Is Liquidity Reflected in Bond Yields?

Evidence from the Euro Corporate Bond Market[1]

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Is Liquidity Reflected in Bond Yields? Evidence from the Euro Corporate Bond Market

We test whether liquidity is priced in the euro-denominated corporate bond market. We use the Arbitrage Pricing Theory to control for other sources of risk. Yields are used to measure the bonds' expected returns and liquidity is approximated by four indirect measures: issued amount, age, number of quotes and dispersion of quotes. Our results show that significant pricing anomalies due to liquidity exist for euro-denominated bonds. We find that the yield premium between liquid and illiquid bonds ranges from 0.2 to 47 basis points, depending on which liquidity indicator is used.

I Introduction

The liquidity of the euro-denominated corporate bond market is lower than its sovereign counterpart. Despite the importance of liquidity risk in corporate bond markets, the number of academic papers on bond liquidity is limited. Many papers have been written on liquidity risk in equity markets though. These papers focussed on the estimation of the relationship between liquidity and expected equity returns. The scarcity of papers on bond liquidity is surprising, since for a bond its yield-to-maturity can be used as expected return measure. Equity studies, on the other hand, always have to resort to approximating expected returns by realized returns, which are, by definition, realizations of a stochastic process instead of expectations. In this paper, we exploit this advantage of bonds over equities to test for pricing anomalies in the euro-denominated corporate bond market that can be attributed to liquidity risk. Our methodology is similar to the one recently employed in equity studies and uses the Arbitrage Pricing Theory (APT) to control for other sources of risk. As far as we know, no earlier papers exist that estimate corporate bond liquidity in the APT framework. We approximate bond liquidity by four indicators: issued amount, age, number of quotes and dispersion of quotes. We use a detailed data set consisting of daily yields of individual corporate bonds denominated in euros or in one of the currencies of the participating countries ('legacy' currencies). We find a substantial yield premium of 50 basis points (bps) between legacy- and euro-denominated bonds. Since this premium dominates the effects of our liquidity indicators, we concentrate on the euro-denominated bonds only. Our results show that pricing anomalies due to liquidity do exist in the euro-denominated corporate bond market. The yield premium between liquid and illiquid euro-denominated bonds ranges from 0.2 to 47 bps, depending on which liquidity indicator is used.

Both theoretical and empirical evidence exists that liquidity risk is priced in security markets. Amihud and Mendelson (1986) argued that illiquid securities have larger bid-ask spreads and developed a theoretical model that showed that the expected asset return is an increasing function of the bid-ask spread. Madhavan (2000) provided an overview on more market microstructure models of asset liquidity. Several empirical papers also documented that liquidity risk is priced in equity markets. Haugen and Baker (1996) regressed the expected equity return on risk, liquidity, price level, growth potential and price history factors. Two liquidity factors, trading volume/market capitalization and trading volume trend, were significant factors in this estimation. Their results implied a rejection of the Efficient Market Hypothesis (EMH). Brennan and Subrahmanyam (1996) used the Fama and French (1993) APT model to control for other priced risks. They assigned each stock in their sample to one of thirty portfolios based on its estimated Glosten and Harris (1988) liquidity measure and its market capitalization. The excess returns of the portfolios were subsequently regressed on the Fama-French equity risk factors. Under the null hypothesis that liquidity has no effect on equity returns, the intercepts for all portfolios should be jointly zero. Brennan and Subrahmanyam (1996) were able to reject this hypothesis, implying that the Fama-French risk factors do not take equity liquidity into account. The relationship between expected equity return and various equity factors was also tested by Brennan, Chordia and Subrahmanyam (1998). They found a strong negative relation between returns and the liquidity proxy trading volume. Chordia, Subrahmanyam and Anshuman (2001) also used proxies for liquidity and for the second moment of liquidity to measure the relationship between equity return and liquidity. After controlling for the Fama-French equity factors and for momentum and dollar volume turnover, a negative relation between equity return and the variability of dollar trading volume and share turnover persisted.

The empirical literature discussed above has focussed on testing the presence of liquidity premiums in equity markets. In this paper, we use the Brennan and Subrahmanyam (1996) methodology to test whether liquidity is priced in the euro-denominated corporate bond market. Since we deal with bonds instead of equities, we make two modifications to the Brennan-Subrahmanyam approach. First, we replace the three-factor Fama-French equity-market model by the two-factor Fama-French bond-market model. Second, we use bond yields instead of realized returns to proxy for expected returns. We use four indirect indicators of euro-denominated bond liquidity: issued amount, age, number of quotes and dispersion of quotes. These bond liquidity proxies are described in a number of papers and are often used by practitioners. The age indicator is particularly interesting, since it has no counterpart for equity markets. For each liquidity indicator, we construct two, mutually exclusive portfolios by ordering all bonds on their value of the liquidity indicator and assigning the first 50% of the bonds to portfolio 1 and the last 50% to portfolio 2. For each trading day, we then calculate the yield of both portfolios as the unweighted average of the bond yields. The two time series of portfolio yields are subsequently used in a Fama-French regression model. Under the null hypothesis that liquidity does not affect bond yields, the regression intercepts should be jointly zero.

