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The Missing Piece of the Puzzle

Liquidity Premiums in Inflation-Indexed Markets

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The missing piece of the puzzle: Liquidity premiums in inflation-indexed markets

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Abstract

We show that in both index-linked bond markets and inflation swap markets liquidity is an important determinant of prices. We do so by means of an asset pricing model with a liquidity risk factor and asset-specific liquidity characteristics. This liquidity risk factor is based on the measures of Amihud (2002) and Roll (1984). The level of liquidity is proxied by asset-level characteristics such as age and amount issued. Using US data, we find strong evidence that the level of liquidity, in contrast to liquidity risk, affects yields on inflation-indexed bonds, whereas inflation swap yields include a liquidity risk premium. We also study liquidity effects in nominal bonds in a similar way, which allows us to study the apparent mispricing between indexed bonds, inflation swaps and nominal Treasuries (Fleckenstein et al (2013)). We find that liquidity premiums explain a substantial part of this mispricing.

Keywords: Liquidity premium, liquidity risk, TIPS, inflation swaps

JEL: C51, G12, G01, H63

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A substantial literature has studied liquidity effects in government bond markets. Several studies show that, at least for the US, nominal bonds are very liquid and thus exhibit only small liquidity premiums[1]. Much less is known about liquidity effects in the markets of inflation-indexed products, such as inflation-indexed bonds (TIPS) and inflation swaps. In this paper we perform a detailed study of liquidity effects in these markets.

Understanding these liquidity effects is important for several reasons. First, liquidity effects directly matter for the relative pricing of nominal and indexed bonds as well as the breakeven inflation rate implied by these prices. Similarly, liquidity effects in inflation swaps affect the inflation expectations that can be extracted from these swap prices. Finally, recent work by Fleckenstein et al. (2013) finds evidence for large mispricing of nominal bonds relative to a replicating strategy of indexed bonds and inflation swaps, and based on additional analyses they argue that this is due to mispricing of the indexed bonds. We assess whether part of this mispricing is due to liquidity premiums.

Our paper has two main contributions. The first contribution is that we show that in both index-linked bond markets and inflation swap markets liquidity is an important determinant of prices. We do so by estimating a model with both a liquidity risk factor and asset-specific liquidity characteristics. The use of a liquidity risk factor is inspired by Pastor and Stambaugh (2003) and Acharya and Pedersen (2005). To estimate the effect of liquidity risk, we measure an asset's exposure to our non-traded liquidity factor. In addition to this liquidity risk exposure, the level of liquidity is proxied by asset-level characteristics, following Krishnamurthy (2002) and Houweling et al (2003). We also study liquidity effects in nominal bonds in a similar way, so that in total we analyze liquidity premiums in three markets.

We conduct our analyses based on two alternative assumptions –we either propose the three markets being segmented, such that prices are independently determined, or integrated markets[2]. In our benchmark specification, corresponding to segmented markets, we find in the TIPS market the effect of illiquidity risk is dominated by asset characteristics such as age and the size of an issue, together carrying a sizeable premium of 32.68 basis points. This effect means that higher age and lower size together increase the yield of a TIPS issue, which translates into a lower price. Age and size are bond characteristics that capture liquidity of an issue as in Houweling et al (2003). They argue that the more time passes since issuance, the more likely an issue gets locked up in buy-and-hold investor portfolios, which decreases liquidity. On the other hand, larger bond issues tend to be more liquid. As for inflation swaps, we find that illiquidity risk is priced yet the premium and the implied economic effect, 1.65 basis points, is small. Finally, we find a small liquidity risk premium[3] in nominal

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[1] See for instance Krishnamurthy (2002), Longstaff (2004), among many others.

[2] Under the assumption of market segmentation, our estimates are bounded by the mathematics of factor models: the average of our market betas is one and that of the liquidity betas is zero by construction, whereas in the integrated case there are no such restrictions. Consequently, we define our benchmark results as that corresponding to the segmented case. This specification is more conservative and is also less prone to biased estimates due to omitted variables.

[3] The magnitude of our estimate is similar to the on-the-run spread of Krishnamurthy (2002), yet smaller than the premium estimated by Fontaine and Garcia (2012).

bond markets. These novel results are robust to the inclusion of various controls and to shifting to the proposition of integrated markets. Then results regarding TIPS and nominal Treasuries are akin to the benchmark case, while for swaps the price of illiquidity risk is negative and twice as large relative to the benchmark case, -3.41 basis points.

Our second main contribution is that we scrutinize whether the above diversity in exposure to liquidity and liquidity risk could explain the persistent difference in relative bond prices, as documented in Fleckenstein et al (2013). They show that there exist substantial price differences between a nominal Treasury bond and its synthetic counterpart - a swapped TIPS issue. We provide evidence that when controlling for liquidity, a large part of this apparent mispricing disappears.

By showing the importance of liquidity for the three markets we contribute to the long-standing literature on the effect of liquidity on asset prices (Amihud and Mendelson (1986), Amihud (2002), Bekaert et al (2007), Bongaerts et al (2011) among many others). More specifically, we follow the footsteps of Pastor and Stambaugh (2003) and Acharya and Pedersen (2005) to show that liquidity risk is priced and provide novel evidence for Treasury bonds and inflation swaps. Moreover we are also among the first ones to examine the effect of liquidity on inflation swaps, an important inflation derivative market (see e.g.: Chen et al (2005), Bongaerts et al (2011) and Tang and Yan (2012) on liquidity of other derivative markets, and Kerkhof (2005) and Fleming and Sporn (2012) on inflation swaps specifically).

The paper also contributes to the literature on inflation-indexed bond pricing; more specifically we enrich the strand of papers that tackles liquidity of TIPS. For instance, D'Amico, Kim and Wei (2008), Gürkaynak et al (2010), and Haubrich et al (2012) propose term structure models where they incorporate potential illiquidity of real bonds. Besides, Fleming (2003) and Fleming and Krishnan (2009, 2012) focus on the microstructure characteristics of TIPS. Others like Campbell, Pflueger and Viceira (2009), Christensen and Gillan (2011), Pflueger and Viceira (2011, 2013), Fleckenstein, Lustig and Longstaff (2013) and Fleckenstein (2013) specifically focus on the relative pricing of nominal and indexed Treasuries and the breakeven rate, which is the yield difference between these two securities. Our study deepens the understanding on this matter by examining the effect of both liquidity and liquidity risk of these securities. Our work is distinguished from prior literature by the empirical strategy that simultaneously examines the no-arbitrage relation between TIPS and nominal Treasures and the liquidity characteristics of constituent asset markets within the framework of a tradable strategy.

The approach of this paper is the closest related to Pflueger and Viceira (2013) and Fleckenstein et al (2013). Similarly to Pflueger and Viceira, we identify risk premiums[4] and liquidity effects in bond yields. Yet unlike their paper, we do not incorporate a time varying behavior of risk premiums and the consequent return predictability in our analysis, as our primary objective is to quantify the effect of liquidity and liquidity risk on expected returns

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[4] Like in Cochrane and Piazzesi (2002, 2005), Vayanos (2004), Buraschi and Jitsov (2005) among others.

of TIPS, nominal Treasuries and inflation swaps. We also aim to answer to what extent the mispricing, found by Fleckenstein et al (2013), is an artifact of liquidity premiums. We view our work as an extension of Fleckenstein et al (2013) and Fleckenstein (2013), as we investigate the same no-arbitrage relationship between nominal and indexed Treasuries. Fleckenstein et al. (2013) provide evidence that part of this mispricing is caused by slow moving capital (see Gromb and Vayanos (2002), Mitchell and Pulvino (2007), Brunnermeier and Pedersen (2009), Duffie (2010) and Ashcraft, Garleanu and Pedersen (2010)), while we show that market liquidity premiums are important to understand the price differences of indexed and nominal bonds.

In conclusion, our work differs from these abovementioned papers in four main aspects. First, unlike Pflueger and Viceira (2013) and Fleckenstein et al (2013), we estimate the effect of liquidity based on a factor model that allows us to differentiate between liquidity premiums stemming from level and risk effects. Second, our primary liquidity proxy, Amihud's (2002) ILLIQ measure does not rely on any implicit assumptions on the relative liquidity of nominal and indexed bonds, like in Pflueger and Viceira (2013) who assume nominal Treasuries to be perfectly liquid. In line with previous empirical evidence, we allow nominal Treasuries to also carry compensation for liquidity risk or a convenience yield (Krishnamurthy (2002), Longstaff (2004), Krishnamurthy and Vissing-Jorgensen (2010)). Third, we study the liquidity effects in inflation swap markets. And finally, we assess to what extent the mispricing between indexed and nominal can be explained by liquidity premiums.

Our data are an extended and updated version of Fleckenstein et al (2013): we include a larger cross-section of bond issues and longer span (July 2004 - December 2011). The data consist of maturity-matched indexed and nominal issues and zero coupon inflation swaps. We complement this data with input for liquidity proxies and additional controls from multiple sources[5].

To show that in both index-linked bond markets and inflation swap markets liquidity is an important determinant of prices, we estimate a model with both a liquidity risk factor and asset-specific liquidity characteristics. We define the risk factor as the surprise or unexpected illiquidity which is captured by the residual from an autoregressive process imposed on the illiquidity measure. This approach is similar to Acharya and Pedersen (2005), while we use Amihud's (2002) ILLIQ measure. To estimate the effect of liquidity risk, we measure an asset's exposure to our non-traded liquidity factor. We do this by following a two-stage Fama-MacBeth procedure in which we estimate market and liquidity betas from excess returns in the first stage. In the second stage we run repeated-cross sectional regressions of yields on these betas, the level of liquidity proxied by asset-level characteristics and additional controls. We estimate betas and risk loadings in each market separately and under the assumption of integrated or segmented markets. Given the liquidity measures at

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[5] Bloomberg, Datastream, Primary Dealer Historical Search database of the Federal Reserve of New York, Kenneth French's website and St. Louis Fed's FRED database

hand, we are able to measure the covariation of a security's return with the market liquidity, the same covariance as in Pastor and Stambaugh (2003).

We also study liquidity effects in nominal bonds in a similar way, which allows us to inspect the relative pricing of indexed and nominal Treasuries, following Fleckenstein et al (2013). The idea behind their TIPS-Treasury arbitrage is that an investor matches the maturities and payoffs of a nominal bond issue and its synthetic counterpart. The latter is essentially an inflation swapped-indexed bond, whose cash flows are converted to fix payments exactly matching those of a corresponding nominal bond. We incorporate the effect of liquidity by adjusting the yields of nominal and indexed Treasuries by the estimated premiums of the benchmark cases. We also include the effect of liquidity on inflation swap positions concerning every coupon payment within the strategy.

The remainder of the paper is organized as follows. Section I discusses the methodology of our study, whereas Section II describes the data and the constituent asset markets. In Section III we present our empirical results, and finally, Section IV concludes.

I. Is liquidity priced in indexed, nominal bond and in the inflation swap markets?

In this section we explain our empirical strategy to examine the effects of liquidity and liquidity risk on prices of nominal and indexed Treasuries alongside with inflation swaps. We base our empirical identification strategy on previous empirical findings: Amihud and Mendelson (1986) and Amihud (2002) show that average liquidity is priced on stock markets, both in the cross-section of stocks and over time. Pastor and Stambaugh (2003) find that return sensitivity to market liquidity is priced, whereas Acharya and Pedersen (2005) present a model that disentangles three sources of liquidity risk - each being priced in the market.

We aim to test the following relationship between excess returns and liquidity:

$$E\left(R_{i,t} - R_{f,t}\right) = E\left(Liq_{i,t}\right) + \lambda_{LIQ}\beta_{LIQ,i} + \lambda_{MKT}\beta_{MKT,i} \tag{1}$$

Where $E\left(Liq_{i,t}\right)$ is the unconditional expectation of the liquidity measure corresponding to asset i at time t, that aims to capture the level of liquidity of that asset. Furthermore β_{LIQi} is the measure of an asset's exposure to marketwide illiquidity risk, proxied by a non-traded risk factor η_t. Likewise, β_{MKTi} captures the covariance between returns of an asset and the market. λ_{LIQ} and λ_{MKT} are the marketwide prices of exposure to liquidity and market risks, respectively.

