos
University of Piraeus
Dept. of Banking & Financial Management
80 Karaoli & Dimitriou street
Piraeus 18534, Greece
E-mail: antzoul@unipi.gr

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Abstract

With the elimination of foreign exchange risk among the E.M.U.-member countries, the yield of, say, French benchmark government bonds (henceforth, the *yield*) should be equal to that of German bonds, plus some credit and liquidity premia. Since both premia are not likely to change substantially from one day to the other, the *yield* should move in tandem with the German one and the corresponding spread should remain relatively stable. Yet, the yield exhibits a small but economically and statistically significant *undershooting* in response to changes in the German one, as a result of which the spread tends to decline when the latter increases, and vice-versa. We propose that the *undershooting* is the product of lagged adjustment in the European bond portfolios that is driven by liquidity considerations and, in particular, by the possibility of excessive bond-price movements in response to changes in the German yield. The empirical results are consistent with this proposition and additionally suggest that the adjustment can last for as long as four days.

Keywords: Benchmark Government Bonds, E.M.U., Credit and Liquidity Premia, Bid/Ask Spread

J.E.L. Classification Numbers: E43, F36, G11, G15

1. Introduction

Overshooting/undershooting – also known as overreaction/underreaction - has been a feature of many financial and economic models, and has also been observed in many financial series. For example, Dornbusch, in his 1976 seminal paper, shows that the exchange rate may overshoot in response to monetary policy changes, driven by the sluggish adjustment of the price level. Campbell and Schiller (1991), Hardouvelis (1994) and Sutton (1997, 1998), among many, document that in several industrial countries the long interest rates overreact to changes in the expected future short rates, the main explanation being a subtle violation of rational expectations (Hardouvelis [1997]). More recently, Poteshman (2001) presents evidence that options market investors tend to underreact to daily changes in instantaneous variance and to overreact during periods of mostly increasing or decreasing variance, a behavior that is consistent with Barberis et al.'s (1998) conjecture that investors tend to overreact to information that is preceded by large amounts of similar information.

This paper, in turn, documents a yield undershooting of the E.M.U. benchmark government bonds that not only is inconsistent with interest-rate convergence in the Euro area, but additionally has important implications for the ongoing process of financial market integration for which E.M.U. was a catalyst. In greater detail, with the introduction of the Euro and the attendant elimination of foreign exchange risk among the E.M.U.-member countries, the yield of, say, French government bonds (henceforth, the *yield*) should be equal to that of German bonds, plus some credit and liquidity premia. These two premia should not change substantially from one day to the other for economic and financial conditions do not change either. Hence, one would reasonably expect that the yield move in tandem with the German one and the corresponding spread remain relatively stable. At a first look, this expectation seems consistent with the data. Specifically, the average change in the spread during the first twenty two months of E.M.U.'s existence, January 1999 – October 2000, is virtually zero.

On closer, inspection, however, this finding appears intriguing for there seemingly exists a negative correlation between changes in the German yield and changes in the spread. That is, when the German yield increases, the spread tends to decrease, and vice-versa. This implies an *undershooting* of the yield in response to changes in the German one; i.e., when the German yield increases (decreases), the yield increases (decreases) by less. This undershooting, though small, is statistically and economically significant. Moreover, it tends t o be bigger when the changes in the German yield are relatively big as well.

We propose that the yield undershooting is the product of lagged adjustment in the European bond markets that is driven by liquidity considerations and, in particular, by the possibility of excessive bond-price movements in response to changes in the German yield. In greater detail, when the German yield increases, the price of the underlying bonds decreases, making them relatively more attractive. Investors would have the incentive to shift funds from other European bonds into German bonds, driving the price of the former down and their yield up. Owing, however, to the lower liquidity of the other European bond markets, this portfolio readjustment may cause a price overshooting; i.e., a bigger decline than would be justified by the equilibrium spread. To avoid the attendant capital loss, investors may not act immediately and, perhaps, wait to see whether the increase in the German yield is maintained (the latter justified by the fact that in our sample changes in the German yield are very hard to predict). As a result of this lagged adjustment, bond prices may fall by less than justified by the change in the German yield, leading to a smaller rise in the yield and, hence, to a decrease in the spread. The lagged adjustment triggered by a decrease in the German yield works in the opposite way. (Note that the presumed lagged adjustment is the product of rational behavior and does not rely on subtle violations of it, as in Hardouvelis [1994], or on cognitive biases, as in Poteshman [2001]. It is also similar to the infrequent trading in the presence of trading costs of recent equilibrium asset pricing models, as in Lo et al. [2001], and to the reduced willingness to trade in periods of increased market uncertainty, as in Muranaga and Shimizu [1999]; and reminiscent of the price rigidities in Dornbusch [1976].)

To test this proposition, we derive conditions that are based on the observed changes in the spread and the German yield, under which the yield undershooting should be stronger. (The corresponding tests are in the spirit of recently-developed non-linear forecasting models. For pertinent details, see, Bajo-Rubio et al. [2001]). Additionally, we derive an error-correction-type equation for the spread in which the speed of adjustment is positively related to liquidity.

The econometric results are consistent with expectations. Briefly, as the theoretically derived conditions for a likely undershooting get stronger, the observed undershooting becomes bigger and more significant. In addition, the time series evidence from the estimation of the aforementioned equation indicates that the lagged adjustment can last for as long as four days. Providing further support for the paper's proposition, the results of the two tests are consistent with each other; that is, the speed of adjustment deduced from the time-series evidence is higher for the countries where the undershooting is smaller.

The rest of the paper is organized as follows. Section 2 describes the data and documents the aforementioned undershooting. Section 3 proposes an explanation and derives the conditions under which the yield undershooting should be stronger, plus the error-correction-type equation for the spread. Section 4 presents the empirical results, while Section 5 investigates their implications for hedging interest-rate risk in portfolios of European bonds with futures. Section 5 further provides a rational explanation for the overshooting attributed to cognitive bias in the spirit of Barberis et al. (1998).

2. Data and Preliminary Results

We focus on the ten-year benchmark government bonds whose qualitative and quantitative characteristics are sufficient homogeneous across the sample countries for a meaningful analysis and cross-country comparison. Most importantly, the ten-year benchmark government bonds (and to a lesser extend the thirty-year ones, which, however, are not issued by Ireland, Finland and Portugal) have similar characteristics. In addition, their maturity is close to that at issuance, while their liquidity is higher than that of other maturities. Further, unusual changes in their yields are mostly due to the change in the benchmark bond when a new one is issued.[1] These unusual changes, however, smooth out relatively quickly.

The importance of these factors is amply illustrated with reference to a specific case (for details, see Vallianatos [2000]). During the sample period, the coupons of two-year German government bonds were between 3.00% and 4.00%. The listed bonds were (Code names in Bloomberg) BKO 3.00 15/12/00, BKO 3.00 16/03/01, BKO 3.00 15/06/01, BKO 3.50 14/09/01 and BKO 4.00 14/12/01. BKO is the short-hand notation of the two-year bonds in the German market –that of the ten-year bonds is DBR. The number after BKO is the coupon, while the last field is the maturity date. For the two-year Dutch bonds, however, the coupons ranged between 3.00% and 9.00%. These were

1 Indicatively, when the German government bond maturing on July 4, 2009 and with coupon 4% became the benchmark bond on May 13, 1999, replacing the bond maturing on January 4, 2009 and with coupon 3.75%, the benchmark yield fell by 2.8 b.p., while the benchmark spreads fell by 5.0 to 7.2 b.p.. The spreads, however, returned to their previous levels two days later.

the NETHER 9.00 15/05/00, NETHER 9.00 15/01/01 and NETHER 3.00 15/02/02. The first two were originally issued as ten-year bonds and the last as a three-year one. Their only common characteristic pertains to the two years left to maturity at the time of listing. Because of the different coupons, the three two-year Dutch bonds have different duration: the first two, with the higher coupon, have lower duration, and hence lower price sensitivity to interest rate changes, as compared to the third. For this reason, they also have lower yields. Putting everything together, they exhibit lower spreads vis-à-vis the two-year German government bonds.