In our empirical analysis, we first look at the differences between bonds denominated in euros and in legacy currencies. We find an average yield premium of 50 bps of legacy bonds over euro bonds, indicating that the market generally considers legacy bonds to be illiquid securities. Since this legacy premium dominates the yield premium arising from our four liquidity indicators, and because legacy bonds will gradually disappear from the market, we only use euro-denominated bonds in our further analyses. Our results show that liquidity plays an important role in the pricing of euro bonds. The null hypothesis of the APT model is always rejected. Therefore, the liquidity of a corporate bond is a significant determinant of its price. The size of the yield difference between the liquid and illiquid bond portfolios depends on the employed liquidity indicator. We find a negligible liquidity premium for the indicator issued amount of 0.2 bps, a substantial liquidity impact for age and number of quotes of 14 and 27 bps, respectively, and a large effect for the dispersion indicator of 47 bps.

Lo and MacKinlay (1990) showed that serious biases can arise in the test statistics when portfolios are used to test the efficient market hypothesis. The portfolios are constructed by sorting securities on empirical characteristics, which typically follow either from own research on a data base or from results of other papers that have analyzed the same database. If the statistical tests are carried out on exactly the same data base, significant biases in the tests can occur. Lo and MacKinlay (1990) called this *data-snooping*. In our analysis, data-snooping is probably limited, since our liquidity indicators originate from two sources. Some of our indicators follow from theoretical models. The remaining indicators have been taken from empirical research on other corporate bond data bases, so that no data mining has been applied to our data base.

The content of this paper is as follows. In Section II, the Brennan-Subrahmanyam approach of testing the compensation for liquidity in equity returns and the Fama-French model are explained and our modifications to both approaches are given. This section also describes the portfolio construction and discusses the four liquidity indicators that are used in this construction. Next, in Section III, the data that are used to test the hypotheses of corporate bond liquidity are described. In Section IV, the results from the model implementation are shown and explained. Finally, Section V summarizes.

II Methodology

We use the Brennan and Subrahmanyam (1996) approach to test whether liquidity-related pricing anomalies exist in the euro-denominated corporate bond market. Therefore, we first describe their framework in Section II.A, followed by our implementation in Section II.B. Our liquidity indicators are presented in Section II.C.

II.A Brennan-Subrahmanyam Approach

Brennan and Subrahmanyam's (1996) portfolio construction made use of two variables. First, the stocks were divided into size quintiles according to the firm's market capitalization. Next, within each size quintile, the stocks were assigned to one of five portfolios with each portfolio containing an equal number of stocks based on their estimated Glosten and Harris (1988) liquidity measure. In this way, Brennan and Subrahmanyam (1996) had evenly divided the total sample of stocks into portfolios depending on the size and liquidity criteria. Then they tested whether the constructed portfolios had significantly different returns. To control for other sources of risk, Brennan and Subrahmanyam used the Fama and French (1993) equity-market model.

Fama and French found three common factors that explained the return of an equity portfolio: an overall market factor, a size factor and a book-to-market factor. To test their model, Fama and French subdivided the stocks in their sample in portfolios based on several criteria, and regressed the portfolios' excess returns over the default-free interest rate on the three factors. The intercept coefficients from these regressions were almost never statistically significant, indicating the validity of their model on their data set.

Similarly, Brennan and Subrahmanyam regressed the realized excess returns of their portfolios on the Fama-French equity market factors. For each portfolio they ran a Fama-French regression model augmented with an intercept term. Under the null hypotheses that liquidity has no additional power in explaining excess equity returns, the intercepts of these regressions should not be jointly significantly different from zero. This null hypothesis was also tested by an alternative regression model. Again the portfolios' excess returns were used as dependent variables. However, the portfolio-specific intercepts were replaced by a common intercept for all portfolios, and portfolio-specific liquidity variables were added to the regression equation. For both regression models the null hypothesis had to be rejected, implying that the Fama-French risk factors do not take into account equity liquidity, or, in other words, that liquidity is an additional source of risk that is priced by financial market participants.

II.B Implementation

We use Brennan and Subrahmanyam's (1996) methodology to test whether liquidity is priced in the euro-denominated corporate bond market. We make two modifications to their method. First, we use bond yields instead of realized returns to proxy for expected returns. The following argument provides some intuition why the yield of a bond should contain a compensation for liquidity. Suppose an investor wants to buy an illiquid bond. Since the bond is illiquid, he faces higher trading costs, due to a larger bid-ask spread, than for a comparable, liquid bond. In order to persuade him to buy the illiquid bond the investor should be compensated by a lower price. The yield of the illiquid bond should thus be higher than that of the liquid bond. The advantage of yields over realized returns is twofold. First, yields really represent the market's expectation of a bond's expected return; realized returns, on the other hand, are, by definition, realizations of a stochastic process rather than expectations. The second advantage of yields over realized returns can be understood by considering the hypothetical case where the prices of a liquid and an illiquid bond always have a fixed ratio to each other; the realized returns of these bonds will be exactly equal, but their yields will differ. So, to the extent that there is a fixed percentual price discount for illiquidity, realized returns are unsuited to determine whether liquidity is a determinant of security prices.

