An Empirical Decomposition of Risk and Liquidity in Nominal and Inflation-Indexed Government Bonds

Carolin E. Pflueger and Luis M. Viceira[1]

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[1]Pflueger: Harvard Business School, Boston MA 02163. Email cpflueger@hbs.edu. Viceira: Harvard Business School, Boston MA 02163 and NBER. Email lviceira@hbs.edu. We are grateful to John Campbell, Graig Fantuzzi, Josh Gottlieb, Robin Greenwood, Arvind Krishnamurthy, Jeremy Stein, to seminar participants at the HBS-Harvard Economics Finance Lunch and participants at the HBS Research Day for helpful comments and suggestions. We are also grateful to Martin Duffell and Anna Christie from the UK Debt Management Office for their help providing us with UK bond data. This material is based upon work supported by the Harvard Business School Research Funding.

Abstract

This paper decomposes excess return predictability in inflation-indexed and nominal government bonds into liquidity, market segmentation, real interest rate risk and inflation risk. We estimate a liquidity premium, which appears systematic in nature. It is around 40 to 70 bps during normal times but much larger during the early years of TIPS and during the financial crisis in 2008-2009. We find evidence for large time-varying liquidity premia and real rate risk premia in TIPS and a time-varying inflation risk premium in nominal bonds. We find no evidence for segmentation between nominal and inflation-indexed bond markets in the US or UK.

Over the 10 year period starting in 1999 the average annualized excess log return on 10 year TIPS equalled a substantial 4.16%, almost a full percentage point higher than that on comparable nominal US government bonds. This significant return differential is puzzling, because both nominal and inflation-indexed bonds are fully backed by the US government. Moreover, the real cash flows on nominal bonds are exposed to surprise inflation while TIPS coupons and principal are inflation protected.

This paper asks to what extent liquidity and market segmentation can explain the differences in yields and returns between nominal and inflation-indexed bonds. We also investigate and quantify real cash flow risks as a source of return predictability in nominal and inflation-indexed bonds and disentangle these from liquidity differentials.

While US nominal Treasury bonds are among the most liquid investments in the world, TIPS empirically have a smaller and less liquid market and this was especially true during their earlier years.[2] There are reasons to believe that liquidity differentials between the nominal bond market and the inflation-indexed bond market might persist beyond an initial stage of learning and supply buildup. For any investor the riskless asset is an inflation-indexed bond whose cash flows match his consumption plan (Campbell and Viceira 2001, Wachter 2003), so that inflation-indexed bonds should typically be held by buy-and-hold investors. Thus the return differential might have been the result of a liquidity discount demanded by investors that has diminished—but not necessarily disappeared—over time with the growth in TIPS trading and adoption among investors.

We examine these questions adopting an empirically flexible approach. We estimate the

[2] For evidence of relatively lower liquidity in TIPS see Campbell, Shiller, and Viceira (2009), Gurkaynak, Sack, and Wright (2010), Fleming and Krishnan (2009), Dudley, Roush, and Steinberg Ezer (2009).

liquidity differential between inflation-indexed bonds and nominal bonds using a variety of proxies for liquidity. Specifically, we use the transaction volume of TIPS, the financing cost for buying TIPS, the 10-year nominal off-the-run spread and the Ginnie Mae (GNMA) spread. These liquidity variables can explain two thirds of the time-variation in the difference between US nominal and inflation-indexed bond yields.

We find a statistically significant and economically important time-varying liquidity component in the yield differential between nominal bonds and inflation-indexed bonds, popularly known among practitioners as "breakeven inflation." Over our sample period the yield on TIPS has been about 71 to 106 basis points larger on average than it would have been if TIPS had been as liquid as nominal Treasury bonds. This high average reflects extraordinary events associated with very low liquidity in this market. We find a high liquidity discount in the years following the introduction of TIPS (about 70 to 120 bps), which we attribute to learning and low trading volume, and during the fall of 2008 at the height of the financial crisis (beyond 200 bps). We estimate a much lower but still significant liquidity discount of between 40 to 80 bps between 2004 and 2007 and after the crisis in 2009.