The data for Austria, Ireland, Finland and Portugal come from Bloomberg, and for the remaining countries from Reuters. Luxemburg is not included in the analysis for its tiny bond market. The data includes the yield of the aforementioned bonds, provided by the International Securities Markets Association (ISMA), and the bid and ask prices of the bonds, P^b and P^a, provided by major financial institutions of the countries concerned. Appendix Table A-1 provides information about the bid/ask prices of the sample bonds. Specifically, it reports the sources of the prices (Column [2]), plus three statistics for the bid/ask spread, P^a-P^b: the minimum (Column [3]), the average (Column [4]) and the maximum (Column [5]), as percent of the average bid/ask price, $(P^a+P^b)/2$. Lastly, it provides some details pertaining to the variation of the spread (Column [6]).

As Table A-1 indicates, the minimum spread varied between 0.01 (Italy) and 0.10 (Finland) percent of the average bid/ask price; the average between 0.08 percent (Austria) and 0.14 percent (Finland, Spain); and the maximum –leaving aside Italy that seems to be an outlier at 2.06 percent— between 0.09 (Austria) and 0.59 (Finland) percent. Further, the variability of the bid/ask spread suggests the existence of three groups of countries: Those with a constant spread (Austria, Belgium, Ireland, Portugal), those with a highly variable one (Italy, Spain), and the rest in between (Finland, France, the Netherlands). Notably, Germany has the lowest average and highest spread, 0.03 and 0.05 percent of $(P^a+P^b)/2$, and one of the lowest minimum spreads, 0.03 percent as opposed to Italy's 0.01 percent and Spain's 0.02 percent.

Leaving aside that liquidity is a multi-dimensional concept, of which the bid/ask spread is just one dimension,[2] the figures in Table A-1 do not readily allow a comparison of li-

2 The dimensions of liquidity usually employed in market microstructure studies are tightness, depth and resiliency. Tightness refers to how far transaction prices diverge from mid-market prices, and is usually measured by the bid/ask spread. Depth usually denotes the volume of transactions that can be made without affecting prices. Lastly, resiliency refers to the speed with which trading-related price fluctuations dissipate or the speed with which imbalances in order flows are adjusted. As noted in BIS

quidity across the sample countries. Consider, for example, Austria and Italy. The first has a constant bid/ask spread, fixed either by market convention or government regulation—suggesting lower liquidity, and the second a highly variable one—pointing to higher sensitivity to market conditions and hence higher liquidity. Yet, Austria's average bid/ask spread is lower than Italy's. Nevertheless, it is widely accepted that liquidity is highest for Germany (see, McCauley [1999]).

Following the market convention, we express the yield spread –not to be confused with the bid/ask spread– of country *i* at period *t*, $S_{i,t}$, as the difference between the yield of the country's benchmark government bond, $y_{i,t}$, and Germany's corresponding yield, $y_{G,t.}$ In mathematical terms, $S_{i,t} = y_{i,t} - y_{G,t}$. To simplify notation, the country-subscript *i* is dropped. By the way, this convention reflects not only the higher liquidity of the German government bond market, but also the perceived lower riskiness of German government bonds relative to the bonds of the other E.M.U.-member countries.

Table 1 presents some summary statistics pertaining to the yield spread (from now on referred to as the *spread*) and the German yield. Specifically, the first column shows the country, while the following three report the average spread and its standard error (in parentheses) for the whole sample period, January 1999 – December 2000, and for January – December 1999 and January – December 2000. For comparison purposes, it also reports the same statistics for the yield of the German bond.

As Table 1 documents, the average spread rose in 2000, in all countries but Finland. So did the German yield. The biggest rises occurred in Austria, Belgium and Italy, in excess of 6 b.p., and the smallest in the Netherlands and Spain, less than 2 b.p.

Since there is no currency risk, the spread is equal to the sum of the (credit) risk and the liquidity premium, denoted respectively as RP_t and LP_t. That is, for any country except Germany,

$$S_t = RP_t + LP_t \qquad (1)$$

(1999), the three dimensions do not always point to the same direction. For other drawbacks, see Fleming (2001).

Table 1: Ten-Year Benchmark Government Bond Spreads [basis points]

Country (1)	1999-2000 (2)	1999 (3)	2000 (4)
Austria	24.96 (0.27)	20.42 (0.26)	29.41 (0.26)
Belgium	29.75 (0.24)	26.21 (0.26)	32.33 (0.26)
Finland	22.32 (0.16)	24.08 (0.22)	20.58 (0.18)
France	12.78 (0.15)	11.56 (0.22)	14.01 (0.17)
Ireland	23.05 (0.26)	21.61 (0.47)	24.47 (0.19)
Italy	30.60 (0.25)	26.75 (0.21)	34.48 (0.31)
Netherlands	14.97 (0.12)	14.57 (0.20)	15.37 (0.13)
Portugal	32.48 (0.27)	30.28 (0.41)	34.70 (0.29)
Spain	26.25 (0.16)	25.35 (0.24)	27.16 (0.21)
Memorandum Item			
Yield of German Govern. Bond [%]	4.86 (0.02)	4.49 (0.04)	5.25 (0.01)
# of Observations	517	260	257

Notes:
1. Sample: January 4, 1999 to December 31, 2000.
2. Sources: Bloomberg, Reuters and authors' calculations.
3. The first figure in each cell corresponds to the sample mean and the second (in parentheses) to its standard error.

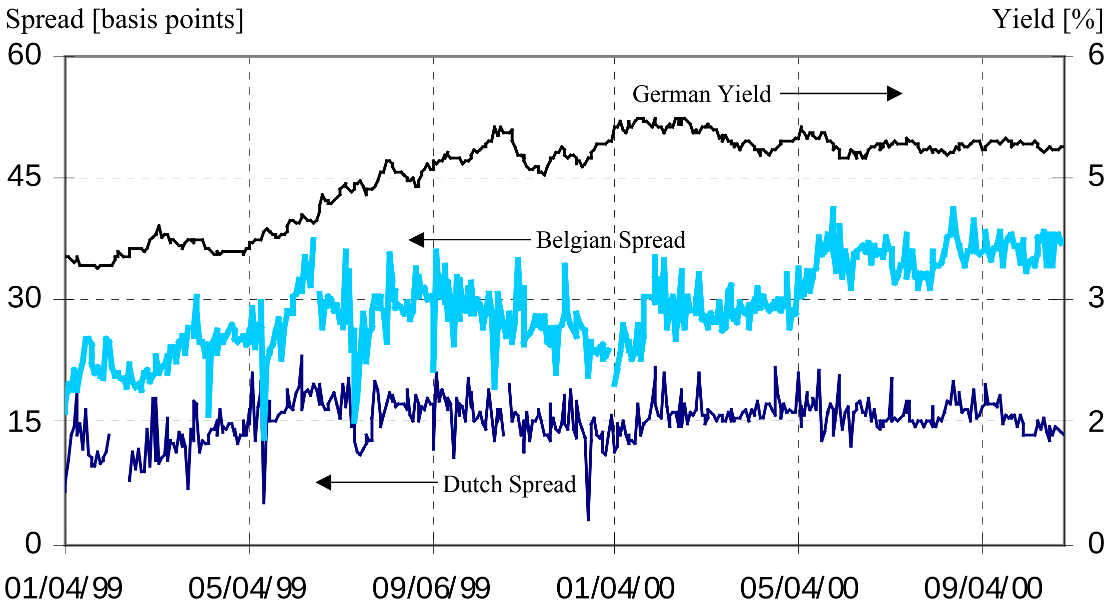
Though disentangling the two premia is very difficult, their relative magnitude probably varies across countries. Consider for example, the Netherlands, for which a knowledgeable observer, Dr. Jürgen Stark, Deputy Governor of the Bundesbank, notes that the spread must be driven mostly by the lower liquidity of the Dutch government bonds vis-à-vis the German bonds (Stark, 1999). Consider next countries like Austria, Belgium, Italy and Portugal, that have worse creditworthiness indicators than Germany and, consequently, their risk premia should be a considerable part of the spread.