The second modification to the Brennan-Subrahmanyam framework is that we replace the three-factor Fama and French (1993) equity-market model by their two-factor bond-market model. Fama and French (1993) found two common risk factors in the returns on bonds. The two bond-market factors explained the excess returns of seven bond portfolios: two government bond portfolios with average maturities of 1 to 5 years and 6 to 10 years, and five corporate bond portfolios with average, Moody's ratings of Aaa, Aa, A, Baa and below Baa. The excess return was defined as the portfolio return minus the one-month Treasury rate. Fama and French defined the first bond-market factor as the difference between the long-term government bond return and the one-month Treasury rate at the end of the previous month. Thus, this *slope factor* tried to explain variations in excess bond returns by changes in the slope of the Treasury yield curve. The second factor was defined as the difference between the long-term corporate bond return and the long-term Treasury return. This *credit factor* was therefore related to the likelihood of credit events in the corporate bond portfolio. These two factors did a very good job in explaining the excess returns of the seven bond portfolios (Fama and French, 1993, Table 3): all estimated parameters were statistically significant with t-values ranging from 8 to 140 and the R^2-

values were also high, with values ranging from 79% to 98%. Moreover, the intercepts of all five corporate bond portfolios were statistically not significant.

In their analysis, Fama and French used the government curve to calculate the excess returns and the two bond-market factors. In contrast, we use the swap curve. Recently, fixed income investors have moved away from using government securities to extract default-free interest rates and started using interest rate swap rates instead. Golub and Tilman (2000) and Kocić, Quintos and Yared (2000) mentioned the diminishing amounts of US and European government debts, the credit and liquidity crises of 1998, and the introduction of the euro in 1999 as primary catalyzing factors for this development. Empirical research by Houweling and Vorst (2001), on the same market and over the same time period, indicated that the swap curve is a better proxy for the default-free curve than its government counterpart.

We consider four different liquidity indicators, which are detailed in Section II.C. For each indicator, we construct two time series of portfolio yields as follows. Every two weeks, we order all bonds in the sample by the value of the liquidity indicator; only bonds that have already been issued and have not matured or been redeemed yet on the construction date are used in the ordering. Then, 50% of the bonds gets assigned to portfolio 1 and 50% to portfolio 2. We do this in such a way that, irrespective of the liquidity indicator used, portfolio 1 (respectively 2) contains the bonds that are hypothesized to be liquid (respectively illiquid). Every day we calculate the portfolio yield as the unweighted average of the yields of the bonds that make up the portfolio. The bond yield is calculated as follows: if a bond is not quoted, we disregard it for that day; if it is quoted by one pricing source, we use that yield; if it is quoted by more than one pricing source, we use the average quote. We also use this procedure to calculate the yield premium between legacy and euro bonds, see Section IV.B.

Like Brennan and Subrahmanyam (1996), we consider two regression models. The first model is

$$Y_{it} = \alpha_i + \beta_i S_t + \gamma_i C_t + \varepsilon_{it},\ \varepsilon_{it} \sim N\left(0, \sigma_i^2\right), \tag{1}$$

where

- Y_{it} is the excess yield of portfolio i on day t,
- α_i is the intercept of portfolio i,
- S_t is the slope factor on day t,
- C_t is the credit factor on day t,
- ε_{it} is the regression error of portfolio i on day t.

In this regression model, the null hypothesis that liquidity has no additional power in explaining bond yields above the two Fama-French factors, can be tested by examining the joint significance of the intercepts α_i. We estimate regressions (1) for all portfolios simultaneously, so that the joint significance of the intercepts can be tested by an F-test.

The second regression model reads

$$Y_{it} = \alpha + \beta_i S_t + \gamma_i C_t + \delta\left(L_{it} - \bar{L}_t\right) + \varepsilon_{it},\ \varepsilon_{it} \sim N\left(0, \sigma_i^2\right), \tag{2}$$

where L_{it} is the liquidity indicator of portfolio i at day t and $\bar{L}_t$ is the average of the liquidity indicator at day t. In equation (2), the portfolio-specific intercepts of (1) have been replaced by a single intercept α and an additional regressor has been introduced that contains a proxy for portfolio i's liquidity. Therefore, the constant liquidity premium of α_i in the first regression model has been replaced by a time-varying premium $\alpha + \delta\left(L_{it} - \bar{L}_t\right)$.

By taking $L_{it} - \bar{L}_t$, δ gives the effect of the deviation of a liquidity indicator from its mean.

For both regression models, we assume that the error terms of different portfolios are independently and heteroscedastically distributed. This assumption constitutes a deviation from Brennan and Subrahmanyam's (1996) framework, who also allowed the disturbances to be correlated. However, for our data set, the error terms are so strongly correlated that the variance-covariance matrix is singular.