We find that our estimated liquidity differential exhibits a highly significant positive CAPM beta. This suggests that investors in TIPS bear systematic risk due to time-varying liquidity and should be compensated for this in terms of a return premium.

We use these estimates to compute a liquidity-adjusted measure of breakeven inflation. Breakeven inflation is often used by practitioners as a gauge of long-term inflation expectations and our findings suggest that liquidity-adjusted breakeven has been stable around three percent over our sample period.

We next try to understand the role of liquidity and market segmentation as sources of return-predictability in nominal and inflation-indexed bond markets. It is well-known that the excess return on US nominal government bonds over the return on Treasury bills exhibits predictable variation over time (Campbell and Shiller 1991, Fama and Bliss 1987, Cochrane and Piazzesi 2005). In recent work, Pflueger and Viceira (2011) provide strong empirical evidence that the expected excess return on inflation-indexed bonds and the return differential between nominal and inflation-indexed bonds are also time varying both in the US and in the UK.

We investigate the hypothesis that the markets for nominal and inflation-indexed debt are segmented, leading to relative price fluctuations and return predictability. Recent research has emphasized the role of limited arbitrage and bond investors' habitat preferences to explain predictability in nominal bond returns (Modigliani and Sutch, 1966, Vayanos and Vila, 2009). In the context of real versus nominal bonds, it seems plausible that the preference of certain investors—such as pension funds with inflation-indexed liabilities—for real bonds, and the preference of others—such as pension funds with nominal liabilities—for nominal bonds might lead to imperfect market integration between both markets and this could generate return predictability.

Following Greenwood and Vayanos (2008) and Hamilton and Wu (2010) we use the outstanding supply of real bonds relative to total government debt as a proxy for supply shocks in the inflation-indexed bond market. We cannot find any evidence for bond supply effects either in the US or in the UK. One potential interpretation for this finding could be that governments understand investor demand for the different types of securities and adjust their issuance accordingly, effectively acting as an arbitrageur between the two markets.

Having found no evidence for market-segmentation as a source of bond return predictability, we next analyze the role of liquidity. Adjusting TIPS yields for our estimated liquidity premium we can disentangle bond return predictability due to liquidity and due to cash flow risks. Although government bonds in large and stable economies are generally considered default-free, their real cash flows are exposed to other risks. The prices of both inflation-indexed and nominal government bonds change with the economy-wide real interest rate. Consequently, bond risk premia will reflect investors' perception of real interest rate risk, which may vary over time. The prices of nominal government bonds, but not inflation-indexed government bonds, also vary with expected inflation, so that inflation risk will impact their risk premia.[3] In this paper we find that liquidity is a large contributor to return predictability in inflation-indexed bonds, but that real rate risk and inflation risk are also statistically and economically significant contributors to return predictability in government bonds.

This paper relates to a number of recent papers that estimate liquidity premia in TIPS. In recent work, Fleckenstein, Longstaff and Lustig (2010) show that inflation-swaps, which allow investors to trade on a synthetic measure of breakeven inflation, appear to be mispriced relative to breakeven inflation in the cash market for TIPS and nominal Treasury bonds. In the absence of financing costs, synthetic breakeven inflation rates should be similar to cash breakeven inflation but in practice they have been consistently larger. This significant mispricing appears to be related to financing costs to levered investors (Campbell, Shiller, and Viceira, 2009, and Viceira, 2011), and raises the question why unlevered investors have not taken advantage of it. We estimate the liquidity differential between TIPS and Treasury

[3]For models of real cash flow risks in nominal government bonds see Campbell and Viceira (2001), Campbell, Sunderam, and Viceira (2010), and Christensen, Lopez, and Rudebusch (2010).

bonds over a significantly longer time period and find it to be even higher than the pricing differential in synthetic breakeven markets.