We examine the above relation by estimating the two-step procedure defined in Equations 2 and 3 in the time series of asset returns and in the cross-section of yields, respectively:

$$\mathrm{R}_{\mathrm{i},\mathrm{t}} - \mathrm{R}_{\mathrm{f,t}} = \alpha_i + \beta_{MKT,i}(R_{MKT,t} - \mathrm{R}_{\mathrm{f,t}}) + \beta_{LIQ,i}\eta_t + \varepsilon_{i,t}, \quad for\ t = 1,2 \ldots \mathrm{T\ for\ each\ i} \tag{2}$$

$$\mathrm{Y}_{\mathrm{i},\mathrm{t}} - \mathrm{Y}_{\mathrm{f,t}} = \gamma_t + \kappa_t Liq_{i,t} + \hat{\beta}_{MKT,i}\lambda_{MKT,t} + \hat{\beta}_{LIQ,i}\lambda_{LIQ,t} + \upsilon_{i,t}, \quad for\ i = 1,2 \ldots \mathrm{N\ for\ each\ t} \tag{3}$$

That is excess returns on an asset are driven by our market and liquidity factors, whereas excess yield can be explained by the level of liquidity as well as by exposure to the market and liquidity risk premiums. Note, that the liquidity beta in our model corresponds to commonality in liquidity in the Pastor and Stambaugh (2003) sense:

$$\beta_{LIQ,i} = \frac{Cov(\eta_t \ ,\mathrm{R}_{\mathrm{i}\ ,\mathrm{t}})}{Var(\mu_t)} \tag{4}$$

The above beta captures the covariance between individual asset return and the marketwide liquidity factor. This relationship implies that the more illiquid the market is, the higher return investors would prefer.

To estimate the relationship described by Equations 1-3, we apply the following five steps:

1. We calculate monthly asset and market returns for each asset in all three markets.
2. We define both asset and market level liquidity proxies for each of the markets at a monthly granularity and describe additional controls.
3. We construct a non-traded liquidity factor by taking the residual from an imposed AR structure of the liquidity measure in our model.
4. We describe how we proxy expected returns
5. And finally we discuss in detail the estimation strategy: given the above theory we test this relationship by means of factor models. In these models we incorporate both the level and risk aspects of liquidity. For the latter we add a non-traded liquidity factor to our analysis to see whether the risk exposure to liquidity affects prices.

1. *Asset and market returns*

For bond markets one can apply the standard return definition based on the ratio of consecutive prices including a correction term when coupon payments occur[6]. However, calculating returns of zero investment products is nontrivial. We define returns on inflation swaps in accordance with bond market conventions as the change in the swap rate from one period to the other multiplied by the duration of the contract. We calculate duration as that of a bond, which has a coupon rate that equals the swap's yield and maturity of the swap contract[7] [8]:

$$\mathrm{R}_{\mathrm{swap,i,t}} = -\left(\mathrm{r}_{\mathrm{i,t}} - \mathrm{r}_{\mathrm{i,t-1}}\right) * \mathrm{Dur}_{\mathrm{swap,i,t}} \tag{5}$$

In addition to asset specific returns, we also construct market returns as equally weighted average returns, where we average over all available assets at a given point in time. This is similar to for instance Amihud (2002) and Chordia et al (2000), whereas Acharya and Pedersen (2005) also test their model on value-weighted average returns. In our sample

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[6] This correction applied at the coupon date is essentially identical to what one would do to adjust returns of a dividend paying stocks at dividend date.

[7] The minus of the quantity is taken to make the return definition resemble that of the convention for bonds.

[8] An alternative return proxy is the swap breakeven rate itself, which is a similar concept to breakeven inflation rate.

there is no variable based on which we could weigh swap contracts and issuance amount weighted bond return figures are virtually identical to the ones that we apply. Moreover, by equally weighting our assets, we can compensate for overrepresentation of larger thus potentially more liquid bond issues.

2. *Measures of liquidity and additional controls*

For our empirical analysis, we need to define both individual asset and market level liquidity proxies. Unfortunately in case of all three markets the data on the directly observable candidate, on the bid-ask spread, do not seem to be reliable over our sample period so we need to look for alternatives.

Given the limited data availability in this specific market, in order to capture swap market liquidity, we construct measures that can be derived from the above swap return definition. Therefore we propose the proportion of zero returns and the Roll measures as liquidity proxies. Similarly to Bekaert et al (2007), the proportion of zero returns over a given period is measured as the percentage of days with zero returns over a month. This measure is particularly useful for asset classes where data availability is limited, like for the case of inflation swaps. Our second swap liquidity proxy is based on Roll (1984). The Roll measure is derived from the autocovariance of returns, which captures the transitory component in observed prices. It is calculated as the scaled autocovariance for the case when it is strictly negative – otherwise the measure is truncated at zero[9].

$$Roll_{i,t} = \begin{cases} 2\sqrt{-cov(R_{i,t}, R_{i,t-1})} & cov(R_{i,t}, R_{i,t-1}) < 0 \\ 0 & otherwise \end{cases} \tag{6}$$

Measuring bond illiquidity also poses challenges, as many of the commonly applied measures, such as bid-ask spreads are unreliable, whereas the proportion of zero returns or the Roll measure are uninformative over our sample period[10]. Consequently we turn to certain asset characteristics that are linked to a security's liquidity.

Houweling et al (2003) propose issued amount and age of bond issues as such measures. The reasoning behind a bond's age being a proxy for liquidity is simple: the more time passes since issuance, the more likely that a bond gets locked-up in buy-and-hold investors' portfolios which decreases its liquidity. This suggests a positive relationship between illiquidity and age, whereas issued amount is negatively related to the latter: larger issues tend to be more liquid. We define age as the days since issuance, whereas we used the natural logarithm of the original issued amounts.

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[9] A convenient interpretation of the Roll measure is the implied bid-ask spread, which is the bid-ask spread that can be derived from the autocovariance of returns. However an important underlying assumption of the Roll measure's interpretation is that asset returns are identically and independently distributed over time.

[10] More specifically, over our sample period all bonds are traded on a daily basis, thus the proportion of zero returns does not provide us with either cross-sectional or time series variation As for the Roll measure, the basic assumption of i.i.d. returns is not fulfilled because bond returns have positive autocorrelation in the sample.

In the spirit of Krishnamurthy (2002), we also include an indicator variable, that equals 1 if the given issue is on-the-run – meaning that it is the latest issued security of its tenor – and zero otherwise. It can be concluded from the issuance calendars that TIPS are issued on an annual basis, whereas the cycle for nominal bonds is six month, thus the dummies are set accordingly. Based on the idea that new issues are more liquid as previous ones therefore carry smaller liquidity premium if at all, we expect the sign of this variable to be negative.

In addition to the previous liquidity proxies, we construct additional controls that we include in our analysis, such as yield volatility or a control for the slope of term structure of bonds. Yield volatility is defined as the difference between the standard deviations of individual issues and the cross-sectional average standard deviation of quoted yields, where the average is taken over the different maturities for a given month. This definition is the same across both swaps and bonds[11]. For bonds we also include time-to-maturity, which is defined as the days until maturity of a given issue. This variable is supposed to control for the linear maturity structure of bonds and incorporate the slope effect of the term structure.

3. *Non-traded illiquidity factor and its construction*

To answer whether liquidity risk is priced in our markets of interest, we turn to specifying marketwide liquidity proxies. These measures are calculated on a monthly frequency.

By means of the aggregate volume data[12] on primary dealer bond transactions, it is a natural choice to construct Amihud's (2002) ILLIQ measure. We define the measure as a ratio of weekly absolute bond market returns over weekly aggregate trading volume, where the volume is aggregated across all dealers and all securities within their class. As most of our variables are at a monthly frequency, we smooth this variable by taking its average over the four observations in a given month.

We use the ILLIQ measure to construct the illiquidity factor in our benchmark analysis, but in the robustness checks we incorporate two alternative measures. In the first case (BOND_PC), we take the first principal component of the ILLIQ measures corresponding to TIPS, all nominal Treasuries and to 10-year nominal bonds. Our second alternative measure (ALL_PC) aims to capture a wider definition of liquidity and investor sentiment, by incorporating all bond ILLIQ measures, the TED spread, alongside with the VIX index and the average Roll measure across all swap maturities for a given month. For the swap market we simply apply either the average Roll measure as defined previously or the ALL_PC measure.

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[11] A bond's yield volatility could also serve as a proxy for liquidity, since it functions as a measure of yield uncertainty. In case of more volatile yields, investors and especially market makers are uncertain of the bond's value, which increases bid-ask spreads and therefore leads to lower liquidity. On the other hand, volatility is likely to be correlated with potentially omitted factors in our models, thus we decided to include it in our regressions to partially control for those factors. Note that this makes it more difficult for our liquidity affects to survive.

[12] Volume figures on primary dealer transactions can be accessed via the Federal Reserve of New York, where they provide information on primary dealer transactions and holdings that are reported on a weekly frequency. The published figures are aggregated over all primary dealers for a given security class and week.

To examine the effect of liquidity on asset prices, we construct a factor that captures marketwide liquidity risk. In unreported regressions we show that our liquidity measures are persistent, thus we can define this risk as the surprise or unexpected liquidity, which is the difference between expected and realized liquidity. Thus for the aforementioned marketwide liquidity measures we define the non-traded risk factor the following way:

$$\eta_t = LIQ_t - E_{t-1}[LIQ_t] \tag{7}$$

To compute these innovations, we impose an autoregressive structure for the liquidity measures, similarly to Acharya and Pedersen (2005). To determine the number of lags included in these models, we require the residual or unexpected liquidity to behave as white noise. Consequently, we propose an AR(3) structure for the ILLIQ measure, and AR(1) for the average Roll measure and for the principal components BOND_PC and ALL_PC.

4. *Measuring expected returns*

We should point out that our estimation strategy differs from the standard asset pricing approach in two aspects. First, we run our tests not on pre-sorted portfolios but on individual assets to be able to take advantage of the larger cross-sectional variation. This approach is inspired by Ang et al (2010). Second, in asset pricing tests, one usually proxies expected returns with their realized historical counterparts. However, in our case returns seem to be too noisy, thus we turn to yields, which under a special set of assumptions[13] can be viewed as a forward-looking proxy for expected returns. This approach is similar to Pflueger and Viceira (2013) as they also look at yields to identify liquidity premium in TIPS prices.

These assumptions vary across our three assets. In general, we have to assume that markets are frictionless and that the term structure of expected returns is flat. For nominal bonds this relationship holds if we assume that yields follow a random walk process. For TIPS, in addition to the previous assumption we need that inflation is constant in expectation and it is independently and identically distributed with yields. For swap one would ideally show that the swap rate equals the breakeven rate. In frictionless markets the breakeven inflation rate does not contain any inherent risk premiums, thus it can be proxied by the difference of nominal and real yields. Then the difference between two random walk processes of these yields would also follows random walk dynamics.

5. *Estimation strategy*

In this section we study how liquidity can affect expected returns. For that we estimate the marketwide premiums on market and liquidity factors as well as on our liquidity proxies.

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[13] Later we are planning to incorporate an appendix where these assumptions are derived from stylized models for each market.

In light of existing evidence on liquidity being priced in sovereign bond markets (Krishnamurthy, 2002, Goyenko et al 2011, Fleckenstein et al, 2013, Pflueger and Viceira, 2013 among many others), the purpose of this section is to show whether liquidity risk carries a premium in Treasury bonds. In addition, we also want to discover the aforementioned question in the context of the inflation swap market. So far no empirical evidence has been published on the relationship between inflation swaps and liquidity, despite the anecdotal evidence[14] on the market not being perfectly liquid at all times.

We approach the above question by following a two-stage Fama-MacBeth procedure in which we estimate market and liquidity betas from excess returns in the first stage, whereas in the second stage we run repeated-cross sectional regressions of yields on these betas and additional controls. We estimate betas and risk loadings in each market separately. Given the liquidity measures at hand, we are able to measure the covariation of a security's return with the market liquidity, as shown in Equation 4. This covariance suggests that market liquidity affect required returns positively, such that the more illiquid a market is, the higher returns investors expect which decreases the asset's price.

In the first stage we run the following time series OLS regressions to obtain the betas:

$$\mathrm{R}_{\mathrm{i},\mathrm{t}} - \mathrm{R}_{\mathrm{f,t}} = \alpha_i + \beta_{MKT,i}(R_{MKT,t} - \mathrm{R}_{\mathrm{f,t}}) + \beta_{LIQ,i}\eta_t + \varepsilon_{i,t}, \quad for\ t = 1, 2 \ldots \mathrm{T\ for\ each\ i} \tag{8}$$

Where we include excess market returns and unexpected liquidity, which is the residual from the AR process discussed above.