II.C Liquidity Indicators

In empirical papers that examined liquidity in equity markets, both direct and indirect measures of liquidity were used. Examples of direct liquidity measures are the bid-ask spread and the amount bought or sold of a security. These direct measures are often not reliable and difficult to obtain for corporate bonds, because most transactions occur on the over-the-counter market. Therefore, we consider four indirect liquidity indicators: issued amount, age, number of quotes and dispersion of quotes. The indicator issued amount is static, as it is a fixed characteristic of a bond. The age indicator changes gradually over time. The number and dispersion of quotes indicators, on the other hand, are dynamic and depend on market information. We will now discuss each indicator in more detail.

The *issued amount* of a corporate bond is often assumed to give an indication of its liquidity. The idea is that bonds with smaller issued amounts tend to get locked in buy-and-hold portfolios more easily, reducing the tradeable amount and thus their liquidity. Consequently, a large issued amount may give a higher bond liquidity than a small issued amount. Most investment banks use the issued amount as liquidity criterion in building their bond indices. For example, Lehman Brothers' Euro-Aggregate Corporate Bond index uses this criterion. At its initiation, the minimal issued amount to be included in the index was 100 million euro, meanwhile this amount was raised to 150 million euro, and on January 1^{st} 2002, the amount has risen further to 300 million euro. McGinty (2001) named issue size as one of the determinants of corporate bond liquidity, which he measured by transaction volume information from TRAX, ISMA's trading and reporting system. However, McGinty also mentioned that issue size is not the same thing as liquidity; his analysis showed that most large issues were liquid, but some large issues were also illiquid and some small issues were liquid. The relationship between issue size and yields was analyzed by Crabbe and Turner (1995). They found no relationship between the yield of large issue corporate bonds and small issue medium term notes of the same issuer with the same issuance and maturity date: the large and the small issues had statistically the same yields. Gehr and Martell (1992) regressed corporate bond spreads on issue size. Their results showed that this liquidity indicator had the expected negative sign, but the coefficient was not significant.

The age of a corporate bond is our second measure of bond liquidity. As the bond gets older, an increasing percentage of its issued amount is absorbed in investors' buy-and-hold portfolios. Thus, the older the corporate bond gets, the less liquid it becomes. This claim is supported by evidence in Schultz (1998), who analyzed a data base of US dollar-denominated corporate bond trades. He showed that most traded bonds in his sample were of very young age; almost no old bonds were traded. Moreover, in his sample most bonds were bought and not sold; in other words, the bonds were put into buy-and-hold portfolios. McGinty (2001) also pointed to age as a possible indicator of corporate bond liquidity. Market practitioners often use thresholds of 3 to 6 months to determine if a bond is 'old' or 'young'. Preliminary calculations showed that a 4-month threshold works best for our data set (see Section IV.E). So, portfolio 1 consists of bonds of at most 4 months old, and portfolio 2 of bonds with an age of at least 4 months. This is a deviation from the portfolio construction process of the other indicators; using that process for the age indicator would give portfolios with an average age much larger than four months so that both portfolios would contain 'old' bonds.

The average number of quotes per day since the previous portfolio rebalancing date is our third signal of a bond's liquidity. The idea behind this liquidity indicator is that there is more trading in liquid bonds, so that more market participants will quote them. Hence, more quotes may mean a higher liquidity. Schultz (1998) showed that there was a positive relation between the number of trades in a bond and the number of dealers as counterparties in his sample of US dollar-denominated corporate bonds. Gehr and Martell (1992) regressed the corporate bond spread on the number of dealers. The result of their regression showed that this liquidity indicator had the expected negative sign, but the coefficient was not significant.

Our final liquidity measure is the average *quote dispersion* since the previous portfolio rebalancing date. The yield dispersion D_{it} of bond i at day t is measured as

$$D_{it} = \frac{1}{n_{it} - 1} \sum_{j=1}^{n_{it}} |y_{itj} - \bar{y}_{it}| \tag{3}$$

where

y_{itj} is the yield of bond i quoted by pricing source j on day t,

$\bar{y}_{it}$ is the average yield of bond i on day t,

n_{it} is the number of quotes of bond i on day t.

The motivation behind this liquidity indicator is as follows: a liquid bond is traded more often than an illiquid bond so that its price better reflects available information. As a result, yield quotes by different pricing sources tend to be less spread out around the mean for a liquid bond than for an illiquid bond. A larger yield dispersion is thus associated with lower liquidity. This liquidity measure naturally follows from the number of quotes liquidity indicator; it tries to capture the volatility in the quoted yields. If it is not possible to calculate the dispersion D_{it} for a bond on a rebalancing date, that bond is ignored until the next rebalancing date.

Table 1 summarizes our four liquidity indicators. Portfolio 1 always contains the bonds that are hypothesized to be liquid, i.e. large issued amount, low age, large number of quotes or small quote dispersion. Portfolio 2, on the other hand, contains bonds that we expect to be illiquid so, denominated in a small issued amount, high age, small number of quotes or large quote dispersion.