Our estimates for the liquidity premium are consistent with the magnitudes estimated in other recent papers. D'Amico, Kim and Wei (2009) estimate a liquidity premium in a structural model of nominal and real government bonds. Christensen and Gillan (2011) derive a set of bounds for the liquidity premium in TIPS yields. Our approach differs from other papers in that we estimate the liquidity differential between TIPS and nominal Treasury bonds using a simple and transparent empirical methodology and that we focus on the economic significance of liquidity differentials as a source of return predictability.

The structure of this paper is as follows. Section I estimates the liquidity premium in US TIPS versus nominal bonds using our liquidity proxies. Section II tests the market segmentation hypothesis in the US and in the UK, and section III considers time-varying real interest rate risk and inflation risk premia. Finally, section IV offers some concluding remarks.

I Estimating the Liquidity Component of Breakeven Inflation

Our approach to modelling liquidity premia is empirical. We estimate the US TIPS liquidity premium by regressing inflation compensation on measures of liquidity, following authors such as Gurkaynak, Sack, and Wright (2010). We use four liquidity proxies: the nominal off-the-run spread, the GNMA spread, relative TIPS transaction volume and the difference

between TIPS asset-swap-spreads and nominal US Treasury asset-swap spreads. Since we have data for liquidity proxies only for the US in the most recent period, this part of our estimation is restricted to the last 10 years of US experience.

One might think that when TIPS were first issued in 1997, investors needed to learn about TIPS and the market for TIPS took some time to get established. We proxy for this idea by using the transaction volume of TIPS relative to the transaction volume of Treasuries, a measure previously used by Gurkaynak, Sack, and Wright (2010). Fleming and Krishnan (2009) previously found that trading activity is a good measure of cross-sectional TIPS liquidity, lending credibility to relative transaction volume as a liquidity proxy in our time series setup.

We interpret relative TIPS transaction volume as a measure of TIPS-specific liquidity. Following Weill (2007) and others one can also think of TIPS transaction volume as a measure of illiquidity due to search frictions[4]. This should be reflected in initially low trading volumes in TIPS and high yields during the early period.

Part of the liquidity differential between nominal and inflation-indexed bonds might also be driven by "flight-to-liquidity" episodes. In a flight to liquidity episode some market participants suddenly prefer highly liquid securities, such as on-the-run nominal Treasury securities, rather than less liquid securities.

The Treasury regularly issues new 10 year nominal notes, and the newest 10 year note, also known as the "on-the-run" note or bond, is considered the most liquidly traded security in the Treasury bond market. After the Treasury issues a new 10-year note, the prior note

[4]See Duffie, Garleanu and Pedersen (2005, 2007) and Weill (2007) for models of over-the-counter markets, in which traders need to search for counterparties and incur opportunity or other costs while doing so.

goes "off-the-run." The off-the-run bond typically trades at a discount over the on-the-run bond—i.e., it trades at a higher yield—, despite the fact that it offers almost identical cash flows with a very similar remaining time to maturity. A second type of government-backed bond that is also less liquidly traded than on-the-run Treasuries is GNMA bonds. The Government National Mortgage Association (GNMA) guarantees the timely payment of interest and principal on residential mortgage backed securities.

Flight-to-liquidity effects have been documented in Longstaff (2004) for agency bonds and Krishnamurthy (2002) for off-the-run nominal Treasury bonds.[5] We therefore interpret the on-the-run versus off-the-run spread in Treasury bonds and the GNMA-Treasury spreads as empirical proxies for flight-to-liquidity episodes.