In the second stage we run repeated cross-sectional regressions of yields on the betas estimated in the previous step, asset level liquidity proxies and additional controls, such as the volatility of yields. Estimates from the repeated regressions are averages across time and the errors include both a 12-lag Newey-West correction[15] and account for the averaging of the coefficients[16]:

$$\mathrm{Y}_{\mathrm{i},\mathrm{t}} - \mathrm{Y}_{\mathrm{f,t}} = \gamma_t + \kappa_t Liq_{i,t} + \hat{\beta}_{MKT,i}\lambda_{MKT,t} + \hat{\beta}_{LIQ,i}\lambda_{LIQ,t} + \upsilon_{i,t}, \quad for\ i = 1,2 \ldots \mathrm{N\ for\ each\ t} \tag{3}$$

As a result of this step we get estimates of the market price of liquidity and liquidity risk as well as each asset's individual exposure to this risk.

These models can be formulated based on two opposed propositions: either we assume that these markets are perfectly segmented and all forms of liquidity are priced separately on the three markets or we price liquidity risk in fully integrated markets. The difference between the two approaches is stemming from the consequent definition of the market. In the integrated case the market return is that equally weighted average of all asset that are in positive net supply: thus nominal and indexed bonds. Given the evidence that nominal bonds are the most liquid among our test assets, this method is likely to produce larger

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[14] See for instance Fleming and Sporn (2012).

[15] Later on, we are planning to incorporate a Shanken-type error correction that take into account the errors-in-variable problem, which is stemming from the fact that both our liquidity measures and the consecutive betas are pre-estimated. We might incorporate clustered errors too, where we would cluster by assets. See Petersen (2009).

[16] For the exact formula see p. 229 in Cochrane (2005).

liquidity effects for swaps and TIPS. On the other hand, in segmented markets, the average of market betas is one, whereas that of liquidity betas is zero by construction. As opposed to this, in the integrated case, our estimates are not bounded by the mathematics of factor models. We choose the segmented case to be our benchmark as these estimates are more conservative for the aforementioned reasons.

II. The data and the three markets

In this section, we describe in detail the data and the markets with evidence on liquidity issues for both nominal and indexed Treasuries and inflation swaps.

1. The data

The data consist of daily closing mid prices of TIPS and nominal Treasury bonds alongside with zero coupon inflation swap quotes. These data are obtained from Bloomberg and are similar to Fleckenstein et al (2013)[17] as they span most of the existing TIPS issues and only include a fraction of the long-term nominal Treasury market. The data contain maturity-matched[18] indexed and nominal issues[19], whose maturities range between 2007 and 2041. The daily closing bond prices are adjusted by accrued interest following the market convention. Moreover, our sample contains inflation swap quotes that are the constant rate on a fixed contract's leg. Following Fleckenstein et al (2013), we choose contracts with maturities ranging between 1 to 10, 12, 15, 20, 25 and 30 years. We apply the simplest approach to get intermediate (non-traded) maturities: we use a linear interpolation technique and include no correction for potential seasonal patterns in inflation[20]. We collect data for the US market from July 2004 to December 2011.

As our main purpose is to investigate the effect of liquidity on these three markets, we need to construct proxies for liquidity. Therefore we also gather information on the bonds' issue and maturity dates, the amount issued and their coupons. To formally test whether liquidity risk is priced we download additional controls from Bloomberg, such as the TED spread and the VIX index next to deriving measures from prices themselves. We complement these data with zero coupon yield curves that Datastream constructs from the par yield curve.

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[17] Our data are an extended and updated version of Fleckenstein et al (2013) as we include a larger cross-section of bond issues, as well as we have a longer time span. Moreover, we complement this data with input for liquidity proxies and additional controls as described below.

[18] For the exact procedure of maturity matching, see Fleckenstein et al (2013).

[19] The original sample consisted of 41 TIPS and 40 maturity-matched nominal issues. However, for the asset pricing test we decided to apply two filters: we omitted issues from the sample that had less than 24 months of data and also only kept observations up to six month before a bond's maturity. Interestingly both bonds after issuance and quotes preceding maturity are considerably more volatile than the rest of the sample and they resulted in extreme beta and premiums estimates.

[20] The inflation index based on which both the principal amount of TIPS and swap contracts are adjusted on a daily basis is CPI-U or CPI for All Urban Consumers.

To construct our benchmark liquidity proxy, we need volume figures on primary dealer transactions. These data can be accessed via the Primary Dealer Historical Search database of the Federal Reserve of New York, where they have information on primary dealer transactions and holdings that are reported on a weekly frequency. The published figures are aggregated over all primary dealers for a given security class and week.

Finally, to run the asset pricing tests we also obtain risk free rates from Kenneth French's website and risk free yield from St. Louis Fed's FRED database.

2. *Constituent asset markets*

In this section we provide a short description of the TIPS and inflation swap markets specifically focusing on market characteristics that could lead to illiquidity. We also contrast the liquidity features of the three markets under scrutiny based on prior empirical work.

a. *The TIPS market*

The first TIPS auction took place in 1997 and ever since the market gradually grew into one of the largest and most-actively traded fixed income markets in the world (Fleckenstein et al, 2013). As of the end of our sample period 41 individual TIPS issues have been auctioned on a regular cycle, with five-year, 10-year and 30-year maturities[21].

TIPS in most respects are similar to nominal Treasuries, the main difference being that the principal amount is adjusted on a daily basis to changes in CPI to All Urban Consumers[22]. This implies that semiannual coupons, that are a fixed percentage of the principal linked to changes in inflation, also vary over time. Another noteworthy feature of TIPS is the embedded deflation option, which protects investors from losses: in any case investors are entitled to the maximum of the final principal amount or its inflation-adjusted counterpart.

Despite the growing size of the market, an increasing number of studies have shown that TIPS carry a liquidity premium compared to their nominal counterparts of similar maturities (Fleckenstein et al, 2013; Pflueger and Viceira, 2013; Haubrich et al, 2012; Campbell et al, 2009). Moreover, we also know from those studies that liquidity carries a positive premium, as one would expect in a positive net supply market.

b. *The inflation swap market*

Kerkhof (2005) argues that the US zero-coupon inflation swap market has been a rapidly growing segment of the inflation derivatives market in the past decade as market participants began making markets to hedge their inflation risk exposures. However, the current size of the market is still about a couple of percent that of nominal interest rate

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[21] Previously TIPS with 20-year maturities were also issued by the Treasury.

[22] This is a non-seasonally adjusted inflation rate corresponding to urban consumers in the US.

swaps and is atomic compared to Treasury securities. In line with this, Fleming and Sporn (2012) report that there are relatively few trades occurring in this market.

An inflation swap is a bilateral derivative transaction in which one party agrees to swap a fixed payment to a floating one that is tied to inflation, for a given notional amount and period of time. Inflation swaps, similarly to TIPS, are also linked to CPI-U, and the fixed rate is negotiated in over-the-counter transactions that are traded in a dealer-based market (Fleming and Sporn, 2012). The most frequently traded inflation swap contracts are the zero coupon contracts, in which cash flows are only exchanged at the maturity of the contract.

So far only a handful of studies investigated the breakeven rate or its relationship with inflation swaps (Campbell et al, 2009, Gürkaynak et al, 2010, Christensen and Gillan, 2011, Pflueger and Viceira, 2013 and Fleckenstein et al, 2013), but as Fleming and Sporn (2012) point out empirical evidence on inflation swap liquidity is still lacking: no study ever considered modeling liquidity of this market. Despite that the size of the market and the fact that trades occur rarely suggest that liquidity is likely to have an effect on swap returns, we cannot predict its expected direction. Bongaerts et al (2011) show that a battery of factors, such as non-traded risk exposures in investors' portfolios, individual risk aversion liquidity's correlation with investors' hedging demands, determines the direction of liquidity's effect on markets that are in zero net supply (e.g.: derivative markets). Since these factors are unobservable, especially on the aggregate level, we cannot predict the expected sign of liquidity.

c. *The nominal Treasury market and liquidity*

In fact many claim the nominal Treasury bond market to be the most liquid and most frequently traded fixed-income market in the world and thus it is often taken as a reference point in investigating other securities' liquidity. Krishnamurthy (2002) uses the commercial paper-T-bill spread to capture changes in liquidity demand, whereas Longstaff (2004) applies the RefCorp-Treasury spread to capture flight-to-liquidity premium in economically distressed times. Pflueger and Viceira (2013) treat nominal Treasuries as perfectly liquid to quantify the premium inherent in TIPS returns and determine bond return predictability.

On the other hand, Krishnamurthy (2002) has shown that the liquidity of nominal bonds does vary significantly over the issuance cycle therefore liquidity premium can indeed be found in Treasury returns too. For this reason we also take a look at these bonds' liquidity.

Note that although our sample contains all available TIPS that are issued prior to December 30, 2011, it could contain significantly more nominal issues. This is because the data has been collected in the spirit of Fleckenstein et al (2013), such that it comprises of maturity-matched indexed and nominal bond pairs alongside with inflation swap contracts. Besides, we believe that our sample of bonds exhibits enough variation in liquidity features such that our results can be generalized to the entire population of long-maturity nominal Treasuries. In this case having a larger sample of bonds would only make our results stronger.

III. Empirical results

This section presents the result of estimating the two-stage model described in Section I. We first discuss the descriptives and our estimated betas from Equation 4, alongside with the properties of the liquidity factor. We proceed with showing our benchmark results for all three markets. Next, we also provide robustness tests including other liquidity measures or alternative assumptions regarding the relationship of our markets. And finally, we demonstrate how our results apply to the trading strategy described in Fleckenstein et al (2013).

1. Descriptives, betas and the illiquidity factor

Table I contains the descriptives of our liquidity proxies for all three markets in our sample, whereas Table II provides the distribution of the betas estimated in the first stage of our analysis. Table I reports all quantities but the ILLIQ measure and the on-the-run dummy in percentages and shows the main characteristics and the distribution of our liquidity measures. In the swap market the average yield is 2.47%. The relative yield volatility measure by construction equals to zero, but individual issues can significantly differ from the cross-sectional average. The Roll measure implies an average bid-ask spread of 24.5 basis points. On average 5.82% of the times we have zero returns on this market – this suggests no trading activity on average 1.8 days a month.

For TIPS the average yield is 74 basis points and yield volatility of individual issues varies in a wider range than for swaps. The age of the average bond in our sample is 4.38 years with average time to maturity of 9.12 years. The average issue size is $16.1 billion. The dummy variable shows that 12.67 % of the issues are on-the-run. We also present the ILLIQ measure[23], a price impact proxy in our sample.

In comparison, nominal Treasuries have higher yields, on average 1.58%, with lower relative yield volatility than TIPS or inflation swaps. These bonds are older, with the average age of 5.86 years with also somewhat longer time to maturity, 9.48 years. The average nominal issue is also larger than that of TIPS, with $21 billion. Only 4% of the issues are on the run, which is less than for TIPS[24].

Figure 1 depicts the time evolution of our non-traded liquidity factors that are residuals from autoregressive processes: AR(3) for ILLIQ measures concerning TIPS, and AR(1) for the nominal Treasury ILLIQ and the average Roll measure. The TIPS and nominal bond series are relatively highly correlated, with a correlation coefficient of 0.6131, whereas their correlation with the inflation swap market series is 0.1680 and 0.4133, respectively. Apparently the TIPS liquidity factor has larger swings and more spikes than the other two series, whereas the nominal bond and inflation swap factors shoot up during the recent

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[23] The ILLIQ measure is the absolute dollar change triggered by volume, however this number depends on rescaling.

[24] This is not surprising given that the nominal bond issuance cycle is half that of TIPS, thus 6 months.

financial crisis. Both time paths are in line with anecdotal evidence and previous empirical findings of illiquid periods in the corresponding markets.

For the sake of brevity[25] Table II focuses on the distribution of betas that we estimate from time-series regressions[26] of returns on the market excess return and the illiquidity factor Note that our market factor in this context is practically an interest rate risk or duration factor, which explains the patters in Figures 2-4. These graphs depict the betas sorted on average age of an issue for TIPS and nominal Treasuries and contract maturity for inflation swaps. We present result for both cases of integrated and segmented markets[27].