The magnitude of the two premia likely varies over time as well, with both probably having contributed to the spread rise in 2000. Theoretically speaking, higher interest rates, here precipitated by the rising German yield, increases the cost of servicing the existing debt, making default more likely and leading, as a result, to higher risk premium and higher spread. Such a phenomenon was observed during 1994, when the then tightening of U.S. monetary policy was followed by a widening of Emerging Market spreads (for details and pertinent references, see IMF, 2000). In addition, higher interest rates in a key country, like Germany, may cause a “flight to liquidity” (McCauley, 1999, p. 8) and hence lead to a higher liquidity premium.

The assessment that both premia contributed to the spread rise in 2000 is supported by the observation that a rising German yield is not always accompanied by rising spreads. In greater detail, as Figure 1 illustrates, while the German yield was rising from early May through mid November 1999, the spreads of Belgium of the Netherlands were rising for the first half of this period and declining for the second. Then, during the first half of 2000, when the German yield was declining, the Belgian spread was increasing while the Dutch one remained relatively stable. For further related arguments, see also Galati and Tsatsaronis (2001, p. 10).

Nevertheless, owing to the small daily changes in the German yield, one could expect that the average daily change in the two premia and the spread (by equation [1], $\Delta S_t = \Delta RP_t + \Delta LP_t$) to be small. Indeed, the average daily spread-change is insignificant for all countries with all *t*-statistics below 0.3.

Figure 1. Benchmark Yield (Germany) & Spreads (Netherlands, Belgium)

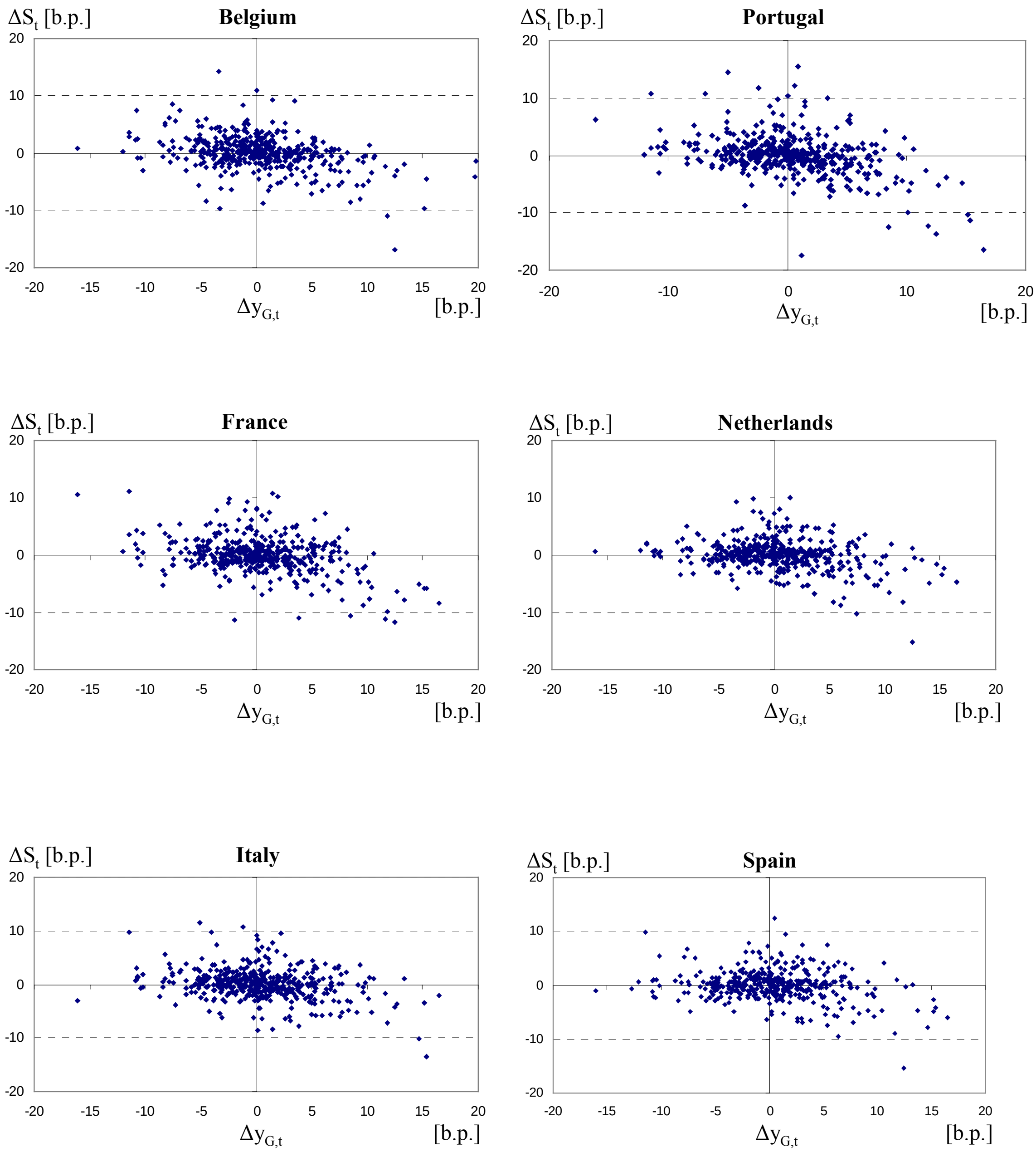


On closer inspection, however, this result appears intriguing. As Figure 2 indicates, there seems to exist a negative relationship between spread-changes, ΔS_t, and German-yield changes, $\Delta y_{G,t}$. That is, positive German-yield changes are seemingly associated with negative spread-changes, and vice-versa. These patterns, which apply to all sample countries, seem to be stronger for the countries that have a constant bid/ask spread (Austria, Belgium, Ireland, Portugal), and least so –yet easily discernible– for the countries that have a highly variable bid/ask spread (Italy, Spain).

The visual evidence in Figure 2 is presented more formally in Table 2. The average spread (and its standard deviation in parentheses) during the whole sample is shown in Column (2) for the periods of a rising German yield, $\Delta y_{G,t} > 0$, and in Column (3) for the periods of a falling yield, $\Delta y_{G,t} < 0$. Column (4) shows their difference and the corresponding *p-value* for a two-tailed test regarding their equality. To detect any changes as financial markets in the E.M.U. got with the passage of time more integrated, the next three columns show the same statistics for 1999, and the last three columns for 2000.

Table 2 not only confirms the evidence in Figure 2, but further indicates that it is of economic significance as well. In greater detail, during 1999-2000, the average spread change associated with a rising German yield was negative and significant at the 5 percent level or higher. The only exception applies to Spain, where it was significant at the 10 percent level. As for the average spread change associated with a falling German yield, it was positive and significant at the 1% level for all countries.

Figure 2. Change in the Spread (ΔS_t) vs. Change in the German Yield ($\Delta y_{G,t}$)



More importantly, during 1999-2000, the difference in the average spread change is significant at very high levels for all countries. Moreover, it is smaller in magnitude for Italy and Spain, 0.98 b.p. and 0.77 b.p., respectively. In contrast, it is considerably higher for Belgium (1.37 b.p.), Ireland (1.94 b.p.) and Portugal (1.58 b.p.), three of the four countries with a constant bid/ask spread.[3]

In addition to being statistically significant, the difference is economically significant as well, at least for the countries with a constant bid/ask spread. To see it, consider Austria's bond RAGB that had a modified duration of 7.761 when it became the benchmark on November 5, 1999. (As a reminder, the modified duration measures the proportional sensitivity of a bond's price to a small change in its yield.) For this bond, a 1 b.p. change in the yield will cause a 0.07761 percent change in the price. For yield changes equal to the difference in column (4), 1.05, the percent price change will be this figure multiplied by 0.07761. For Austria (marginally), Belgium, Ireland and Portugal the resulting figure exceeds the average bid/ask spread reported in the fourth column of Appendix Table A-1.