Finally, we want to capture the cost that levered investors would incur when holding TIPS. Such investors looking for TIPS exposure can either borrow by putting the TIPS on repo or they might consider entering into an asset swap, which requires no initial capital. An asset swap is a derivative contract between two parties where one party receives the cash flows on a particular government bond (e.g. TIPS or nominal) and pays $LIBOR$ plus the asset-swap-spread (ASW), which can be positive or negative. Our fourth measure of liquidity is the difference between the asset-swap-spread for TIPS and the asset-swap-spread for nominal Treasuries,

$$ASW_{n,t}^{spread} = ASW_{n,t}^{TIPS} - ASW_{n,t}^{\$} \tag{1}$$

This is a measure of the relative cost of financing a long position in the TIPS market versus

[5] In the search model with partially segmented markets of Vayanos and Wang (2001) short-horizon traders endogenously concentrate in one asset, making it more liquid. Vayanos (2004) presents a model of financial intermediaries and exogenous transaction costs, where preference for liquidity is time-varying and increasing with volatility.

in the nominal Treasury market. A widening of this relative spread indicates that the cost of financing a long position in the TIPS market has increased relative to the cost of financing a long position in the nominal Treasury market. Therefore the ASW reflects the current and expected financing costs of holding the long bond position. Empirically, the asset-swap-spread variable captures extraordinary events during the financial crisis.[6]

The liquidity differential between the nominal bond market and the inflation-indexed bond market can also give rise to a liquidity risk premium: If the liquidity of inflation-indexed bonds deteriorates during periods when investors would like to sell, as in "flight to liquidity" episodes, risk averse investors will demand a liquidity risk premium for holding these bonds (Amihud, Mendelson and Pedersen 2005, Acharya and Pedersen 2005).

While the relative transaction volume of TIPS likely only captures the current ease of trading TIPS and therefore a liquidity premium, the off-the-run spread, the GNMA spread and the asset-swap-spread are likely to represent both the level of liquidity and liquidity risk. Our estimated liquidity premium is therefore likely to represent a combination of current ease of trading TIPS versus nominal US Treasuries and the risk that the liquidity of TIPS might deteriorate.

A Bond Notation and Definitions

We denote by $y^{\$}_{n,t}$ and $y^{TIPS}_{n,t}$ the log (or continuously compounded) yield with n periods to maturity for nominal and inflation-indexed bonds, respectively. We use the superscript $TIPS$ to denote this quantity for both US and UK inflation-indexed bonds.

[6] See Campbell, Shiller, and Viceira (2009) for an account of liquidity events during the Fall of 2008.

We define breakeven inflation as the difference between nominal and inflation-indexed bond yields:

$$b_{n,t} = y^{\$}_{n,t} - y^{TIPS}_{n,t} \tag{2}$$

Log excess returns on nominal and inflation-indexed zero-coupon n-period bonds held for one period before maturity are given by

$$\begin{aligned} xr^{\$}_{n,t+1} &= ny^{\$}_{n,t} - (n-1)\, y^{\$}_{n-1,t+1} - y^{\$}_{1,t}, & (3) \\ xr^{TIPS}_{n,t+1} &= ny^{TIPS}_{n,t} - (n-1)\, y^{TIPS}_{n-1,t+1} - y^{TIPS}_{1,t}. & (4) \end{aligned}$$

Therefore, the log excess one-period holding return on breakeven inflation is equal to

$$xr^{b}_{n,t+1} = xr^{\$}_{n,t+1} - xr^{TIPS}_{n,t+1}. \tag{5}$$

Note that this is essentially the return on a portfolio long long-term nominal bonds and short long-term inflation-indexed bonds. This portfolio will have positive returns when breakeven inflation declines, and negative returns when it increases.

The yield spread is the difference between a long-term yield and a short-term yield:

$$\begin{aligned} s^{\$}_{n,t} &= y^{\$}_{n,t} - y^{\$}_{1,t}, & (6) \\ s^{TIPS}_{n,t} &= y^{TIPS}_{n,t} - y^{TIPS}_{1,t}, & (7) \\ s^{b}_{n,t} &= b_{n,t} - b_{1,t}. & (8) \end{aligned}$$

Inflation-indexed bonds are commonly quoted in terms of *real* yields, but since $xr^{TIPS}_{n,t+1}$

is an excess return over the *real* short rate it can be interpreted as a real or nominal excess return. In all regressions we approximate $y^{\$}_{n-1,t+1}$ and $y^{TIPS}_{n-1,t+1}$ with $y^{\$}_{n,t+1}$ and $y^{TIPS}_{n,t+1}$.