In the case of inflation swaps, when considered as a segmented market, we see that liquidity betas have a larger spread than market betas. Loadings on the market factor are all positive. In the integrated case, where we take market as the sum of the nominal and indexed bonds, our estimates change: the average market beta is still close to zero however certain issues load on the market factor with negative sign. We also see that the magnitude and the spread of liquidity betas substantially increase, whereas they always have a negative sign. The two panels of Figure 2 confirm these findings.

Figures 3 and 4 expose that in both the segmented and integrated cases TIPS and nominal bonds have strictly positive market betas, which vary in a narrower range than those of swaps. We observe a similar difference in range for segmented liquidity betas of TIPS. Ex ante we would expect TIPS prices to decrease if liquidity decreases. In contrast with expectations, when we assume markets are integrated, most TIPS issues load positively on our illiquidity factor, whereas nominal bonds tend to have negative and sizeable illiquidity betas.

2. *Benchmark results*

We estimate our benchmark models (i) under the assumption of market segmentation; (ii) using illiquidity factors derived from ILLIQ for bonds and average Roll measure for inflation swaps; (iii) for the period between July 2004 and December 2011. To define the baseline specification, we pick models that are significant yet parsimonious. Consequently for nominal Treasuries and inflation swaps we pick the model with the market and the illiquidity factors as our baseline specifications; whereas for TIPS, based on unreported univariate regressions, we extend the latter model with two characteristics: age and issued amount of a bond. We also include the economic effect of risk premiums in the last rows of the tables. To capture the impact of market and liquidity risks, we calculate the interquartile

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[25] After applying our data filters, we estimate market and liquidity betas for 15 swap, 31 TIPS and 32 nominal bonds. Thus given the large number of individual assets, in the table we focus on the distribution of our estimates.

[26] We conclude from unreported regressions, that market betas are highly significant in case of most assets, whereas the statistical significance of individual liquidity betas varies a lot.

[27] In segmented markets, the average of market betas is one, whereas that of liquidity betas is zero by construction. As opposed to this, in the integrated case, our estimates are not bounded by the mathematics of factor models.

spread: the estimated price of risk multiplied by the difference between the betas corresponding to the first and third quartile in the cross-section of betas. Parameter estimates of the benchmark cases can be found in the first columns of Tables III, V, and VII.

The first column of Table III presents the benchmark case for inflation swaps. Although there is no prior literature on inflation swap liquidity, anecdotal evidence from Fleming and Sporn (2012) suggest it may have an effect on swap yields. However, we cannot predict its expected direction as there are many factors[28] that determine how liquidity impacts markets that are in zero net supply. The key result that we find for inflation swaps is that both market and liquidity risks are priced on this market. The market price of liquidity risk is positive and it is statistically significant, nevertheless the implied economic impact is 1.65 basis points. This effect is small as is often the case in derivative markets. On the other hand, the economic impact of market risk is a sizeable 43.92 basis points.

Table V reports our benchmark case for TIPS. The growing literature[29] on TIPS illiquidity suggests TIPS prices to convey liquidity discount. Therefore we expect liquidity risk to be priced. As for the included characteristics, for age we expect a positive sign as the more time passes since issuance, the more likely an issue gets locked up in buy-and-hold investor portfolios, which increases illiquidity. On the other hand, larger bond issued tend to be more liquid, therefore the expected sign of size of an issue is negative. Our main finding is that for TIPS the effect of illiquidity risk is dominated by asset characteristics such as age and the size of an issue. While market risk is priced, illiquidity is both statistically and economically insignificant. Age of an issue is both statistically and economically important driver of TIPS liquidity, with an impact of 41.71 basis points. If a bond gets one year older, its yield will increase with 9.09 basis points, which implied a decrease in its price. Moreover, the size of an issue also matters – its effect is -9.03 basis points. Similarly to age, once a TIPS issue gets 1% larger, we expect its yield to decrease by 0.31 basis points, thus its price increases.

Turning to nominal Treasury notes and bonds, the benchmark case can be found in the first column of Table VII. In line with previous literature, we presume nominal bonds are more liquid than other securities – as in Krishnamurthy (2002), Longstaff (2004) or Pflueger and Viceira (2013), among many others. Our benchmark specification focuses on the two factors: market and illiquidity. Ex ante the sign of the illiquidity premium is not clear, as for instance Fontaine and Garcia (2012) find negative liquidity premium in nominal Treasuries which makes these securities good liquidity hedge in periods of flight-to-liquidity. We find that in the nominal Treasury market illiquidity risk is priced and carries a positive but fairly small premium of 13.13 basis points. At the same time, the economic effect of the market is substantial, with 183.22 basis points.

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[28] Bongaerts et al (2011) show that non-traded risk exposures in investors' portfolios, individual risk aversion liquidity's correlation with investors' hedging demands are such factors. Since these are unobservable especially on the aggregate level, we cannot predict the expected sign of liquidity.

[29] Including Campbell, Pflueger and Viceira (2009), Christensen and Gillan (2011), Pflueger and Viceira (2011, 2013), Haubrich et al (2012), Fleckenstein, Lustig and Longstaff (2013)

3. *Robustness Checks*

To check the robustness of our benchmark specifications we include additional controls, as well as test the effect of the assumption of integration. In unreported results we also construct and assess other liquidity factors alongside with splitting our period into subsamples[30].

Taking another look at Table III, we find that the aforementioned benchmark case seems to be robust to inclusion of asset characteristics and controls, such as the proportion of zero returns or the volatility of swap yields. In all cases the economic impacts of market and liquidity risk exposure do not change substantially either in sign or magnitude. In contrast, we also perform a similar analysis under the assumption of swap and bond markets being integrated. From Table IV we see that both the market and illiquidity betas are priced. These effects are also highly significant and robust to the inclusion of volatility. It is in line with our expectations that the sign corresponding to the price of illiquidity changes and the implied premium also doubles in size: it is between 18.2 and 34.1 basis points. The negative premium implies that the less liquid a swap issue is, the lower the price and thus the higher the expected return on and the yield of that asset is.

For TIPS we observe that age and the size of an issue matter more than liquidity risk. Other columns in Table V show accordingly. However, if we only include the market and the illiquidity factor, in column 2, liquidity risk seems to carry a significant and sizeable premium of -22.6 basis points, and this remains so after the inclusion of the on-the-run dummy, issued amount and yield volatility. Nevertheless, once age or time-to-maturity is included, these variables wipe out the factor's significance. Similarly to swaps, we repeat the analysis for integrated markets – Table VI contains the corresponding results. In general results do not change: the magnitude of the effects is both statistically and economically similar to the previous case. Therefore we conclude this market is not as sensitive to this assumption as inflation swaps.

Looking at nominal Treasuries, we show that the market and illiquidity premiums are robust to inclusion of asset level characteristics and controls. Interestingly age next to being significant in all specifications, has the wrong sign[31]. Our time-to-maturity control suggests the slope of the term structure to matter, besides other variables, such as the on-the-run dummy, issued amount and yield volatility, are never significant. In comparison if we take the integrated market case in Table VIII, the characteristics and controls seem to carry a more important role. The market and illiquidity factors are highly significant with similar premiums estimates as under market segmentation assumption. Age still has the wrong sign, but now the size and yield volatility of an issue are significant determinants of yields.

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[30] We are planning to incorporate these analyses in later versions.

[31] We suspect that age might have a nonlinear relationship with yields; therefore in the future we are planning to examine such effects.

4. *Is it really liquidity?: The relative pricing of indexed and nominal Treasuries*

In this section, we apply the result of the previous section to look at the effect of liquidity on the relative pricing of nominal and indexed Treasuries that we inspect by the means of Fleckenstein et al's (2013) trading strategy[32]. The idea behind their TIPS-Treasury arbitrage is simple: an investor matches the maturities and payoffs of a nominal bond issue and its synthetic counterpart. The latter is essentially an inflation swapped-indexed bond, whose cash flows are converted to fix payments exactly matching that of the corresponding nominal bond.

To replicate this strategy, an investor should buy a TIPS issue and short a nominal bond at the same time. Additionally, she needs to execute a zero-coupon inflation swap contract with the same maturity and notional amount as the TIPS coupon – and repeat this for each coupon and for the principal amount, which results in the execution of an entire swap portfolio. The rationale for swapping the bond is that the sum of the two cash flows is constant and equal to the nominal coupon or principal. The investor also needs to take a small position in Treasury STRIPS[33] due to the disparity in the nominal and TIPS coupon payments. Based on this logic the investor applies these steps to all coupon payments, which results in the successful conversion of the TIPS variable cash flow stream to the fixed one of the corresponding nominal bond.

In sum, the investor would short sell the nominal bond, buy the TIPS issue and hold portfolios of zero-coupon inflation swap contracts and Treasury principal STRIPS. The latter three components exactly replicate the fixed periodic coupons and the principal of the nominal bond. Finally, to determine the mispricing, we first price the synthetic bond by calculating the yield to maturity and then the price of the replicating portfolio[34]. Thus, if the resulting prices of the nominal bond and the replicating portfolio differ, a potential arbitrage opportunity arises.

To incorporate the direct effect of liquidity, we adjust the yields of nominal and indexed Treasuries by the estimated premiums of the benchmark cases. We also include the effect of liquidity on inflation swap positions concerning every coupon payment within the strategy. To take account of the liquidity-adjustment in swap contracts[35], we calculate the difference

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[32] A minor change we apply to Fleckenstein et al (2013) is that when we calculate the mispricing, instead of the ones with accrued interest, we apply clean prices. The reason is that the coupon date of most bond issues on our sample coincide, therefore the mispricing based on dirty prices has a jagged pattern, representing the average accrued interest at a given point in time. To circumvent this problem, we use clean prices.

[33] We are aware that STRIPS might also be exposed to liquidity issues (see for instance Daves and Ehrhardt, 1993, Jordan et al, 2000), however Bühler and Vonhoff finds that principal STRIPS are less affected. As the trading strategy presented in this paper uses principal STRIPS, we are less concerned that small positions taken in these assets would carry a sizeable liquidity premium that could distort our current results. A potentially negative premium, which is in line with previous findings, would only work in our favor by reducing the mispricing.

[34] Practically we also need to adjust the price of the nominal bond for the potential maturity mismatch between the two securities.

[35] As the strategy consists of zero coupon inflation swaps, we only need to apply this formula once, corresponding to the maturity o the underlying swap contract.

between the fixed and the floating cash flows of the inflation swap contract by the following formula:

$$Value_{swap,t} = n * \hat{\beta}_{LIQ,swap}\lambda_{LIQ} * \frac{s*(1+y_{swap,n,t})^n}{(1+y_{zc,n,t})^n} \qquad (9)$$

That is the value of the liquidity corrected position is the estimated price of liquidity for a given swap contract, $\hat{\beta}_{LIQ,swap}\lambda_{\mathrm{LIQ}}$, multiplied by the swapped TIPS coupon (s) discounted by the appropriate rate from a nominal zero-coupon yield curve, where $(1 + \mathrm{y}_{\mathrm{swap,n,t}})^{\mathrm{n}}$ is the forward of the contract with n years maturity[36] and $(1 + y_{zc,n,t})^n$ is that of a zero-coupon bond with the same maturity. $y_{swap,n,t}$ is the quoted swap yield of an n-maturity contract at time t, whereas $y_{zc,n,t}$ is the nominal zero-coupon yield of the same maturity at the same point in time.

The result of the liquidity correction of the mispricing can be found in Figure 5 and Table IX. Figure 5 compares the replicated mispricing of Fleckenstein et al (2013) and its adjusted counterparts under the assumptions of segmented and integrated markets. Our key result is that once we take out the estimated liquidity premiums from prices, the mispricing shrinks considerably, if not disappears. This is in accordance with our expectations and the results from previous sections. The shrinkage of price difference is true for both specifications, although the effect of our liquidity adjustment is larger for the segmented market case. Table IX confirms these findings: whereas all values regarding the replicated series are positive, the corrected series based on market segmentation are mostly negative. We also define the difference between the mispricing series, as the difference between the original strategy and our corrected version. We find that this disparity is always positive and often times considerable in magnitude, especially in proportion to the uncorrected series.

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[36] For non-traded and fractional maturities we apply linear interpolation to get the forward rate, as well as the liquidity premium.