Liquidity indicator	**Portfolio 1**	**Portfolio 2**
Issued amount	large	small
Age	young	old
Number of quotes	large	small
Quote dispersion	small	large

Table 1. Portfolio 1 and 2 for each liquidity indicator. Portfolio 1 (resp. 2) contains the bonds that are hypothesized to be liquid (resp. illiquid).

III Data

The data are downloaded from three different sources. Lehman Brothers provides the International Securities Identification Numbers (ISINs) of the members of their Euro-Aggregate Corporate Bond index. From Bloomberg the required characteristics of these corporate bonds are downloaded. Reuters 3000 EXtra provides daily bid yields of each bond quoted by different pricing sources. The download period starts on January 1, 1999 and ends on May 31, 2001. The ISINs are obtained for May 31, 2000. The total number of bonds on this date equals 1190. All bonds that are issued in euros directly after the currency's introduction are included in this analysis. Moreover, the yield time series of each corporate bond has at least twelve months history.

III.A Lehman Brothers

Lehman Brothers provides the ISINs of the corporate bonds in their Euro-Aggregate Corporate Bond index. This index serves as a proxy of the investment-grade euro-denominated, corporate bond market. Lehman Brothers imposes a number of criteria before the corporate bonds can enter its index. All bonds must be denominated in euros or in one of the legacy currencies. Further, all bonds are investment grade, have a fixed-rate coupon, at least one-year to maturity and an issued amount of at least 150 million euro. The country of issuance and the country of the issuer are no index criteria. The credit ratings of all corporate bonds are also provided by Lehman Brothers. All ratings are downloaded for May 31, 2000. We have kept these ratings unchanged during the whole period, since we only use them to give an indication of the average credit worthiness of our constructed portfolios. Finally, their Euro-Aggregate Corporate Bond BBB sub index is used to construct the Fama-French credit factor.

III.B Bloomberg

Bloomberg provides the required bond characteristics. Using the ISINs that are given by Lehman Brothers these characteristics are downloaded. In case an ISIN code is not recognized by Bloomberg, the bond data are obtained from Lehman Brothers' PC Product system. From the initial 1190 ISINs, 3 are not available in the Bloomberg database. The downloaded corporate bond characteristics are: issued amount, issue date, maturity date, currency, call dates, put dates and sinking fund dates. Euro-denominated par swap data, which are used to calculate the two Fama-French factors and the portfolio excess yields, are also downloaded from Bloomberg.

III.C Reuters

Reuters 3000 EXtra provides the bid yields of the selected corporate bonds. Most corporate bond yields in the Lehman Brothers Euro-Aggregate index are bid yields; only newly issued corporate bond have ask yields during their first month in the index (Lehman Brothers, 1999). Therefore, we download bid yields from Reuters. For each corporate bond, all pricing sources (also called contributors) are downloaded. We exclude two Reuters pricing sources, the clearing agency ISMA and two anonymous pricing sources from the list of contributors, since they are averages of other pricing sources. We define a pricing source as relevant if it prices at least one corporate bond at least one time. The total number of different pricing sources thus obtained equals 74.

From the original 1190 ISINs in the Lehman Brothers Euro-Aggregate Corporate Bond index 999 corporate bonds have at least one relevant pricing source. The 191 corporate bonds that are not analyzed have no Reuters Identification Code (RIC) that matches its ISIN, have a RIC but no contributor or have a RIC but no relevant contributor. For these 999 bonds, all bid yields from all relevant pricing sources are downloaded. This means that a number of time series, equal to the number of pricing sources, shows the yield developments of each bond. Most bonds are quoted by more than one pricing source.

IV Results

We first present the results of regressing the portfolio excess yields on the Fama-French bond-market factors. This regression is first conducted for the entire sample in Section IV.A and then for portfolios of euro and legacy bonds in Section IV.B. Next, we describe some characteristics of the constructed portfolios for four liquidity indicators on the euro-denominated corporate bond market in Section IV.C. Finally the regression results for each liquidity indicator are given in Sections IV.D to IV.G.

IV.A Entire Sample

To test whether the euro-dominated corporate bond market can, on average, be described by the two-factor Fama-French model, we first run regression model (1) for a portfolio with all bonds in our sample. The excess yield is calculated as the portfolio yield minus the one-year euro swap rate; the slope factor is defined as the ten-year swap rate minus the one-year swap rate of the previous day; the credit factor is calculated as the Lehman Brothers Euro-Aggregate Corporate Bond BBB sub index minus the ten-year euro swap rate.

Table 2 shows the R^2 and the estimated coefficients along with their t-values in parentheses. The R^2 value is high and comparable to the values reported by Fama and French (1993). The estimated slope and credit coefficients are statistically significant. The intercept coefficient is statistically not significant, so that the APT cannot be rejected for the entire sample.