B Estimation Strategy

At times when TIPS are relatively less liquid than nominal bonds we would expect TIPS to trade at a discount and the TIPS yield to increase relative to nominal yields. To account for this premium, we estimate the following regression for breakeven inflation:

$$b_{n,t} = a_1 + a_2 X_t + \varepsilon_t, \tag{9}$$

where X_t is a vector containing our four liquidity proxies: the off-the-run spread, the GNMA spread, the relative TIPS transactions volume and the difference between TIPS and nominal asset-swap-spreads.

In (9) we would expect variables that indicate less liquidity in the TIPS market, such as the off-the-run spread, the GNMA spread and the asset-swap-spread, to enter negatively. On the other hand higher transaction volume in the TIPS market indicates that TIPS are easily traded and therefore it should enter positively.

The asset-swap spread reflects the financing costs that a levered investor incurs from holding TIPS instead of a similar maturity nominal bonds. If the marginal investor in TIPS is such a levered investor, we would expect breakeven inflation to fall approximately one for one with the asset-swap-spread.

Our liquidity variables are normalized in such a way that they go to zero in a world of

perfect liquidity. When liquidity is perfect the off-the-run spread, the GNMA spread and the asset-swap spread should equal zero. The transaction volume is normalized so that its maximum is equal to zero. That is, we assume that the liquidity premium attributable to low transaction volume was negligible during the period of 2004-2007.

We obtain liquidity-adjusted TIPS yields by assuming that the liquidity premium estimated from the breakeven regression (9) is entirely attributable to time-varying liquidity in TIPS rather than in nominal bonds. The estimated liquidity component in TIPS yields then equals

$$\hat{L}_{n,t} = -\hat{a}_2 X_t, \tag{10}$$

where $\hat{a}_2$ is the vector of slope estimates in (9). Thus an increase in $\hat{L}_{n,t}$ reflects a reduction in the liquidity of TIPS relative to nominal Treasury bonds. Liquidity-adjusted TIPS yields and breakeven inflation then equal

$$y_{n,t}^{TIPS,adj} = y_{n,t}^{TIPS} - \hat{L}_{n,t}, \tag{11}$$

$$b_{n,t}^{adj} = b_{n,t} + \hat{L}_{n,t}. \tag{12}$$

That is, the observed yield on TIPS is larger than the liquidity-adjusted yield during times of low liquidity and accordingly the observed breakeven inflation will be smaller than the liquidity-adjusted breakeven inflation.

C Yield Data

We use data on constant-maturity inflation-indexed and nominal yields both in the US and in the UK. Inflation-indexed bonds have been available in the UK since 1983 and in the US since 1997. Inflation-indexed bonds are bonds whose principal adjusts automatically with the evolution a consumer price index, which in the US is the Consumer Price Index (CPI-U) and in the UK is the Retail Price Index (RPI). The coupons are equal to the inflation-adjusted principal on the bond times a fixed coupon rate. Thus the coupons on these bonds also adjust with inflation.[7]

For the US we use the Gurkaynak, Sack, and Wright (2007) and Gurkaynak, Sack, and Wright (2010, GSW henceforth) data set. GSW have constructed a zero-coupon yield curve starting in January 1961 for nominal bonds and for TIPS starting in January 1999 by fitting a smoothed yield curve. The GSW data set contains constant maturity yields for maturities of 2 to 20 years. Our empirical tests will focus on the 10-year nominal and real yields, because this maturity bracket has the longest and most continuous history of TIPS outstanding. We measure US inflation with the all-urban seasonally adjusted CPI, and the short-term nominal interest rate with the 3 month T-bill rate from the Fama-Bliss riskless interest rate file from CRSP. TIPS payouts are linked to the all-urban non seasonally adjusted CPI and our results become slightly stronger when using the non seasonally adjusted CPI instead.