The above patterns are stronger for 1999 and weaker –but still significant– for 2000 relative to the whole sample period, 1999-2000. Specifically, the difference for 1999 (Column [7]) exceeds that of the whole sample (Column [4]) and of the second subsample (Column [10]). This implies that the forces behind the above patterns weakened with the passage of time and, one may conjecture, the attendant growing integration of European bond markets. They did not disappear though, as the figures for Ireland and Portugal (differences respectively equal to 1.51 and 1.27 in 2000, as compared to 2.39 and 1.89 in 1999) indicate.

3 To the extent the average spread change is driven by liquidity considerations, as this paper postulates, these results echo the argument that the bid/ask spread is not an infallible indicator of market liquidity. To see it, compare Spain, that has average bid/ask spread 14 (as percent of the mean bid/ask price) and average spread change 0.75b.p., with Portugal, that respectively has 10 and 1.73b.p..

Table 2: Change in the Spread [basis points]

	1999-2000			1999			2000		
Sample Country – (1)	$\Delta y_G > 0$ (2)	$\Delta y_G < 0$ (3)	|Diffe-rence| (4)	$\Delta y_G > 0$ (5)	$\Delta y_G < 0$ (6)	|Diffe-rence| (7)	$\Delta y_G > 0$ (8)	$\Delta y_G < 0$ (9)	|Diffe-rence| (10)
Austria	-0.45 (0.19)**	0.61 (0.16)***	1.05 0.0001	-0.51 (0.32)	0.75 (0.31)**	1.26 0.0358	-0.38 (0.19)**	0.48 (0.14)***	0.87 0.0001
Belgium	-0.63 (0.18)***	0.74 (0.16)***	1.37 0.0000	-0.74 (0.28)***	0.92 (0.28)***	1.65 0.0000	-0.50 (0.21)**	0.59 (0.17)***	1.09 0.0001
Finland	-0.49 (0.19)**	0.54 (0.17)***	1.03 0.0001	-0.52 (0.33)	0.62 (0.31)**	1.13 0.0167	-0.45 (0.20)**	0.47 (0.18)***	0.93 0.0018
France	-0.47 (0.20)**	0.58 (0.17)***	1.05 0.0003	-0.58 (0.29)**	0.79 (0.29)***	1.37 0.0040	-0.36 (0.37)	0.39 (0.17)**	0.74 0.0275
Ireland	-0.89 (0.27)***	1.05 (0.20)***	1.94 0.0000	-1.08 (0.41)***	1.31 (0.33)***	2.39 0.0000	-0.68 (0.35)*	0.83 (0.23)***	1.51 0.0000
Italy	-0.44 (0.19)**	0.54 (0.15)***	0.98 0.0000	-0.53 (0.31)*	0.68 (0.28)**	1.21 0.0114	-0.34 (0.20)*	0.42 (0.12)***	0.76 0.0001
Netherlands	-0.48 (0.17)***	0.53 (0.13)***	1.01 0.0000	-0.60 (0.27)**	0.75 (0.22)***	1.36 0.0001	-0.34 (0.20)*	0.32 (0.14)**	0.66 0.0060
Portugal	-0.73 (0.25)***	0.85 (0.17)***	1.58 0.0000	-0.84 (0.39)**	1.05 (0.29)***	1.89 0.0000	-0.61 (0.30)**	0.66 (0.18)***	1.27 0.0000
Spain	-0.34 (0.19)*	0.43 (0.14)***	0.77 0.0014	-0.54 (0.30)*	0.70 (0.26)***	1.25 0.0023	-0.11 (0.21)	0.19 (0.13)	0.30 0.1781
Memorandum Item									
Change in the Yield of the German Gov. Bond [basis points]	3.43 (0.19)***	-3.16 (0.17)***		3.96 (0.29)***	-3.27 (0.27)***		2.84 (0.24)***	-3.06 (0.21)***	
# of Obser-vations	262	252		139	120		123	132	

Notes:

1. Sample: January 4, 1999 to December 31, 2000.
2. Sources: Bloomberg, Reuters and authors' calculations.
3. Δy_G : Daily change of the German Government Bond yield.
4. In the cells of columns (2), (3), (5), (6), (8) and (9),the first figure shows to the sample mean and the second (in parentheses) its standard error. One (*), two (**) and three (***) asterisks denote significance at the 10%, 5% and 1% level, respectively. Owing to the large number of observations, the critical values were taken from the *t-statistic* tables, despite that in almost all cases skewness and kyrtosis were significant.
5. In the cells of columns (4), (7) and (10), the first figure shows the difference in the sample means reported in the preceding two columns, while the second figure shows the *p-value* of a two-sided test that the difference is equal to zero. These *p-values* were computed using the *Wilcoxon rank sum test*, which is a linear transformation of the Mann-Whitney *U* test. For details, see Rice 1995, pp. 402-408.

3. Explanation and Testable Implications

The above results indicate that there is a yield *undershooting* to changes in the German yield. That is, when the latter increases, the yield of other countries increases by less and, as a result, the spread decreases (on Figure 2 it is on the average $\Delta S_t < 0 < |\Delta S_t| < \Delta y_{G,t}$). Conversely, when the German yield decreases, the yield of the other countries decreases by less and, as a result, the spread increases (on the average $0 < \Delta S_t < |\Delta y_{G,t}|$). Moreover, the undershooting is stronger in the second case. It is also more pronounced for Belgium, Ireland and Portugal, three of the four countries with a constant bid/ask spread.

We propose that this undershooting is the product of lagged adjustment in the European bond markets that is driven by liquidity considerations and, in particular, by the possibility of excessive bond-price movements in response to changes in the German yield. This adjustment works as follows. When the German yield increases, the price of the underlying bonds decreases, making them relatively more attractive and inducing investors to shift funds from other European bonds into German bonds. This portfolio readjustment would drive the price of the former down and their yield up. Owing, however, to the lower liquidity of the other European bond markets relative to the German one, this portfolio readjustment may cause a price overshooting; i.e., a bigger decline than would be justified by the equilibrium spread. To avoid the attendant capital loss, investors may not act immediately and, taking into account that the change in the German yield shows virtually no serial correlation and thus is hard to predict, wait to see whether the increase in the German yield is maintained. (No transactions in the presence of trading costs, here arising from liquidity considerations, is a feature of many models. For example, in Lo et al. [2001], small transaction costs can lead to large "no-trade" price regions. In Muranaga and Shimizu [1999], rising uncertainty reduces the willingness to trade.)

As a result of this lagged adjustment, bond prices may fall by less than justified by the change in the German yield, leading to a smaller rise in the yield and, hence, to a decrease in the spread. The lagged adjustment triggered by a decrease in the German yield works in the opposite way.

The dynamics of the proposed lagged adjustment can be illustrated with a simple framework. Let S^* be the equilibrium spread (to simplify notation and exposition, we ignore the time subscript, assuming essentially that the liquidity and risk premia do not change when the German yield changes). Following an increase in the German yield, the spread of, say, French bonds will decrease unless their yield increases too. For the latter to happen, investors must sell French bonds and thus drive their price down (yield up). But owing to the possibility of a price overshooting, they do so only when the spread S falls below a lower threshold, S - L $(L \geq 0)$; i.e., when $S \leq S^*$ - L. If they do sell, the resultant spread will be set equal to the equilibrium one.[4] Conversely, following a decrease in the German yield, the spread will increase, unless investors buy the French bonds and drive their price up (yield down). But they will do so only when the spread rises above an upper threshold, $S^* + U$ $(U \geq 0)$; i.e., when $S \geq S^* + U$. If they do buy, the spread will again be set equal to S^*.