The regression model is again estimated, but with the euro swap rates replaced by the euro government rates; so, the excess yields, the slope and credit factors are now

	Intercept	Slope	Credit
Entire sample	0.0252 (1.644)	0.793 (85.6)	0.199 (18.0)
R^2	98.0%		

Table 2. The regression of the total sample with swap rates as default-free rates using the first regression model.

calculated with government yields. Our proxy for euro government rate is the Lehman Brothers Euro-Aggregate Treasury index. Table 3 shows the regression results. Both the R^2 and the t -values of the slope and credit factors have decreased compared to Table 2. Moreover, the intercept is significantly different from zero. Therefore, the APT should be rejected in case government rates are used as default free rates. This empirically confirms our choice for using swap rates as proxy for default-free interest rates instead of treasury rates.

	Intercept	Slope	Credit
Entire sample	0.391 (26.2)	0.546 (70.4)	0.336 (16.2)
R^2	95.1%		

Table 3. The regression results of the total sample with euro government rates as default-free rates using the first regression model.

IV.B Euro and Legacy Bonds

The market generally sees legacy bonds as less liquid, because these bonds are relatively old, not well known to investors and more difficult to trade due to the legacy currency. To determine the significance of this legacy effect, we follow the same methodology as for our liquidity indicators by creating two portfolios and estimating regression model (1).[1] Portfolio 1 contains the euro-denominated corporate bonds, while portfolio 2 contains bonds denominated in a legacy currency. We hypothesize that a euro-denominated bond

[1] Equation (2) is not implemented for the euro and legacy portfolios, because it would be equivalent to equation (1): since we use a binary indicator (euro versus non-euro), the variable L would be a dummy variable.

has a higher yield than its comparable, legacy-currency counterpart.

The regression results are given in Table 4. All estimated coefficients are significantly different from zero at a 95% confidence level. The table should show a lower intercept coefficient for portfolio 1 than for portfolio 2; this is indeed the case. The null hypothesis is strongly rejected, with a high F-value, so that a pricing anomaly does exist. The mean yield difference between bonds denominated in euros versus bonds denominated in a legacy currency is 50 bps.

Portfolio	**Intercept**	**Slope**	**Credit**
Portfolio 1	-0.389 (14.9)	1.18 (74.9)	0.614 (32.9)
Portfolio 2	0.110 (3.90)	0.706 (41.5)	0.0401 (1.99)
$F\,(\alpha_1{=}\alpha_2{=}0)$	58.0 (0.00)		
R^2	96.1%		

Table 4. Regression results for the liquidity indicator currency for the first regression model.

To conclude, a strong currency-related pricing anomaly exists for our data set. In fact, this strong anomaly dominates the results of our further analyses using the four liquidity indicators: using both euro and legacy bonds in these analyses yields smaller yield premiums that sometimes have counterintuitive signs as compared to using only euro bonds.[2] Therefore, we remove legacy bonds from our sample and focus on the euro-denominated bonds only in the following analyses.

IV.C Portfolio Characteristics

Table 5 contains some summary statistics for the portfolios that are constructed from the euro-denominated bonds in our sample with the four liquidity indicators. All cells in this table are average values over the full estimation window of 602 trading days. We

[2] These results are not shown here, but available from the authors on request.

observe that the average yields of portfolio 1 (containing the hypothesized liquid bonds) and portfolio 2 (illiquid bonds) are quite different. The deviations range from 1 to 15 basis points (bps). However, it is not correct to fully attribute these yield differences to differences in liquidity, since the average maturity and the average credit worthiness also strongly vary. Except for the indicator number of quotes, we could even prematurely conclude that the liquidity premium is negative, since portfolio 1 has a higher average yield than portfolio 2.

Therefore, this table illustrates the necessity of using the Fama-French model to correct for characteristics that also affect a bond's yield: the Fama-French slope factor should correct for maturity differences, whereas the credit factor is designed to absorb variations in credit ratings.

	Yield		**Maturity**		**Rating**	
	P. 1	P. 2	P. 1	P. 2	P. 1	P. 2
Issued amount	5.35	5.22	6.40	5.44	2.21	2.21
Age	5.31	5.16	7.04	6.02	2.40	2.14
Number of quotes	5.29	5.30	6.11	5.75	2.26	2.15
Dispersion of quotes	5.40	5.31	6.90	6.07	2.26	2.32

Table 5. Summary statistics of the constructed portfolios using the four liquidity indicators. **P. 1** (resp. **P. 2**) indicates portfolio 1 (resp. 2). **Maturity** is the average time to maturity in years. **Rating** is the average credit worthiness, measured on the following scale: 1=AAA 2=AA, 3=A, etc.

IV.D Issued Amount

The liquidity indicator issued amount is used to construct two bond portfolios; portfolio 1 containing the bonds with the largest issued amount and portfolio 2 with the smallest issued amount, both in euros. We expect that the relationship between issued amount and liquidity is positive: a larger issued amount should result in greater liquidity. Thus, the excess yield should be lower for larger issues.