While the nominal principal value of TIPS increases with inflation, it is guaranteed to never fall below its original nominal face value. As a consequence of this a recently issued

[7] There are further details such as in inflation lags in principal updating and tax treatment of the coupons that slightly complicate the pricing of these bonds. More details on TIPS can be found in Viceira (2001), Roll (2004), Campbell, Shiller, and Viceira (2009) and Gurkaynak, Sack, and Wright (2010). Campbell and Shiller (1996) offer a discussion of the taxation of inflation-indexed bonds.

TIPS, whose nominal face value is close to its original nominal face values, has a deflation option built into it that is more valuable than that in a less recently issued TIPS with the same time to maturity remaining. During normal times the probability of a severe and prolonged deflation is negligible so that those bonds trade at identical prices, as discussed in Wright (2009). Wright (2009) also points out some of the dramatic price discrepancies between recently issued and seasoned five-year TIPS observed during the financial crisis and attributes them to the increased value of the deflation option during the financial crisis. In the Appendix we show that during the financial crisis our series of 10 year TIPS yields most closely corresponds to the yields of older 10 year TIPS and conclude that it most likely does not reflect the deflation option built into the most recent issuance of 10 year TIPS.

For the UK we use zero-coupon yield curves from the Bank of England. Anderson and Sleath (2001) describe the spline-based techniques used to estimate the yield curves. Nominal yields are available starting in 1970 for 0.5 to 20 years to maturity. Real yields are available starting in 1985 for 2.5 to 25 years to maturity. We use the 20-year maturity in our tests because 20-year nominal and real yields are available from 1985, while for instance 10-year real yields are available only since 1991.[8] Inflation is measured by the non seasonally adjusted Retail Price Index, which serves as the measure of inflation for inflation-indexed bond payouts.

Since neither the US nor the UK governments issue inflation-indexed bills, we need to resort to an empirical procedure to build a hypothetical short-term real interest rate. We follow the procedure described in Pflueger and Viceira (2011). For simplicity we assume that the liquidity premium on one-quarter real bonds is zero. Finally, although our yield data

[8] For some months the 20 year yields are not available and instead we use the longest maturity available. The maturity used for the 20 year yield series drops down to 16.5 years for a short period in 1991.

sets are available at a monthly frequency, we focus on quarterly overlapping bond returns in order to reduce the influence of high-frequency noise in observed inflation and short-term nominal interest rate volatility in our tests.

D Data on Liquidity Proxies

We obtain the 10 year off-the-run spread from the Federal Reserve and from Bloomberg.[9] While GNMA bonds do not contain any default risk, they do contain prepayment risk, because mortgage holders can prepay without penalty. We obtain a GNMA spread adjusted for prepayment risk from Bloomberg.[10]

We obtain Primary Dealers' transaction volumes for TIPS and nominal Treasury securities from the New York Federal Reserve FR-2004 survey. We construct our measure of relative transaction volume as $\log\left(Trans_t^{TIPS}/Trans_t^{\$}\right)$, where $Trans_t^{TIPS}$ denotes the average weekly transactions volume over the past month and $Trans_t^{\$}$ the corresponding figure for nominal bonds. For $Trans^{\$}$ we use the transaction volume of government coupon securities with at least 6 (before 2001) or 7 (from 2001) years to maturity. We choose the transaction volume series for coupon bonds with a long time to maturity because we are aiming at capturing the differential liquidity of TIPS with respect to 10 year nominal bonds. Including all maturities or even T-bills would also reflect liquidity of short-term instruments versus long-term instruments. We then smooth the measure of relative transaction volume over the past three months because we think of it as capturing secular learning effects rather

[9] The on the run data is from Bloomberg (USGG10YR), and the off the run is from the Federal Reserve publication H.15 "Interest Rates".