In this stylized environment, a yield undershooting will occur when $\Delta y_{G,t} > 0$ does not push S_t below the lower threshold to trigger an adjustment and, as a result, y_t will remain the same, $\Delta y_t = 0$, while S_t will decline relative to S_{t-1} (ΔS_t = - $\Delta y_{G,t} < 0$). For a typical change $\Delta y_{G,t} = \delta > 0$, this will happen when S^*-L+$\delta \leq S_{t-1} \leq S^*$+$U$. Also, an undershooting will occur when $\Delta y_{G,t} < 0$ does not push S_t above the upper threshold, and, as a result, y_t will remain the same, $\Delta y_t = 0$, while S_t will increase relative to S_{t-1} ($\Delta S_t > 0$). This will happen when S^*-$L \leq S_{t-1} \leq S^*$+U-δ. Note that for the lagged-adjustment mechanism to be functional, δ must be less than the minimum of L, U. If not, for a typical change in the German yield, the spread will cross the thresholds and adjust to S^*.

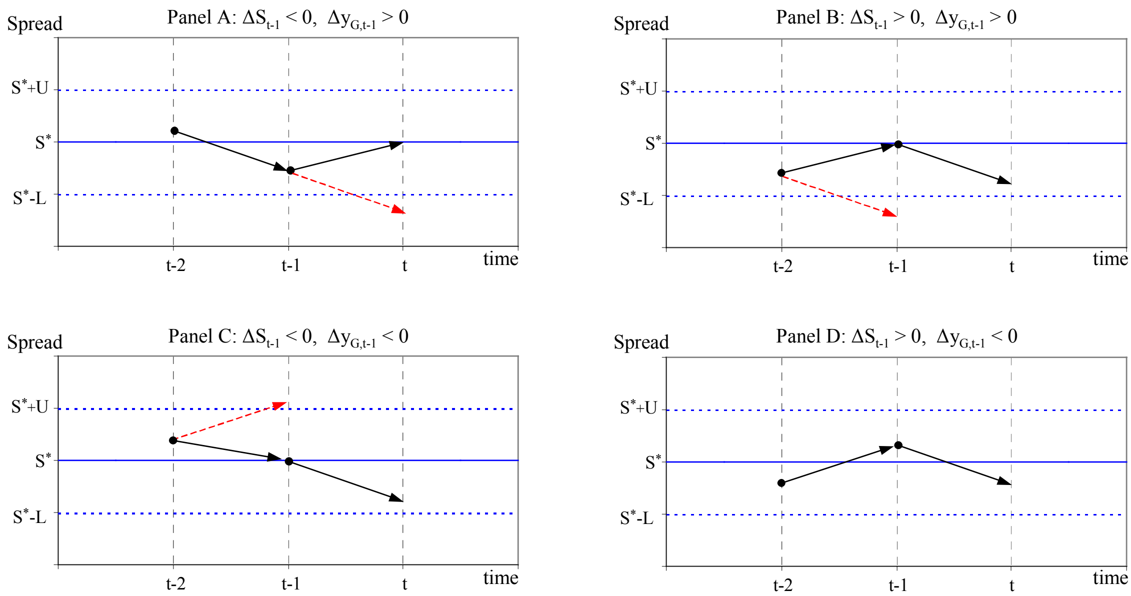
Conversely, an overshooting will occur when $\Delta y_{G,t} > 0$ does push S_t below the lower threshold, triggering an adjustment of S_t to S^*, in which case it will be $\Delta S_t > 0$ and $\Delta y_t > \Delta y_{G,t} > 0$. This will happen when S^*-$L \leq S_{t-1} < S^*$-L+δ. Also, an overshooting will occur when $\Delta y_{G,t} < 0$ does push S_t above the upper threshold, triggering an adjustment of S_t to S^*, in which case $\Delta S_t < 0$ and $\Delta y_t < \Delta y_{G,t} < 0$ or $| \Delta y_t | > | \Delta y_{G,t} |$. This will happen when S^*+U-$\delta < S_{t-1} \leq S^*$+$U$.

Since, however, S^* is not observed, the conditions for a likely spread adjustment could be strengthened in a different way, developing in the process a consistency check for the presumed lagged-adjustment mechanism. The cases depicted in Figure 3 will help in this endeavor. They refer to the four possible combinations of rising/falling spread and rising/falling German yield at t-1, $\Delta S_{t-1} >< 0$ and $\Delta y_{G,t-1} >< 0$. For parsimonious reasons,

4 This can be justified by the fact that the change of the German yield shows virtually no serial correlation and, thus, is hard to predict. So, to economize on transactions, investors will drive the spread to its equilibrium value, S^*, from which a portfolio re-adjustment will be less likely next period when the German yield may increase or decrease.

they refer to an increase in the German yield at period t, $\Delta y_{G,t} > 0$. The analysis for $\Delta y_{G,t} < 0$ is the mirror image of it.

Figure 3. Likely Spread Adjustment when the German Yield Increases ($\Delta y_{G,t} > 0$)



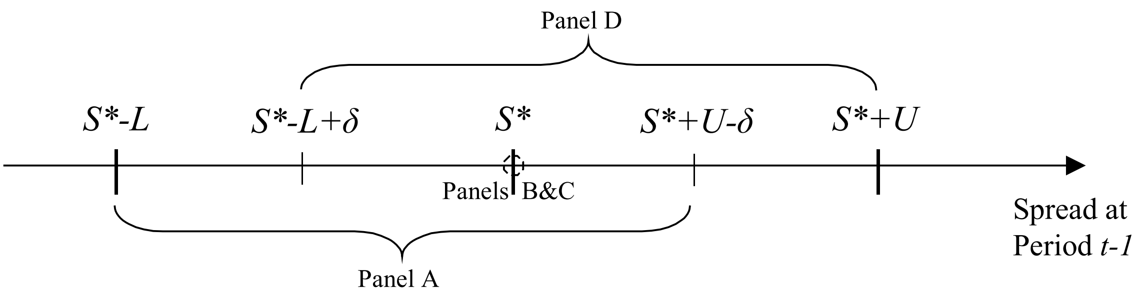
Note: The "solid" arrows show the spread change according to the simple framework outlined in the text. The "dashed" arrows show the cases where the prospect of crossing through the upper, S^*+U, or the lower, S^*-L, threshold triggers the spread adjustment to $S_t = S^*$.

Consider the case depicted in Panel A. At t-2, it was $S^*-L+\delta \leq S_{t-2} \leq S^*+U$. With the increase in the German yield at t-1, $\Delta y_{G,t-1} = \delta > 0$, investors did not sell the bonds. As a result, the yield remained the same and the spread decreased, $\Delta S_{t-1} = -\delta < 0$, without, however, crossing the lower threshold. S_{t-1} will be in the range $[S^*-L, S^*+U-\delta]$ which contains a subset $[S^*-L, S^*-L+\delta]$ for which a yield undershooting will occur when $\Delta y_{G,t} > 0$.

Next, consider the case depicted in Panel B, which is the same as that in Panel A with the difference that S_{t-2} covers the part of the $[S^*-L, S^*+U]$ range not covered by S_{t-2} in Panel A; i.e., $S^*-L \leq S_{t-2} < S^*-L+\delta$. The increase in the German yield at t-1, $\Delta y_{G,t-1} > 0$, pushes the spread at t-1 below the lower threshold (dashed arrow), triggering an adjustment at t-1. Now, with $S_{t-1} = S^*$, the increase in the German yield at t is less likely to push the spread below the lower threshold at t than in the case depicted in Panel A. Hence, an overshooting is less likely than in the case in Panel A and an undershooting more likely.

Continuing, a yield undershooting is more likely when $\Delta y_{G,t-1} < 0$ and $\Delta y_{G,t} > 0$ are matched with $\Delta S_{t-1} > 0$ (Panel D) than with $\Delta S_{t-1} < 0$ (Panel C). In the first case, it is $S^*-L \leq S_{t-2} \leq S^*+U-\delta$ and $S^*-L+\delta \leq S_{t-1} \leq S^*+U$, while in the second $S^*+U-\delta < S_{t-2} \leq S^*+U$ and $S_{t-1} = S^*$.