IV. *Conclusion*

We show that in both index-linked bond markets and inflation swap markets liquidity is an important determinant of prices. We do so by estimating a model with both a liquidity risk factor and asset-specific liquidity characteristics. To estimate the effect of liquidity risk, we measure an asset's exposure to our non-traded liquidity factor. In addition to this liquidity risk exposure, the level of liquidity is proxied by asset-level characteristics. We also study liquidity effects in nominal bonds in a similar way, so that in total we analyze liquidity premiums in three markets. We conduct our analyses based on two alternative assumptions – we either propose the three markets being segmented, such that prices are independently determined, or integrated markets.

Additionally, we also scrutinize whether the exposure to liquidity and liquidity risk could explain the persistent difference in relative bond prices, as documented in Fleckenstein et al (2013). They show that there exist substantial price differences between a nominal Treasury bond and its synthetic counterpart - a swapped TIPS issue. We provide evidence that when controlling for liquidity, a large part of this apparent mispricing disappears.

Yet on the empirical side several extensions of the paper are possible and considered. In important question to be addressed is whether our liquidity proxies are affected by unconventional monetary policy actions, like quantitative easing during the crisis, as studied by Christensen and Gillan (2013) or D'Amico and King (2013). Some other issues also remain to be solved. For instance, we are planning to add a stylized model that justifies our use of yields as a proxy of expected returns. We also want to incorporate more robustness checks regarding other liquidity factors and dividing our data into subsamples where premiums are separately estimates. One could also consider incorporating time-varying risk premiums.

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Table I
Descriptive statistics: swap and bond markets

The table presents descriptive statistics for variables used in our two-stage estimation. Panel A present variables for the analysis of inflation swap markets, whereas Panel B and C show those for TIPS and nominal Treasuries, respectively. Swap yields are quoted breakeven rates of a swap contracts, whereas yield volatility is defined as the difference between the standard deviations of individual issues and the cross-sectional average standard deviation of quoted yields. The Roll measure is the scaled autocovariance of inflation swap returns while the proportion of zero returns is measured as the percentage of days with zero returns over a month. Age and time-to-maturity are defined relative to the issue and maturity dates, respectively. The on-the-run dummy is an indicator variable, that equals 1 if the given issue is the latest issued security of its tenor and zero otherwise. ILLIQ is the monthly average ratio of weekly absolute bond market returns over weekly aggregate trading volume. Yields, volatilities, the Roll and the zero returns measures are in percentages, age and time-to-maturity are measured in years. The data correspond to the sample period between July 2004 and December 2011.

Panel A: Descriptive statistics of inflation swap markets

	Mean	St. Dev.	Min	p25	p75	Max
Swap yield	2.47	0.71	-3.83	2.33	2.87	3.41
Yield volatility	0.00	0.06	-0.35	-0.02	0.01	1.14
Roll measure	0.25	0.43	0.00	0	0.31	5.58
Proportion of zeros	5.82	13.63	0	0	5	100
Average Roll m.	0.25	0.24	0.00	0.09	0.36	1.92

Panel B: Descriptive statistics of TIPS

	Mean	St. Dev.	Min	p25	p75	Max
TIPS yield	0.07	1.67	-3.02	-1.26	1.34	7.47
Age	4.38	3.00	0	1.95	6.54	13.72
Time-to-maturity	9.12	6.93	16	3.80	15.48	27.73
Issued amount	23.50	0.39	22.34	23.43	23.72	24.06
Yield volatility	0.00	0.07	-0.42	-0.02	0.01	1.08
On-the-run	0.13	0.33	0	0	0	1
ILLIQ	1.51	0.45	0.87	1.19	1.77	2.91

Panel C: Descriptive statistics of nominal Treasuries

	Mean	St. Dev.	Min	p25	p75	Max
Nominal yield	1.58	1.31	-0.67	0.46	2.59	4.51
Age	5.86	3.98	0	2.50	8.63	16.88
Time-to-maturity	9.48	7.10	0.13	3.90	16.56	26.56
Issued amount	23.77	0.42	23.07	23.43	24.06	24.92
Yield volatility	0.00	0.03	-0.17	-0.01	0.01	0.23
On-the-run	0.05	0.21	0	0	0	1
ILLIQ	2.38	0.55	1.55	2.01	2.56	5.22

Table II
Beta estimates

The table presents descriptive statistics for betas estimated from the time-series regression of asset returns on market and non-traded illiquidity factors. Panel A present variables for the analysis of inflation swap markets, whereas Panel B and C show those for TIPS and nominal Treasuries, respectively. We estimate market and illiquidity betas for 15 swaps, 31 TIPS and 32 nominal Treasury issues in our sample that spans the period between July 2004 and December 2011.

Panel A: Inflation swap market

	Mean	St. Dev.	Min	p25	p75	Max
Segmented market β	1.00	0.57	0.22	0.57	1.40	2.18
Segmented illiquidity β	0.00	1.50	-4.14	-0.29	0.68	2.95
Integrated market β	0.02	0.26	-0.43	-0.27	0.24	0.43
Integrated illiquidity β	-4.09	3.09	-12.78	-5.59	-2.37	-0.30

Panel B: TIPS market

	Mean	St. Dev.	Min	p25	p75	Max
Segmented market β	0.96	0.45	0.29	0.53	1.42	1.92
Segmented illiquidity β	0.01	0.39	-0.90	-0.26	0.35	0.47
Integrated market β	0.99	0.59	0.16	0.46	1.61	2.04
Integrated illiquidity β	0.46	0.44	-0.68	0.06	0.73	1.17

Panel C: Nominal Treasury market

	Mean	St. Dev.	Min	p25	p75	Max
Segmented market β	0.96	0.57	0.17	0.39	1.66	1.90
Segmented illiquidity β	-0.07	0.25	-0.67	-0.16	0.10	0.51
Integrated market β	0.95	0.56	0.19	0.37	1.66	1.85
Integrated illiquidity β	-0.37	0.37	-1.21	-0.65	-0.12	0.50

Table III

Monthly swap yields and illiquidity - Segmented market case in the full sample

The table reports estimates for the second step (Equation 5) of the Fama-MacBeth procedure under the assumption of markets being segmented. The dependent variable is the inflation swap yield. Market and illiquidity betas are estimated based on Equation 4 as loadings on the market and non-traded illiquidity factors. The Roll measure is calculated as the scaled autocovariance of returns for the case when it is strictly negative – otherwise the measure is truncated at zero. The proportion of zero returns is measured as the percentage of days with zero returns over a month, whereas (lagged) yield volatility is defined as the difference between the standard deviations of individual issues and the cross-sectional average standard deviation of quoted yields, where the average is take over the different maturities for a given month. Displayed coefficients are average figures from monthly repeated cross-sectional regressions where errors take into account the averaging and include a 12-lag Newey-West correction. Calculated economic impact is defined as the interquartile spread - coefficient times the difference between the betas that correspond to the first and third quartile in the cross-section of betas. The sample period is July 2004 until December 2011. t-statistics are given in parentheses and significance is denoted by asterisk.

	Benchmark	**2**	**3**	**4**	**5**	**6**
Market beta	0.5338	0.4269	0.5796	0.5330	0.4518	0.4466
	(3.91)***	(4.38)***	(3.25)***	(3.77)***	(3.93)***	(3.80)***
Illiquidity beta	0.0171	0.0092	0.0048	0.0226	0.0056	0.0106
	(2.18)**	(2.21)**	(1.06)	(1.91)*	(1.67)*	(1.96)*
Yield volatility$_{t-1}$		-2.0809			-1.7160	-1.5542
		(1.78)*			(-1.62)	(-1.64)
Roll measure			-0.1647		0.0516	0.0588
			(-0.86)		(0.65)	(0.79)
Proportion of zero returns				-0.0158		-0.0091
				(-1.46)		(1.67)*
Intercept	1.9402	2.0428	1.9189	1.9602	2.0200	2.0401
	(6.88)***	(8.63)***	(6.57)***	(7.03)***	(8.18)***	(8.27)***
Adj. R^2	0.67	0.85	0.71	0.68	0.86	0.87
Number of obs.	1350	1335	1350	1350	1335	1335
Impact of market risk	**0.4392**	**0.3512**	**0.4768**	**0.4385**	**0.3717**	**0.3674**
Impact of liquidity risk	**0.0165**	**0.0089**	**0.0046**	**0.0218**	**0.0053**	**0.0102**

* $p<0.1$; ** $p<0.05$; *** $p<0.01$

Table IV

Monthly swap yields and illiquidity - Integrated market case in the full sample

The table reports estimates for the second step (Equation 5) of the Fama-MacBeth procedure under the assumption of integrated markets. The dependent variable is the inflation swap yield. Market and illiquidity betas are estimated based on Equation 4 as loadings on the market and non-traded illiquidity factors. The Roll measure is calculated as the scaled autocovariance of returns for the case when it is strictly negative – otherwise the measure is truncated at zero. The proportion of zero returns is measured as the percentage of days with zero returns over a month, whereas (lagged) yield volatility is defined as the difference between the standard deviations of individual issues and the cross-sectional average standard deviation of quoted yields, where the average is take over the different maturities for a given month. Displayed coefficients are average figures from monthly repeated cross-sectional regressions where errors take into account the averaging and include a 12-lag Newey-West correction. Calculated economic impact is defined as the interquartile spread - coefficient times the difference between the betas that correspond to the first and third quartile in the cross-section of betas. The sample period is July 2004 until December 2011. t-statistics are given in parentheses and significance is denoted by asterisk.

	1	**2**	**3**	**4**	**5**	**6**
Market beta	0.4531	0.2626	0.4130	0.4729	0.2508	0.2674
	(2.44)**	(2.38)**	(2.38)**	(2.36)**	(2.40)**	(2.33)**
Illiquidity beta	-0.0662	-0.0462	-0.0621	-0.0607	-0.0402	-0.0353
	(5.03)***	(6.25)***	(4.23)***	(5.34)***	(5.39)***	(5.92)***
Yield volatility$_{t-1}$		-3.2833			-3.3298	-2.8924
		(2.65)***			(2.60)**	(2.82)***
Roll measure			-0.1200		0.3478	0.3463
			(-0.64)		(1.22)	(1.20)
Proportion of zero returns				-0.0051		-0.0084
				(-0.62)		(-1.40)
Intercept	2.1947	2.2759	2.1716	2.2202	2.2578	2.2978
	(10.85)***	(13.04)***	(10.41)***	(12.03)***	(12.52)***	(13.43)***
Adj. R^2	0.59	0.75	0.62	0.61	0.78	0.8
Number of obs.	1350	1335	1350	1350	1335	1335
Impact of market risk	**0.2330**	**0.1351**	**0.2124**	**0.2432**	**0.1290**	**0.1375**
Impact of liquidity risk	**-0.0341**	**-0.0238**	**-0.0319**	**-0.0312**	**-0.0207**	**-0.0182**

* $p<0.1$; ** $p<0.05$; *** $p<0.01$

Table V

Monthly TIPS yields and illiquidity - Segmented market case in the full sample

The table reports estimates for the second step (Equation 5) of the Fama-MacBeth procedure under the assumption of markets being segmented. This implies that the market return is the equally weighted average of indexed Treasuries. The dependent variable is the TIPS yield. Market and illiquidity betas are estimated based on Equation 4 as loadings on the market and the non-traded illiquidity factors. We define age as the years passed since issuance, and time-to-maturity as the years until maturity. The latter captures term structure effects. The on-the-run variable is a dummy that equals one of an issue is the newest of its tenor and zero otherwise. We use the natural logarithm of the original issued amounts; whereas (lagged) yield volatility is defined as the difference between the standard deviations of individual issues and the cross-sectional average standard deviation of quoted yields, where the average is take over the different maturities for a given month. Calculated economic impact is defined as the interquartile spread - coefficient times the difference between the betas that correspond to the first and third quartile in the cross-section of betas. Displayed coefficients are average figures from the monthly repeated cross-sectional regressions where errors take into account the averaging and include a 12-lag Newey-West correction. The sample period is July 2004 until December 2011. t-statistics are given in parentheses and significance is denoted by asterisk.