[10] Ticker GNSF060. This is the prepayment-option adjusted spread based on a 6% coupon 30 year GNMA generic bond. It is adjusted for prepayment risk using the Bloomberg prepayment model.

than capturing short-term fluctuations in liquidity.[11] We normalize the relative transaction volume so that its maximal value is equal to zero.

We obtain asset-swap-spread data from Barclays Live. We only have data on $ASW_{n,t}^{spread}$ from July 2007 until April 2009, and set it to its July 2007 value of 40 bps when the asset-swap-spread series is not available. For the 10 year TIPS asset-swap-spread we use the July 2017 Asset Swap and for the 10 year nominal Asset Swap we use the generic 10 Year On-the-Run Par asset-swap-spread.

Figure 1 shows our four liquidity variables. The dissimilar time-series patterns of the variables suggest that each one represents a different aspect of market liquidity, although the spread variables all jump during the financial crisis of 2008-2009. The on-the-run off-the-run spread exhibits high frequency variation. The GNMA spread, on the other hand, moves relatively slowly. One reason for the difference in the two spreads could be that they have a different investor base. The GNMA spread pattern of a lower spread between 2002 and 2007 agrees with anecdotes of long-term investors who were particularly willing to invest into less liquid securities in order gain yield during that period. The relative transaction volume rises linearly through 2004 and then stabilizes. This suggests that the liquidity premium due to the novelty of TIPS should have been modest in the period since 2004.

Finally the asset-swap-spread variable $ASW_{n,t}^{spread}$ varies within a relatively narrow range of 35 basis point to 41 basis points from July 2007 through August 2008, and it rises sharply during the financial crisis, reaching 130 bps in December 2008. That is, before the crisis

[11] In 2001 the Federal Reserve changed the maturity cutoffs for which the transaction volumes are reported. Before 6/28/2001 we use the transaction volume of Treasuries with 6 or more years to maturity while starting 6/28/2001 we use the transaction volume of Treasuries with 7 or more years to maturity. The series after the break is scaled so that the growth in $Trans^{\$}$ from 6/21/2001 to 6/28/2001 is equal to the growth in transaction volume of all government coupon securities.

financing a long position in TIPS was about 40 basis more expensive than financing a long position in nominal Treasury bonds, but this cost differential rose to more than 120 basis points after the Lehman bankruptcy in September 2008. Campbell, Shiller, and Viceira (2009) argue that the bankruptcy of Lehman Brothers in September of 2008 had a significant effect on liquidity in the TIPS market, because Lehman Brothers had been very active in the TIPS market. The unwinding of its large TIPS inventory in the weeks following its bankruptcy, combined with a sudden increase in the cost of financing long positions in TIPS appears to have induced an unexpected downward price pressure in the TIPS market. This led to a liquidity-induced sharp tightening of breakeven inflation associated with a widening of the TIPS asset-swap-spread.

Table I shows summary statistics for bond spreads and excess returns as well as liquidity variables. One can see that over our sample period breakeven inflation has averaged 2.25% and TIPS yields have averaged 2.55%. The realized average annualized log excess returns on TIPS have been equal to 4.16%, exceeding the log excess returns on nominal government bonds by 91 basis points (bps). The average log excess returns on UK inflation-indexed bonds, on the other hand, have been substantially smaller at only 1.66% over the longer sample period from 1985.4 to 2009.12.

E Estimation Results

Table II reports OLS estimates of the regression (9), adding the liquidity proxies one at a time. Columns 1 through 3 always include $ASW_{n,t}^{spread}$, but with a slope set to its theoretical value of -1. Column 4 presents estimates with freely estimated coefficients for all four liquidity proxies.

Table II shows coefficients whose signs are consistent with expectations and generally statistically significant. Interestingly, our liquidity measures explain a very large fraction of the variability of breakeven inflation, from 44% in column 1 to 67% in column 4. The R^2 increases with every additional liquidity control introduced, indicating that each of the controls helps explain the liquidity premium on TIPS.