From the four cases in Figure 3, which, again, correspond to $\Delta y_{G,t} > 0$, a yield overshooting at t, $\Delta S_t > 0$, is most likely to occur in the case depicted in Panel A, while the undershooting, $\Delta S_t < 0$, is most likely to be bigger in the case depicted in Panel D than in the cases depicted in Panels B and C.[5] The intuition is conveyed by the graph below that depicts the ranges of possible values of the spread at $t-1$ for the Panels in Figure 3. Essentially, the "mass" of S_{t-1} values in Panel A is to the left of S^*—where the corresponding mass for Panels B and C is concentrated, while the mass in Panel D is to the right of S^*.



The above suggest the following test:

Test I: The conditions for a likely yield undershooting are as in the following matrix.

	Conditions for Yield Undershooting at t	
	$\Delta S_{t-1} < 0$ $\Delta y_{G,t-1} > 0$	$\Delta S_{t-1} > 0$ $\Delta y_{G,t-1} < 0$
$\Delta y_{G,t} > 0$	Least Likely	Most Likely
$\Delta y_{G,t} < 0$	Most Likely	Least Likely

Note that the conditions for $\Delta y_{G,t} < 0$ are the mirror image of those for $\Delta y_{G,t} > 0$.

5 That a yield overshooting is likely in one of the four cases on Figure 3, while an undershooting is more likely in the remaining three cases, is consistent with the statistical evidence for undershooting in Table 2.

The conditions in the above matrix are in the spirit of recently developed non-linear forecasting models which, by the way, share several characteristics with technical trading rules. The underlying idea is that financial series exhibit some recurring –but not periodic –patterns. Using them can help improve forecasts, provided that one can recognize their early stages (Bajo-Rubio, 2001) –something the preceding conditions aim at.

Noting, also, the parallel between two consecutive German yield increases and the "large amount of similar information", the proposed adjustment mechanism suggests an alternative, fully rational, explanation for the overreaction of investors to large amounts of similar information postulated in Barberis et al. (1998) and Poteshman (1991). In short, this overshooting is similar to the adjustment in Panel A of the spread towards its equilibrium value that corrects accumulated past deviations from this value.

In addition to the above conditions for a likely yield undershooting, the proposed lagged adjustment has two important implications for the time-series behavior of the observed spread. First, at any period *t*, the spread may deviate from its equilibrium value either from above or from below.[6] Alternatively, the equilibrium spread, S^*, will be equal to a weighted average of the lagged values of the observed spread. Second, the observed change in the yield, $\Delta y_t = y_t - y_{t-1}$, will be a fraction of the equilibrium change, $y_t^* - y_{t-1}$, where $y_t^* = y_{G,t} + S_t^*$.

The second implication requires some elaboration. Given the characteristics of a bond, and in particular of its modified duration, the change in the yield, $\Delta y_t = y_t - y_{t-1}$, will determine the change in its price, with big yield changes associated with big price changes. Due to the possibility of price overshooting and, hence, of excessive capital losses, investors will have the incentive to trade bonds in a way that the yield will adjust gradually to its equilibrium value.

The two implications are summarized in equations (2) through (4).

$$S_t^* = y_t^* - y_{G,t} \tag{2}$$

$$S_t^* = \alpha_0 + \alpha_1 S_{t-1} + \alpha_2 S_{t-2} + \alpha_3 S_{t-3} + \alpha_4 S_{t-4} + \ldots + \alpha_k S_{t-k} \tag{3}$$

$$y_t - y_{t-1} = \varphi(y_t^* - y_{t-1}) + \varepsilon_t \tag{4}$$

6 This is consistent with the empirical evidence in Schulte and Violi (2001), where VARs reveal that there is a significant transitory component in the fluctuations of E.M.U. government bond spreads.

in which α_i $(0 \leq i \leq k)$ are (unknown) non-negative coefficients, $0 \leq \alpha_i < 1$, φ measures the spread of adjustment, $0 \leq \varphi \leq 1$, and ε_t is an i.i.d. stochastic term.

Everything else equal, higher liquidity should be associated with faster yield adjustment; i.e., with higher φ.

Solving equation (4) for y_t, subtracting from the resultant expression $y_{G,t}$ to get S_t, and using equations (2) and (3) to eliminate the unobserved y_t^* and S_t^*, gives the following testable equation:

$$S_t = \varphi\alpha_0 + (\varphi - 1)\Delta y_{G,t} + (1 - \varphi + \varphi\alpha_1) S_{t-1} + \varphi\alpha_2 S_{t-2} + \varphi\alpha_3 S_{t-3} + \ldots + \varphi\alpha_k S_{t-k} + e_t \qquad (5)$$

Test II: In equation (5), it is expected that $0 \leq \alpha_i < 1$ $(0 \leq i \leq k)$ *and* $0 \leq \varphi \leq 1$.

Note that the time series evidence from equation (5) would be consistent with that in Table 2 if $(\varphi - 1) < 0$. In such a case, as the following transformation of equation (5) indicates, an increase in the German yield, $\Delta y_{G,t} > 0$, will tend to be associated with a decrease in the spread, $\Delta S_t < 0$, and vice-versa. Further, the time series evidence would be consistent with the cases in Figure 3, in which the correlation between ΔS_{t-1} and ΔS_t is likely to be negative, if $(-1 + \alpha_1) < 0$.

$$\Delta S_t = \varphi\alpha_0 + (\varphi - 1)\Delta y_{G,t} + \varphi(-1 + \alpha_1)\Delta S_{t-1} + \varphi(\alpha_2 + \alpha_3 - 1)\Delta S_{t-2} + \varphi(\alpha_2 + \alpha_3 + \alpha_k - 1)\Delta S_{t-k} + e_t$$

Test III – Consistency Check: the speed of yield adjustment should be faster (higher φ) for countries with higher bond market liquidity and –hence– lower yield undershooting.

It is worth noting that the conceptual framework above is based on the *depth* dimension of liquidity, i.e., the volume of transactions that can be made without affecting prices (see footnote #2). Yet, *Test I* corresponds to the *tightness* dimension of liquidity –measured here with the magnitude of undershooting instead of the usual bid/ask spread, while *Test II* corresponds to the *resiliency* dimension. *Test III* provides a consistency check; that is, if the empirical results are in line with the expectations from the three tests, this will provide strong evidence in favor of the conceptual framework. In addition, it will be an indication that the three measures of liquidity point to the same direction, something not to be expected from previous studies.

4. Empirical Evidence

Test I

Table 3 summarizes the evidence for *Test I*. Columns (2) and (4) pertain to the two cases of a rising German yield in the matrix describing the conditions for a likely yield undershooting, while columns (5) and (7) pertain to the two cases of a falling German yield. Columns (3) and (6) correspond to Columns (2) and (3) of Table 2 and are provided for the sake of easy comparison. Also, the first figure in each cell corresponds to the sample mean of the spread change and the second to its standard error. One, two and three asterisks (*) denote significance respectively at the 10, 5 and 1 percent levels. Lastly, the third figure in Columns (2) and (4) correspond to the *p-value* for the test that the sample means in these two columns is equal to the sample mean in Column (3). The same applies to the third figure of Columns (5) and (7) with respect to Column (6).

The evidence in Table 3 is largely consistent with expectations. Specifically, as the condition for a yield undershooting gets stronger, moving rightwards on Table 3, so does the undershooting –as measured by the average spread change– both in magnitude and statistical significance. The undershooting is weakest, but still significant, for Italy and Spain, the countries with the highly volatile bid/ask spread, and the Netherlands.

In greater detail, when the German yield is rising at *t*, there is significant overshooting in the case where the undershooting is least likely, column (2). This overshooting differs from the undershooting in Column (3) –Column (2) in Table 2—at very high levels, the exceptions applying to the Netherlands (*p-value* 0.1165), Portugal (*p-value* 0.0413) and Spain (*p-value* 0.0319). Also, the undershooting in Column (4) is bigger than that in Column (3). The difference between the two is also highly significant, though more countries miss the 1% level: Belgium (*p-value* 0.1439), France (*p-value* 0.0129), Italy (*p-value* 0.4069), the Netherlands (*p-value* 0.3436), Portugal (*p-value* 0.0312) and Spain (*p-value* 0.0591).