	Benchmark	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Market beta	1.0317	0.8997	1.0488	-1.2651	0.9483	0.8976	1.3132	1.0455	1.1490	1.0608	1.0691	0.0949
	(3.65)***	(2.94)***	(3.78)***	(4.04)***	(3.18)***	(2.92)***	(4.73)***	(3.74)***	(5.19)***	(5.10)***	(5.10)***	-0.81
Illiquidity beta	-0.0141	-0.3652	-0.0261	0.0310	-0.3053	-0.2975	-0.0602	-0.0566	0.0561	0.0434	0.0326	0.2407
	(-0.18)	(3.73)***	(-0.34)	(0.25)	(3.07)***	(3.16)***	(-0.74)	(-0.76)	(-1.08)	(-0.70)	(-0.52)	(2.95)***
Age	0.0909		0.1000					0.0931	0.0949	0.0887	0.0847	0.0686
	(9.18)***		(10.30)***					(5.82)***	(11.73)***	(10.19)***	(7.38)***	(7.46)***
Time-to-maturity				0.1573								0.0832
				(9.46)***								(4.30)***
On-the-run indicator					-0.2737			0.0019			0.0031	-0.0137
					(3.62)***			(0.03)			(0.07)	(0.70)
Issued amount	-0.3135					-0.4330				-0.3121	-0.3041	-0.2177
	(7.19)***					(10.42)***				(6.79)***	(6.40)***	(9.87)***
Yield volatility$_{t-1}$							7.1119		2.1668	0.9783	0.9843	2.7513
							(3.49)***		(1.35)	(0.58)	(0.57)	(1.98)*
Intercept	5.8625	-0.9874	-1.5563	-0.3890	-0.9789	9.1904	-1.4018	-1.5264	-1.6431	5.8072	5.6280	3.8707
	(6.17)***	(2.38)**	(3.95)***	(1.00)	(2.35)**	(9.11)***	(3.91)***	(3.78)***	(4.54)***	(5.62)***	(5.28)***	(8.90)***
Adj. R^2	0.88	0.59	0.83	0.71	0.65	0.69	0.69	0.84	0.87	0.92	0.92	0.94
Number of obs.	2,092	2,092	2,092	2,092	2,092	2,092	2,059	2,092	2,059	2,059	2,059	2,059
Impact of market risk	**0.9186**	**0.8011**	**0.9338**	**-1.1264**	**0.8443**	**0.7992**	**1.1693**	**0.9309**	**1.0231**	**0.9445**	**0.9519**	**0.0845**
Impact of liquidity risk	**-0.0086**	**-0.2236**	**-0.0160**	**0.0190**	**-0.1869**	**-0.1822**	**-0.0368**	**-0.0346**	**0.0344**	**0.0266**	**0.0200**	**0.1474**
Impact of age	**0.4171**	**-**	**0.4590**	**-**	**-**	**-**	**-**	**0.4271**	**0.4355**	**0.4070**	**0.3886**	**0.3149**
Impact of issuance	**-0.0903**	**-**	**-**	**-**	**-**	**-0.1247**	**-**	**-**	**-**	**-0.0899**	**-0.0876**	**-0.0627**

* $p<0.1$; ** $p<0.05$; *** $p<0.01$

Table VI

Monthly TIPS yields and illiquidity- Integrated market case in the full sample

The table reports estimates for the second step (Equation 5) of the Fama-MacBeth procedure under the assumption of markets being integrated. This implies that the market return is the equally weighted average of assets in zero net supply, thus indexed and nominal Treasuries. The dependent variable is the TIPS yield. Market and illiquidity betas are estimated based on Equation 4 as loadings on the market and the non-traded illiquidity factors. We define age as the years passed since issuance, and time-to-maturity as the years until maturity. The latter captures term structure effects. The on-the-run variable is a dummy that equals one of an issue is the newest of its tenor and zero otherwise. We use the natural logarithm of the original issued amounts; whereas (lagged) yield volatility is defined as the difference between the standard deviations of individual issues and the cross-sectional average standard deviation of quoted yields, where the average is take over the different maturities for a given month. Calculated economic impact is defined as the interquartile spread - coefficient times the difference between the betas that correspond to the first and third quartile in the cross-section of betas. Displayed coefficients are average figures from the monthly repeated cross-sectional regressions where errors take into account the averaging and include a 12-lag Newey-West correction. The sample period is July 2004 until December 2011. t-statistics are given in parentheses and significance is denoted by asterisk.

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Market beta	0.7800	0.7360	0.7910	-1.0904	0.7594	0.7320	0.9124	0.8112	0.8530	0.7996	0.8335	-0.0234
	(3.87)***	(3.30)***	(4.04)***	(12.81)***	(3.44)***	(3.23)***	(4.41)***	(3.95)***	(5.46)***	(5.19)***	(5.10)***	(-0.28)
Illiquidity beta	-0.0394	-0.3557	-0.0428	-0.0462	-0.3140	-0.2842	-0.2094	-0.0356	0.0222	0.0134	0.0428	0.2034
	(-0.55)	(3.94)***	(-0.54)	(-0.30)	(3.33)***	(3.24)***	(3.18)***	(-0.45)	(0.32)	(0.21)	(0.62)	(2.48)**
Age	0.0898		0.1007					0.0953	0.0982	0.0894	0.0876	0.0690
	(8.87)***		(11.40)***					(6.27)***	(11.79)***	(9.12)***	(6.55)***	(6.39)***
Time-to-maturity				0.1694								0.0883
				(7.36)***								(3.81)***
On-the-run indicator					-0.2235			0.0576			0.0578	0.0366
					(2.56)**			(0.58)			(0.72)	(0.74)
Issued amount	-0.2930					-0.3933				-0.2957	-0.2875	-0.2268
	(8.09)***					(10.87)***				(7.62)***	(7.02)***	(9.95)***
Yield volatility$_{t-1}$							4.7524		2.0170	0.7822	1.0465	2.5372
							(3.67)***		(1.36)	(0.51)	(0.67)	(1.83)*
Intercept	5.6259	-0.6874	-1.3082	-0.5694	-0.6802	8.5267	-0.9506	-1.3234	-1.4020	5.6377	5.3974	4.0676
	(7.10)***	(-1.63)	(3.36)***	(-1.34)	(-1.56)	(9.39)***	(2.59)**	(3.45)***	(3.78)***	(6.38)***	(5.86)***	(9.10)***
Adj. R^2	0.89	0.67	0.84	0.75	0.71	0.75	0.72	0.85	0.87	0.92	0.92	0.94
Number of obs.	2,092	2,092	2,092	2,092	2,092	2,092	2,059	2,092	2,059	2,059	2,059	2,059
Impact of market risk	**0.8925**	**0.8422**	**0.9051**	**-1.2477**	**0.8690**	**0.8376**	**1.0441**	**0.9282**	**0.9761**	**0.9151**	**0.9538**	**-0.0268**
Impact of liquidity risk	**-0.0264**	**-0.2385**	**-0.0287**	**-0.0310**	**-0.2106**	**-0.1906**	**-0.1404**	**-0.0239**	**0.0149**	**0.0090**	**0.0287**	**0.1364**
Impact of age	**0.4121**	**-**	**0.4623**	**-**	**-**	**-**	**-**	**0.4372**	**0.4506**	**0.4104**	**0.4020**	**0.3166**
Impact of issuance	**-0.0844**	**-**	**-**	**-**	**-**	**-0.1133**	**-**	**-**	**-**	**-0.0852**	**-0.0828**	**-0.0653**

* $p<0.1$; ** $p<0.05$; *** $p<0.01$

Table VII
Monthly nominal Treasury yields and liquidity- Segmented market case in the full sample

The table reports estimates for the second step (Equation 5) of the Fama-MacBeth procedure under the assumption of markets being segmented. This implies that the market return is the equally weighted average of nominal Treasuries. The dependent variable is the nominal Treasury yield. Market and illiquidity betas are estimated based on Equation 4 as loadings on the market and the non-traded illiquidity factors. We define age as the years passed since issuance, and time-to-maturity as the years until maturity. The latter captures term structure effects. The on-the-run variable is a dummy that equals one of an issue is the newest of its tenor and zero otherwise. We use the natural logarithm of the original issued amounts; whereas (lagged) yield volatility is defined as the difference between the standard deviations of individual issues and the cross-sectional average standard deviation of quoted yields, where the average is take over the different maturities for a given month. Calculated economic impact is defined as the interquartile spread - coefficient times the difference between the betas that correspond to the first and third quartile in the cross-section of betas. Displayed coefficients are average figures from the monthly repeated cross-sectional regressions where errors take into account the averaging and include a 12-lag Newey-West correction. The sample period is July 2004 until December 2011. t-statistics are given in parentheses and significance is denoted by asterisk.

	Benchmark	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Market beta	1.4434	1.4677	0.8223	1.4425	1.4461	1.3114	0.7446	0.7585	0.7093	0.7391	0.7280	0.7402
	(3.92)***	(3.90)***	(1.91)*	(3.92)***	(3.92)***	(3.89)***	(1.91)*	(1.99)**	(1.85)*	(2.17)**	(2.22)**	(2.25)**
Illiquidity beta	0.4913	0.4220	0.6758	0.4852	0.4763	0.3993	0.6321	0.6429	0.6532	0.5452	0.5566	0.5594
	(2.99)***	(3.30)***	(2.94)***	(3.05)***	(3.42)***	(3.76)***	(3.38)***	(3.35)***	(3.59)***	(4.27)***	(4.45)***	(4.37)***
Age		-0.0128					-0.0110	-0.0117	-0.0106	-0.0091	-0.0091	-0.0091
		(1.97)*					(1.88)*	(1.94)*	(2.12)**	(1.72)*	(2.00)**	(2.00)**
Time-to-maturity			0.0558				0.0657	0.0650	0.0686	0.0551	0.0555	0.0544
			(1.98)*				(2.79)***	(2.77)***	(2.93)***	(3.49)***	(3.58)***	(3.39)***
On-the-run indicator				0.0268				-0.0116				0.0031
				(1.16)				(-0.74)				(0.24)
Issued amount					0.0269				-0.0047		-0.0103	-0.0143
					(0.60)				(-0.25)		(-0.57)	(-0.85)
Yield volatility$_{t-1}$						3.6673				2.3864	2.5547	2.4881
						(1.74)*				(1.22)	(1.29)	(1.26)
Intercept	0.1528	0.2003	0.1779	0.1515	-0.4904	0.2535	0.2435	0.2468	0.3551	0.3385	0.5862	0.6833
	(0.70)	(0.89)	(0.96)	(0.70)	(-0.48)	(1.25)	(1.37)	(1.37)	(0.66)	(1.86)*	(1.09)	(1.31)
Adj. R^2	0.89	0.94	0.94	0.89	0.92	0.94	0.96	0.96	0.96	0.97	0.97	0.97
Number of obs.	2,132	2,132	2,132	2,132	2,132	2,100	2,132	2,132	2,132	2,100	2,100	2,100
Impact of market risk	**1.8322**	**1.8631**	**1.0437**	**1.8311**	**1.8356**	**1.6646**	**0.9452**	**0.9628**	**0.9003**	**0.9382**	**0.9241**	**0.9396**
Impact of liquidity risk	**0.1313**	**0.1128**	**0.1806**	**0.1296**	**0.1273**	**0.1067**	**0.1689**	**0.1718**	**0.1745**	**0.1457**	**0.1487**	**0.1495**

* $p<0.1$; ** $p<0.05$; *** $p<0.01$

Table VIII

Monthly nominal Treasury yields and liquidity- Integrated market case in the full sample

The table reports estimates for the second step (Equation 5) of the Fama-MacBeth procedure under the assumption of markets being segmented. The dependent variable is the nominal Treasury yield. Market and liquidity betas are estimated based on Equation 4 as loadings on the market and the non-traded liquidity factors. We define age as the days passed since issuance, and time-to-maturity as the days until maturity. The latter captures term structure effects. The on-the-run variable is a dummy that equals one of an issue is the newest of its tenor and zero otherwise. We use the natural logarithm of the original issued amounts; whereas (lagged) yield volatility is defined as the difference between the standard deviations of individual issues and the cross-sectional average standard deviation of quoted yields, where the average is take over the different maturities for a given month. Calculated economic impact is defined as the interquartile spread - coefficient times the difference between the betas that correspond to the first and third quartile in the cross-section of betas. Displayed coefficients are average figures from the monthly repeated cross-sectional regressions where errors take into account the averaging and include a 12-lag Newey-West correction. The sample period is July 2004 until December 2011. t-statistics are given in parentheses and significance is denoted by asterisk.