The regression results using equation (1) are shown in Table 6. All estimated parameters in this table are highly significant. We observe that the slope and credit coefficients of portfolio 1 are larger than those of portfolio 2. This reflects the findings of Table 5 that portfolio 1 has, on average, a larger maturity and a lower credit rating. Further, we find that the intercept of portfolio 1 is slightly smaller than the intercept of portfolio 2. This confirms the hypothesized relation between issued amount and liquidity. The difference between the intercepts of only 0.2 bps is the average liquidity premium between small and large issues. The F-test shows that the hypothesis that both intercepts are equal to zero can always be rejected, as indicated by the p-value of 0.00. This means that the liquidity indicator issued amount does determine the excess yield of the constructed portfolios and a pricing anomaly exists.

Portfolio	**Intercept**	**Slope**	**Credit**
Portfolio 1	-0.0893 (4.90)	0.946 (86.2)	0.354 (27.1)
Portfolio 2	-0.0867 (4.33)	0.856 (70.9)	0.316 (22.0)
$F\,(\alpha_1{=}\alpha_2{=}0)$	10.3 (0.00)		
R^2	97.1%		

Table 6. Regression results for the liquidity indicator issued amount for the first regression model.

Next, the two portfolios are used in regression model (2). Table 7 displays the results. The slope and credit parameters are statistically significant and show the same relative coefficients as in Table 6. Liquidity coefficient δ has a negative value, which is in line with our expectations, but is insignificant. The null hypothesis that α and δ are jointly equal to zero should be rejected.

In short, we see that the portfolios that are constructed using the liquidity indicator issued amount generate statistically significant intercepts, and the liquidity parameter has the right sign according to our expectations. Also, the APT should be rejected for both

Portfolio	Slope	Credit
Portfolio 1	0.963 (77.1)	0.374 (25.2)
Portfolio 2	0.836 (60.9)	0.293 (18.0)
Intercept α	-0.0857 (6.35)	
Liquidity δ	-0.111 (1.87)	
$F\,(\alpha{=}\delta{=}0)$	12.3 (0.00)	
R^2	97.1%	

Table 7. Regression results for the liquidity indicator issued amount for the second regression model.

model (1) and (2). The liquidity premium is negligible though (only 0.2 bps), so that the indicator issued amount has limited practical implications.

IV.E Age

For the liquidity indicator age, portfolio 1 contains the bonds with an age of 4 months and portfolio 2 with an age of at least 4 months. We expect that the relationship between age and liquidity is negative; a higher age results in lower liquidity.

The regression results from equation (1) are given in Table 8. All coefficients are significantly different from zero. The ordering of the slope coefficients corresponds to the average maturities from Table 5, but the ordering of the credit coefficients is not in line with Table 5. The intercept coefficients correspond with our expectations. Their size implies a mean liquidity premium of 14 bps of old bonds over young bonds. The null hypothesis of zero intercepts can always be rejected as the p-value is equal to 0.00.

Portfolio	Intercept	Slope	Credit
Portfolio 1	-0.414 (16.5)	1.20 (78.9)	0.615 (27.0)
Portfolio 2	-0.273 (8.42)	1.00 (50.8)	0.617 (21.0)
$F\,(\alpha_1{=}\alpha_2{=}0)$	89.9 (0.00)		
R^2	96.5%		

Table 8. Regression results for the liquidity indicator age for the first regression model.

Table 9 shows the results from estimating equation (2). Again the relative slope coefficient are in line with the expectations from Table 5, however this does not apply for the credit coefficients. The other results are intuitive, since the liquidity parameter has a positive sign. Also the intercept and liquidity coefficients are jointly statistically significant.

Portfolio	**Slope**	**Credit**
Portfolio 1	1.18 (89.8)	0.578 (29.6)
Portfolio 2	1.04 (64.3)	0.669 (28.2)
Intercept α	-0.353 (17.3)	
Liquidity δ	0.0147 (1.60)	
$F\,(\alpha{=}\delta{=}0)$	86.0 (0.00)	
R^2	96.5%	

Table 9. Regression results for the liquidity indicator age for the second regression model.

Summarizing, the liquidity indicator age gives intuitive results. Equation (1) generates correctly ordered intercepts and equation (2) shows a liquidity indicator coefficient with a sign corresponding to our expectations. Moreover, these results are statistically significant. A liquidity premium between young and old bonds exists and equals 14 bps.

IV.F Number of Quotes

The liquidity indicator number of quotes is used to construct two bond portfolios: portfolio 1 contains the bonds with the largest number of quotes and portfolio 2 has the bonds with the smallest number of quotes. We expect that a larger number of quotes increases liquidity and lowers excess yields.

Table 10 shows the regression results for the intercept, slope and credit coefficients. From Table 5, we expect that the slope and credit coefficients of portfolio 1 are larger than of portfolio 2, which is indeed the case. Moreover, the construction of the two portfolios implies a lower intercept of portfolio 1 compared to portfolio 2, because the number of quotes is larger in portfolio 1. The table also confirms this expectation and shows an average excess yield of 27 bps of portfolio 2 over portfolio 1. The null hypothesis is strongly rejected with a p-value of 0.00.