When the German yield is falling, the overshooting in Column (5), though mostly insignificant, differs significantly from the undershooting in Column (6)—Column (3) in Table 2, missing the 1 percent level only in France (*p-value* 0.1210), Italy (*p-value* 0.0158) and Spain (*p-value* 0.0136). In addition, the undershooting in Column (7) is significantly bigger than that in Column (6), the only countries missing the 1 percent level being Italy (*p-value* 0.0174) and Spain (*p-value* 0.0210).

Table 3: Test I – Strengthening the Conditions for A Likely Yield Undershooting

	$\Delta y_{G,t-1} > 0$ .AND.			$\Delta y_{G,t-1} < 0$ .AND.		
	$\Delta S_{t-1} < 0$ $\Delta y_{G,t-1} > 0$ (2)	$\Delta S_{t-1} \gtrless 0$ $\Delta y_{G,t-1} \gtrless 0$ (3)	$\Delta S_{t-1} > 0$ $\Delta y_{G,t-1} < 0$ (4)	$\Delta S_{t-1} > 0$ $\Delta y_{G,t-1} < 0$ (5)	$\Delta S_{t-1} \gtrless 0$ $\Delta y_{G,t-1} \gtrless 0$ (6)	$\Delta S_{t-1} < 0$ $\Delta y_{G,t-1} > 0$ (7)
COUNTRY	Condition for Undershooting Strengthens ⇒ ⇒ ⇒			Condition for Undershooting Strengthens ⇒ ⇒ ⇒		
Austria	0.90 (0.31)*** 0.0003	-0.45 (0.19)**	-1.70 (0.29)*** 0.0001	-0.56 (0.25)* 0.0001	0.61 (0.16)***	1.74 (0.33)*** 0.0005
Belgium	0.24 (0.41) 0.0152	-0.63 (0.18)***	-1.24 (0.28)*** 0.1439	-0.36 (0.32) 0.0012	0.74 (0.16)***	1.95 (0.29)*** 0.0002
Finland	1.15 (0.28)*** 0.0000	-0.49 (0.19)**	-1.58 (0.34)*** 0.0072	-0.78 (0.35)** 0.0005	0.54 (0.17)***	1.76 (0.28)*** 0.0003
France	0.79 (0.35)** 0.0031	-0.47 (0.20)**	-1.55 (0.33)*** 0.0129	-0.07 (0.25) 0.1210	0.58 (0.17)***	1.85 (0.39)*** 0.0003
Ireland	1.17 (0.54)** 0.0002	-0.89 (0.27)***	-2.19 (0.37)*** 0.0084	-0.24 (0.39) 0.0004	1.05 (0.20)***	2.71 (0.36)*** 0.0000
Italy	1.00 (0.39)** 0.0004	-0.44 (0.19)**	-0.73 (0.31)** 0.4069	-0.22 (0.23) 0.0158	0.54 (0.15)***	1.23 (0.28)*** 0.0174
Netherlands	0.13 (0.42) 0.1165	-0.48 (0.17)***	-0.69 (0.28)*** 0.3436	-0.49 (0.21)** 0.0003	0.53 (0.13)***	1.43 (0.26)*** 0.0029
Portugal	0.19 (0.51) 0.0413	-0.73 (0.25)***	-1.66 (0.34)*** 0.0312	0.01 (0.24) 0.0041	0.85 (0.17)***	2.02 (0.34)*** 0.0018
SPAIN	0.61 (0.38) 0.0319	-0.34 (0.19)*	-1.09 (0.33)*** 0.0591	-0.28 (0.24) 0.0136	0.43 (0.14)***	1.17 (0.29)*** 0.0210

Notes:

1. Sample: January 4, 1999 to December 31, 2000.
2. Sources: Bloomberg, Reuters and authors' calculations.
3. Δy_G : Daily change in the German Government Bond yield.
4. Columns (3) and (6) correspond to Columns (2) and (3) of Table 2.
5. The first figure in each cell corresponds to the sample mean and the second to its standard error of the change in the spread.
6. The third figure in Columns (2) and (4) correspond to the *p-value* for the test that the sample means in these two columns is equal to the sample mean in Column (3). The same applies to the third figure in Columns (5) and (7) with respect to Column (6). These *p-values* were computed using the *Wilcoxon rank sum test*, which is a linear transformation of the Mann-Whitney *U* test. For details, see Rice 1995, pp. 402-408.
7. One (*), two (**) and three (***) asterisks denote significance at the 10%, 5% and 1% level, respectively. Owing to the large number of observations, the critical values were taken from the *t-statistic* tables, despite that in almost all cases skewness and kyrtosis were significant.

Test II

Equation (5) was estimated following a *specific to general* modeling approach. We started with one lag of the spread and continued adding more lags, one at a time, until two conditions were met: there was no evidence of serial correlation in the residuals and additional lags did not improve the adjusted R^2. The results are summarized in Table 4, which, in addition to the estimated coefficients, reports the implied φ and α_1.

The results in Table 4 are also consistent with expectations. The coefficient of $\Delta y_{G,t}$, $(\varphi - 1)$, is negative, less than one in absolute value, and significant at the 1% level for all countries except Spain for which it is significant at the 5 percent level. The implied speed of adjustment, φ, ranges from 0.712 for Ireland to 0.933 for Spain.

Table 4: Test III -- Time-Series Evidence

$S_t = \alpha_0 + (\varphi-1)\Delta y_{G,t} + (1-\varphi+\varphi\alpha_1)S_{t-1} + \varphi\alpha_2 S_{t-2} + \ldots + \varphi\alpha_k S_{t-k} + \varepsilon_t$									
Estimated Coefficients	Austria	Belgium	Finland	France	Ireland	Italy	Nether-lands	Portugal	Spain
α_0	1.371 (3.09)***	2.424 (4.53)***	3.867 (4.66)***	2.960 (5.51)***	2.457 (2.04)**	1.888 (3.16)***	3.119 (4.76)***	3.917 (4.39)***	4.492 (5.87)***
φ-1	-0.200 (-6.03)***	-0.223 (-7.15)***	-0.151 (-4.73)***	-0.177 (-5.71)***	-0.288 (-8.23)***	-0.136 (-4.41)***	-0.074 (-2.92)***	-0.271 (-7.36)***	-0.067 (-2.23)**
1-φ-$\varphi\alpha_1$	0.343 (6.77)***	0.484 (9.21)***	0.416 (7.99)***	0.366 (7.61)***	0.422 (6.63)***	0.494 (8.95)***	0.356 (6.13)***	0.598 (7.59)***	0.458 (7.89)***
$\varphi\alpha_2$	0.309 (5.61)***	0.294 (5.31)***	0.442 (8.39)***	0.151 (3.52)***	0.250 (3.23)***	0.332 (4.80)***	0.199 (3.44)***	0.135 (1.84)*	0.373 (6.51)***
$\varphi\alpha_3$	0.159 (2.96)***	0.144 (2.70)***		0.125 (2.60)***	0.127 (2.56)**	0.114 (1.82)**	0.064 (1.33)	0.150 (2.51)**	
$\varphi\alpha_4$	0.138 (2.85)***			0.132 (3.13)***	0.096 (1.95)*		0.174 (3.59)***		
R^2-bar	0.882	0.823	0.581	0.467	0.746	0.829	0.434	0.760	0.623
D.W.	1.90	1.97	1.92	1.94	1.92	2.04	2.02	1.97	2.03
# of Obs.	472	508	488	506	469	505	506	508	511
Implied φ	0.800	0.777	0.845	0.823	0.712	0.864	0.926	0.729	0.933
Implied α_1	0.179	0.336	0.309	0.230	0.187	0.415	0.304	0.445	0.420

Notes:

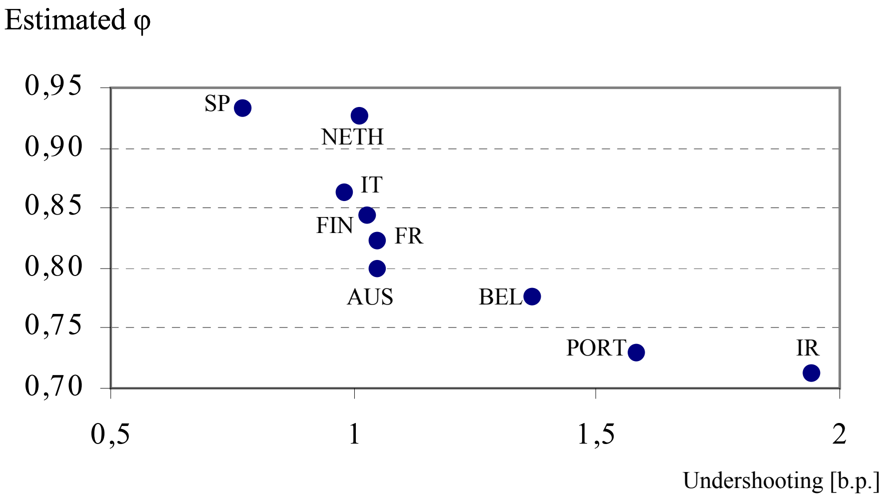
1. Sample: January 4, 1999 to December 31, 2000.
2. Sources: Bloomberg, Reuters and authors' calculations.
3. Estimation Method: OLS with the White correction for heteroscedasticty.
4. The numbers in parentheses correspond to *t*-statistics.
5. One (*), two (**) and three (***) asterisks denote significance at the 10%, 5% and 1% levels, respectively.

Also, all α_i $(i=1,\ldots k)$ for all countries are positive and less than one. Further, with α_1 ranging from 0.179 (Austria) to 0.445 (Portugal), $1- \alpha_1$ is negative, suggesting a negative correlation between ΔS_t and ΔS_{t-1}, as suggested by the conceptual framework.

Test III

Figure 4 summarizes the results of this qualitative test. Essentially, it confirms the expectation that there should be a negative correlation between the speed of adjustment and the magnitude of undershooting in Column 4 of Table 2.

Figure 4. Consistency Check-Undershooting vs. Adjustment Speed



5. Concluding Remarks

To summarize, we document a small, yet economically and statistically significant yield undershooting in the E.M.U. benchmark government bond markets which, we propose, is due to the lagged adjustment that is driven by liquidity considerations and, in particular, by the possibility of excessive bond-price movements in response to changes in the German yield. We formalize this lagged adjustment with a conceptual framework based on the depth dimension of liquidity, and develop two tests, one based on the tightness dimension and the other on the resiliency dimension, plus a qualitative test to examine the consistency of the first two. The empirical results not only are consistent with expectations, but additionally suggest that the three dimensions of liquidity point to the same direction.

Could, however, the proposed lagged adjustment and the attendant yield under- and overshooting, which here emerge as the product of rational behavior, be explained by some cognitive bias as in Poteshman (2001)? As a reminder, the latter rests on Barberis et al.'s conjecture that investors tend to overreact to information that is preceded by similar information (Barberis et al. [1998]). In this paper's context, such information is a rising (falling) German yield at *t* following a rising (falling) yield at *t-1*.

Our findings indicate that the probable answer is negative. To begin with, the degree of under/overshooting is affected by the sign of the spread change at *t-1* which, essentially, suggests that the degree of over/undershooting is affected by the accumulated deviations from the equilibrium value of the benchmark yield spread. In addition, the magnitude of the under/overshooting declined in 2000, in line with the increased liquidity brought about by the growing E.M.U. bond market integration.

Thus, an alternative, fully rational, explanation for the aforementioned conjecture emerges which calls for a re-examination of the evidence of previous studies. Briefly, due to some transaction costs, the prices of financial assets may adjust sluggishly and thus occasionally deviate from their equilibrium values. The deviation may become so large when a series of similar shocks occurs, large amounts of similar information in the terminology of Barberis et al., as to trigger an adjustment that corrects all the accumulated deviations of previous shocks. This adjustment will qualify as overshooting.

Lastly, the empirical results, together with the proposed lagged adjustment, have important implications for the futures markets on European government bonds. Briefly, just before the onset of the E.M.U., knowledgeable market observers and practitioners were foreseeing as the most likely development the emergence of a European bond market with two futures contracts: one on German bonds, used for hedging the bonds of the low-spread countries, and one on Spanish or Italian bonds, used for hedging the bonds of the remaining countries (McCauley [1999]). The results, however, suggest a different configuration: one based not on spreads/credit, but on liquidity. That is, a configuration in which there will be two futures contracts, one on the German bond, for the high-liquidity countries (including Italy and Spain), and another –possibly on the French bond– for the low liquidity countries. More importantly, the growing integration of the European government bond markets, and the attendant gradual elimination of the documented yield undershooting, may render one of the two futures contracts redundant, leaving the contract on the German bonds alone to compete more effectively with that on U.S. government bonds.

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APPENDIX

Table A-1: Ten-Year Benchmark Government Bonds – Bid/Ask Prices

Country (1)	Source (2)	100*(P^a-P^b)/[(P^a+P^b)/2] Min (3)	Ave-rage (4)	Max (5)	Details on (P^a-P^b) (6)
Austria	Die Erste Vienna	0.07	0.08	0.09	Constant throughout the sample period at 0.08.
Belgium	Bank Br. Lambert	0.09	0.10	0.12	Constant throughout the sample period at 0.10.
Finland	Merita Bank	0.10	0.14	0.59	It started at 0.18 on ¼/99 and gradually declined to 0.13 until 5/5/00, staying constant for long periods in between; thereafter, constant at 0.10.
France	Societé Gene-ral de Paris	0.05	0.11	0.20	Constant at 0.12 until 3/8/00; 3/9-4/27: 0.06; 4/28 & 5/2: 0.14; 5/3-5/12: 0.08; 5/15: 0.14; 5/16-6/1: 0.05; 6/2-6/6: 0.12; 6/8-6/12: 0.20; 6/13 & 6/14: 0.14; thereafter: 0.10.
Ireland	Davy Stock-brokers	0.09	0.11	0.12	Constant at 0.10 except on the following six dates: 5/20/99: 0.20; 5/21/99: 0.09; 9/15/99: 0.20; 12/1/99: 0.33; 8/16/00: 0.06; 8/17/00: 0.03. The *min* and *max* values in the previous cells do not include the above six days.
Italy	Mercato Telematico	0.01	0.11	2.06	Very variable, ranging from 0.03 to 0.69.
Netherlands	ABN Amro Bank	0.06	0.10	0.22	4/1/99-2/9: 0.10; 2/10: 0.20; 2/11-2/28: 0.25; 2/29-5/26: 0.10; 5/29-9/29/99: 0.08; thereafter: 0.06.
Portugal	Banco Espirito	0.09	0.10	0.12	Constant throughout the sample period at 0.10.
Spain	Gesmosa	0.02	0.14	0.21	Highly variable, fluctuating on a daily basis between 0.02 and 0.21 until end of May 2000; therefter, mostly equal to 0.10.
Memorandum Item					
Germany	Deutsche Bank	0.03	0.05	0.07	Relatively stable. From 1/4/99-4/9: 0.05; 4/7-7/15: 0.07; 7/16-8/24: 0.05; 8/25-9/7: 0.06; 9/8-3/3/00: 0.05; 3/6-4/7: 0.04; 4/10-7/26: 0.03; 7/27-10/24: 0.06.

Notes:

1. Sources: Reuters and authors' calculations.
2. P^b and P^a denote the bid and ask prices quoted by the institutions mentioned in the second column.
3. 100*(P^a-P^b)/ [(P^a+P^b)/2] is the bib/ask spread as percent of the average bid/ask price.