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Market beta	1.4396	1.4751	0.9771	1.4551	1.4533	1.2287	0.8515	0.8441	0.9433	0.7475	0.8331	0.8375
	(4.01)***	(4.09)***	(2.13)**	(3.97)***	(4.09)***	(4.11)***	(2.09)**	(2.06)**	(2.06)**	(2.55)**	(2.51)**	(2.50)**
Illiquidity beta	0.2414	0.1940	0.4578	0.2659	0.2559	0.1235	0.4497	0.5266	0.5028	0.3137	0.3510	0.3784
	(2.38)**	(2.44)**	(2.26)**	(2.23)**	(3.32)***	(2.48)**	(2.46)**	(2.60)**	(2.81)***	(2.58)**	(3.01)***	(3.09)***
Age		-0.0175					-0.0157	-0.0168	-0.0215	-0.0117	-0.0164	-0.0161
		(2.26)**					(2.13)**	(2.04)**	(2.53)**	(1.94)*	(2.45)**	(2.34)**
Time-to-maturity			0.0478				0.0639	0.0686	0.0577	0.0529	0.0471	0.0482
			(1.53)				(2.38)**	(2.51)**	(2.09)**	(3.27)***	(2.90)***	(2.95)***
On-the-run indicator				-0.0047				-0.0766				-0.0124
				(-0.09)				(-1.01)				(-0.37)
Issued amount					0.0180				-0.1040		-0.0799	-0.0781
					(0.35)				(3.52)***		(4.37)***	(4.40)***
Yield volatility$_{t-1}$						5.4332				4.7186	4.6556	4.3847
						(2.03)**				(1.87)*	(1.87)*	(1.87)*
Intercept	0.2270	0.2771	0.2119	0.2202	-0.2042	0.3685	0.2909	0.2929	2.7727	0.4521	2.3547	2.3047
	(1.09)	(1.26)	(1.30)	(1.06)	(-0.19)	(1.90)*	(1.77)*	(1.77)*	(4.26)***	(2.78)***	(5.81)***	(6.07)***
Adj. R^2	0.88	0.93	0.92	0.88	0.91	0.93	0.95	0.95	0.95	0.97	0.97	0.97
Number of obs.	2,132	2,132	2,132	2,132	2,132	2,100	2,132	2,132	2,132	2,100	2,100	2,100
Impact of market risk	**1.8494**	**1.8950**	**1.2553**	**1.8694**	**1.8671**	**1.5786**	**1.0939**	**1.0845**	**1.2119**	**0.9603**	**1.0703**	**1.0759**
Impact of liquidity risk	**0.1285**	**0.1032**	**0.2436**	**0.1415**	**0.1362**	**0.0657**	**0.2393**	**0.2803**	**0.2676**	**0.1669**	**0.1868**	**0.2014**

* $p<0.1$; ** $p<0.05$; *** $p<0.01$

Table IX
Descriptive statistics: the mispricing

This table presents descriptive statistics for the outcome of the trading strategy described in Fleckenstein et al (2013), henceforth FLL. In this strategy we compare the prices of a nominal Treasury issue to its replicating portfolio that consist of a maturity matched TIPS issue, inflation swap contracts and STRIPS issues. Panel A comprises of the results of the replication of FLL within our sample, alongside with the two cases of liquidity corrections applied to this strategy. The correction is based on adjusting yields with estimated liquidity premiums from Equation 5, both under the assumption of the three markets being segmented and integrated. Panel B exhibits the difference between the original strategy and the adjusted versions, where the difference is defined as the FLL mispricing minus the corrected series. The data correspond to 26 bond pairs in the sample period between July 2004 and December 2011.

	Mean	St. Dev.	Min	p25	p75	Max
Panel A: Mispricing and corrections						
FLL mispricing	2.25	1.42	0.09	1.48	2.45	9.42
Corrected mispricing - segmented	-0.52	1.38	-2.50	-1.21	-0.38	6.65
Corrected mispricing - integrated	0.21	1.61	-2.16	-0.63	0.42	8.37
Panel B: The effect of liquidity correction						
Difference in segmentation	2.76	0.18	2.33	2.66	2.85	3.29
Difference in integration	2.68	0.31	1.97	2.47	2.83	3.79

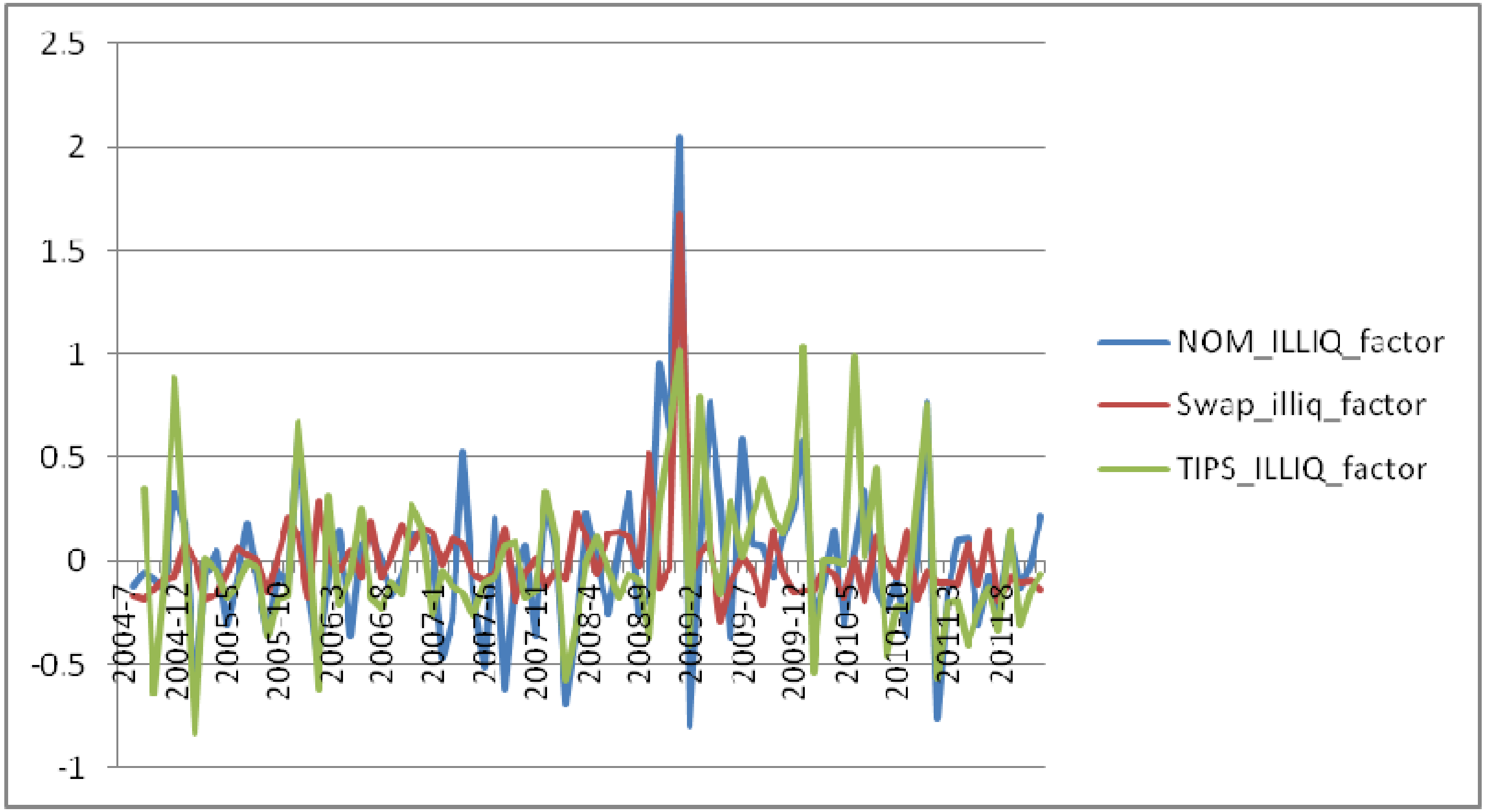


Figure 1 Illiquidity factors

The figure depicts the time evolution of our non-traded liquidity factors that are residuals from autoregressive processes: AR(3) for ILLIQ measures concerning nominal and indexed bonds, and AR(1) for the average Roll measure.

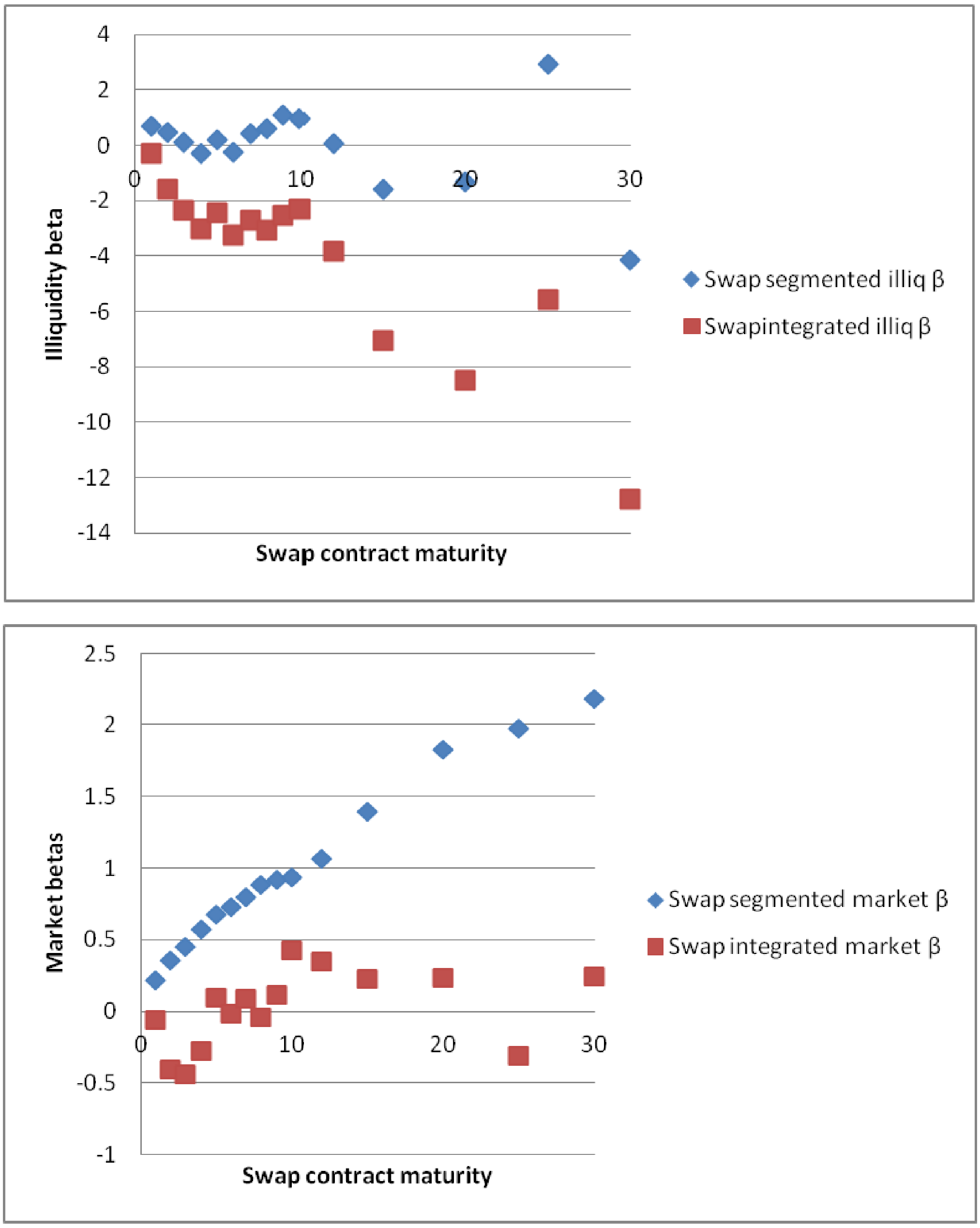
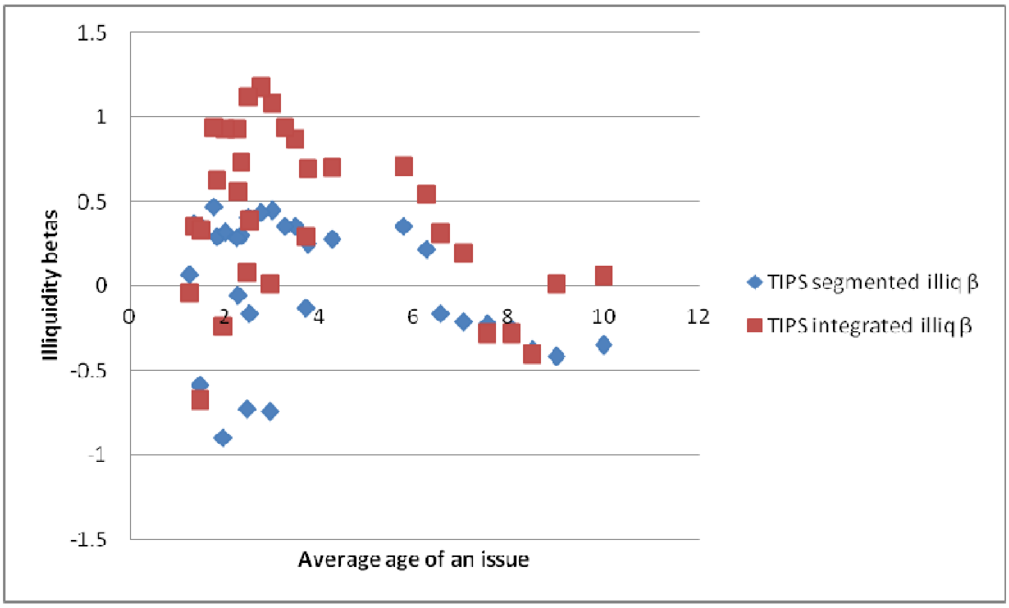


Figure 2 Inflation swap market and illiquidity betas

The scatter plots depict the betas estimated from the time series regressions of inflation swap returns on market and illiquidity factors. The above plot focuses on illiquidity betas, whereas the one below shows market betas, both estimated under the assumption of market segmentation and integration.