Portfolio	**Intercept**	**Slope**	**Credit**
Portfolio 1	-0.226 (11.4)	0.986 (82.5)	0.421 (29.6)
Portfolio 2	0.0492 (2.32)	0.821 (64.1)	0.253 (16.6)
$F\,(\alpha_1{=}\alpha_2{=}0)$	31.4 (0.00)		
R^2	96.6%		

Table 10. Regression results for the liquidity indicator number of quotes for the first regression model.

The regression is also run using equation (2). The results of this regression are given in Table 11. Both slope and credit coefficients are not in line with Table 5. Moreover the liquidity variable has a positive and significant sign. This positive sign is in contrast with our hypothesis. However, the null hypothesis can be rejected for all confidence levels.

Portfolio	**Slope**	**Credit**
Portfolio 1	0.901 (96.4)	0.320 (26.6)
Portfolio 2	0.909 (97.2)	0.357 (29.6)
Intercept α	-0.0912 (6.07)	
Liquidity δ	0.00141 (2.61)	
$F\,(\alpha{=}\delta{=}0)$	10.3 (0.00)	
R^2	96.4%	

Table 11. Regression results for the liquidity indicator number of quotes for the second regression model.

In conclusion, the number of quotes liquidity indicator leads to a rejection of the APT model for both model (1) and (2) . We find the expected ordering of the intercepts, but an unexpected sign for the liquidity variable. A substantial liquidity premium of 27 bps exists between bonds with a small and a large number of quotes.

IV.G Dispersion of Quotes

Finally, the quote dispersion variable from equation (3) is used to construct two bond portfolios. Portfolio 1 has the bonds with the lowest dispersion and portfolio 2 contains the bonds with the highest dispersion. We expect the relationship between the dispersion of quotes and liquidity to be negative. Therefore, we expect a lower intercept coefficient of portfolio 1 compared to portfolio 2.

Table 12 confirms our expectations. The size of both intercepts implies a mean liquidity premium of 47 bps. Moreover, the intercepts are both individually significant, as indicated by their t-values, and jointly significant, as implied by the F-test. Therefore, pricing anomalies do exist according to these regression results. Only the slope coefficients show the expected ordering.

Portfolio	**Intercept**	**Slope**	**Credit**
Portfolio 1	-0.250 (11.1)	1.08 (79.9)	0.459 (28.6)
Portfolio 2	0.224 (9.52)	0.749 (52.9)	0.0494 (2.94)
$F\,(\alpha_1{=}\alpha_2{=}0)$	53.5 (0.00)		
R^2	96.7%		

Table 12. Regression results for the liquidity indicator dispersion of quotes for the first regression model.

The results for equation (2) are given in Table 13. Again the slope coefficients have the expected ordering. The liquidity parameter has the expected sign and is significant. Moreover, the null hypothesis is strongly rejected.

To summarize, the liquidity indicator dispersion of quotes confirms our expectations: it generates the anticipated intercept coefficients and the expected sign of the liquidity indicator parameter. Both regression models show significant pricing anomalies. The liquidity premium that arises from this indicator is an impressive 47 bps.

Portfolio	Slope	Credit
Portfolio 1	0.951 (87.0)	0.305 (22.9)
Portfolio 2	0.877 (80.5)	0.199 (15.0)
Intercept α	-0.00961 (0.553)	
Liquidity δ	0.00922 (4.61)	
$F\,(\alpha{=}\delta{=}0)$	5.50 (0.00)	
R^2	96.1%	

Table 13. Regression results for the liquidity indicator dispersion of quotes for the second regression model.

V Summary

We use the Brennan and Subrahmanyam (1996) methodology to test whether liquidity is priced in the euro-denominated corporate bond market. Yields are used to measure the bonds' expected returns. Four indirect indicators of bond liquidity are employed: issued amount, age, number of quotes and dispersion of quotes. For each liquidity indicator, we construct two mutually exclusive portfolios. The two time series of portfolio yields are subsequently used in a Fama and French (1993) regression model, which controls for differences in maturity and credit worthiness.

We first look at yield differences between bonds denominated in a legacy currency and in euros and find an impressive yield premium of 50 basis points (bps) of legacy over euro bonds. Because this premium dominates the effects of our four liquidity indicators, and given the gradual disappearance of legacy bonds from the market, we have removed the legacy bonds from our further analyses. Our results for the euro-denominated bonds show that liquidity plays an important role in the pricing of these bonds. The null hypothesis of no liquidity premium is always rejected. The size of the yield difference between liquid and illiquid euro-denominated bond portfolio depends on the used liquidity indicator. We obtain a small liquidity premium for the indicator issued amount of 0.2 bps, while the indicators age and number of quotes result in a larger difference of 14 and 27 bps respectively. The largest impact is found for the indicator quote dispersion with 47 bps.

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