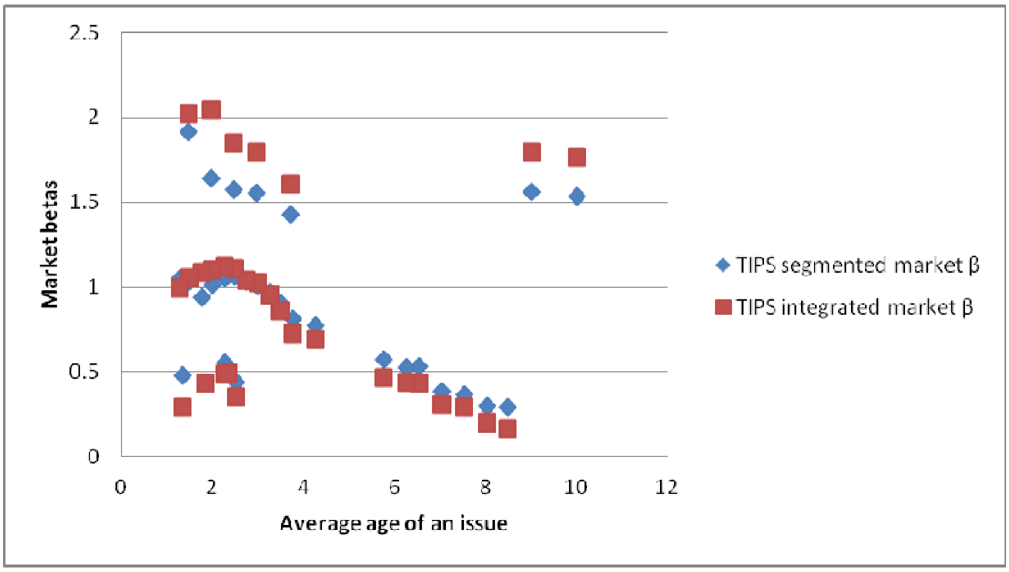
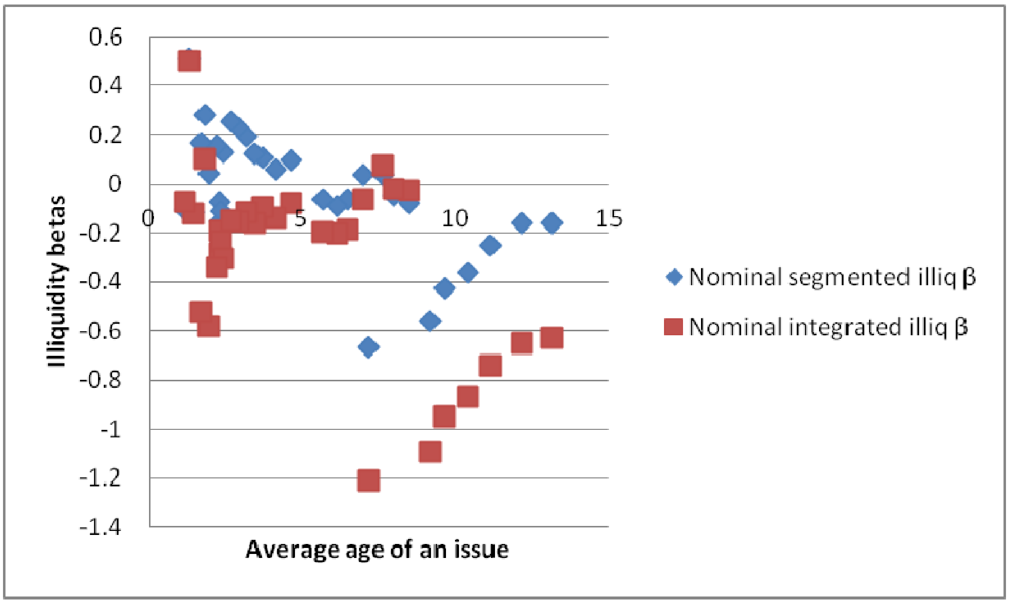


Figure 3 TIPS market and illiquidity betas

The scatter plots depict the betas estimated from the time series regressions of TIPS returns on market and illiquidity factors. The above plot focuses on illiquidity betas, whereas the one below shows market betas, both estimated under the assumption of market segmentation and integration. Betas are sorted on average age of bond issues.



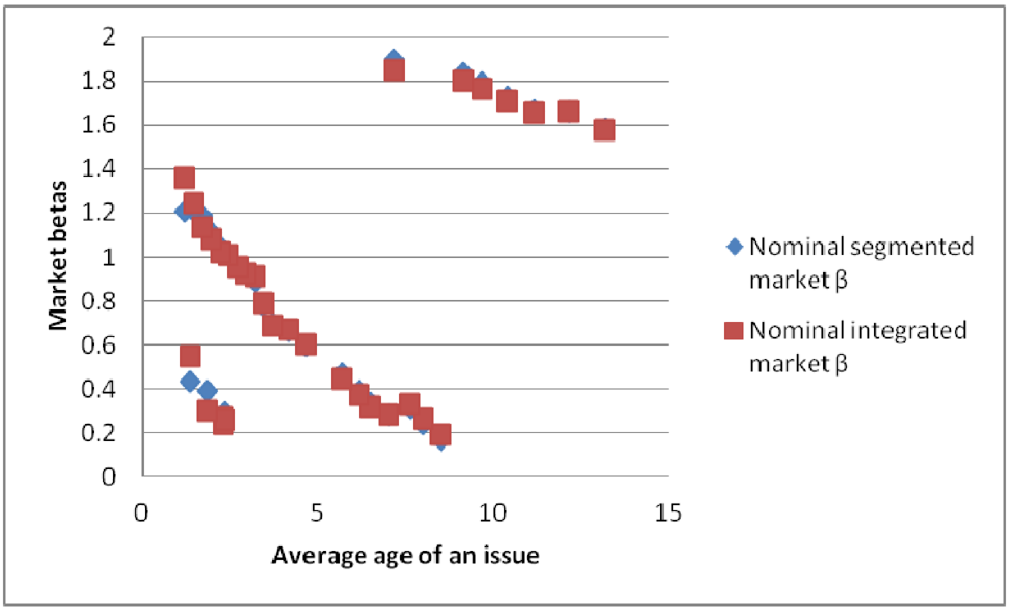


Figure 4 Nominal Treasury market and illiquidity betas

The scatter plots depict the betas estimated from the time series regressions of nominal Treasury returns on market and illiquidity factors. The above plot focuses on illiquidity betas, whereas the one below shows market betas, both estimated under the assumption of market segmentation and integration. Betas are sorted on average age of bond issues.

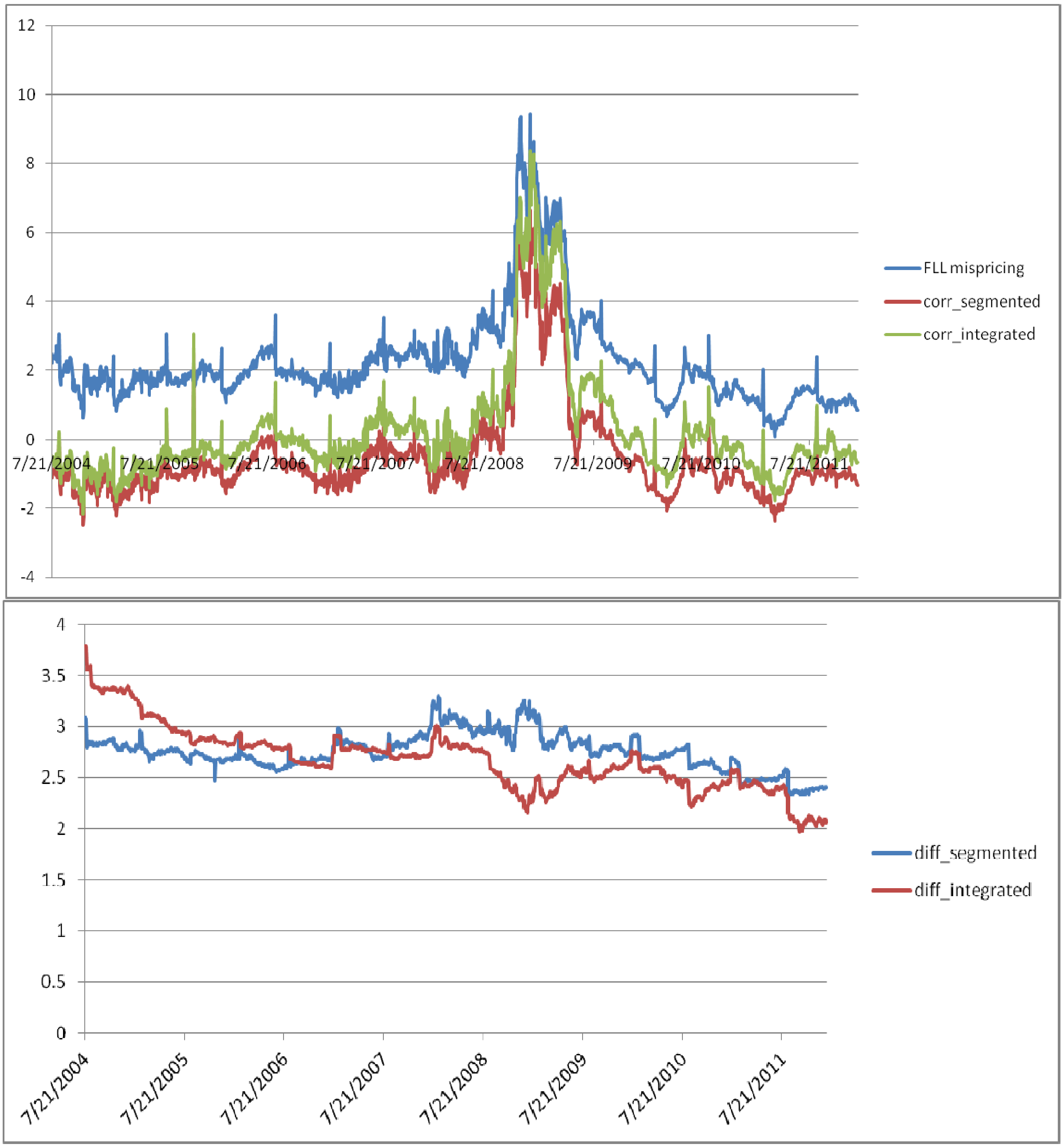


Figure 5 Mispricing and the effect of liquidity correction

The figure depicts the time-series behavior of the equally weighted average mispricing across 26 maturity matched bond pairs from Fleckenstein et al (2013). The mispricing is the price difference between a nominal Treasury issue and its replicating portfolio that consists of a maturity matched TIPS issue, inflation swap contracts and STRIPS issues. The above panel also contains graphs of its liquidity-adjusted counterparts. Below, we show the difference between the replicated mispricing and the one with the liquidity correction.