The negative and significant coefficient on relative TIPS trading volume in Table II indicates that the impact of search frictions on inflation-indexed bond prices appears to have been exacerbated during the early period of inflation-indexed bond issuance, when maybe only a small number of sophisticated investors had a good understanding of the mechanics and pricing of these new bonds.

In Table II breakeven inflation moves negatively with both the on-the-run versus off-the-run spread in Treasury bonds and the GNMA-Treasury spreads in our sample period. This indicates that flight-to-liquidity episodes and more generally investors' preference for trading on-the-run nominal Treasury bonds also help explain the yield differential between nominal yields and inflation-indexed yields. This empirical finding indicates that while during a flight-to-liquidity episode investors rush into nominal on-the-run US Treasuries, they do not buy US TIPS to the same degree. This is especially interesting given that both types of bonds are fully backed by the same issuer, the US Treasury.

Column 4 in Table II shows that the freely estimated coefficient on the asset-swap-spread differential is at -1.59 somewhat larger in absolute value than -1. During the financial crisis securities markets were severely disrupted and the buyers and sellers of asset swaps may not have acted as the marginal buyers and sellers of TIPS. Estimating freely the regression coefficient on the asset-swap-spread accounts for the possibility that the asset-swap-spread

only represents a fraction of the financing cost for the marginal holder of TIPS. The standard error on the regression coefficient indicates that it is precisely estimated. The large size of this parameter suggests the relevance of liquidity factors in explaining the sharp fall in breakeven during the financial crisis, since the asset-swap-spread differential behaves almost like a dummy variable that spikes up during the financial crisis. Nonetheless, the difference between the liquidity component estimated in columns 3 and 4 appears small as indicated by the very similar R^2 and we will focus on the freely estimated version from column 4 for its flexibility.

One might be concerned that our estimation of the liquidity premium L relies on extrapolation outside the range of historically observed liquidity events. The effect of our liquidity proxies on the liquidity premium in TIPS might be nonlinear and this might lead to significant errors in the extreme values of the estimated liquidity premium. We therefore include additional quadratic terms into the estimation of the liquidity premium in column 5. Further results including interaction terms are reported in the Appendix. The squared off-the-run spread and GNMA spread enter significantly and while their addition only yields a small improvement in the R^2 from 67% to 70% one could imagine that their impact would be substantial on our liquidity estimates during events of extreme liquidity or extreme illiquidity.

The results are not sensitive to the inclusion of the financial crisis in the sample period. In column 6 we obtain very similar regression coefficients and an R^2 of 47% over a sample period from 1999 to 2006.

If inflation expectations are correlated with liquidity in the TIPS market one might be worried that this affects our estimation of the liquidity premium in Table II. We therefore complement our regressions with survey inflation expectations as in D'Amico, Kim and Wei

(2008). In order to control for movements in expected inflation we consider the difference between breakeven inflation and survey inflation expectations and regress this difference onto our liquidity proxies. We use the 10 year forecast of CPI inflation from the Survey of Professional forecasters, which is available at a quarterly frequency and is released towards the end of the middle month of the quarter. We therefore can only use quarterly data for this exercise and we use breakeven inflation and our liquidity proxies at the end of the second month of each quarter.

Table II, columns 7 and 8 show the quarterly regression of breakeven inflation and of the difference between breakeven inflation and survey expectations onto the liquidity proxies. Newey-West standard errors with four lags are shown in brackets. The regression coefficients are similar to the monthly regressions reported in the other columns of Table II. If anything the significance of the coefficients increases when taking out survey expectations.

Figure 2 shows our liquidity premium as estimated in our unconstrained linear specification in column 4 as well as the liquidity premium as estimated in columns 3 and 5. We will refer to column 3 as the "constrained" estimate, because the coefficient on the asset-swap-spread is set to -1. The estimate from column 5 with quadratic terms will be referred to as "nonlinear".

Our unconstrained linear specification yields an average spread due to liquidity of around 106 bps. Although this average is high, one must take into account that it reflects periods of very low liquidity in this market. Figure 2 shows a high liquidity premium in the early 2000's (about 120 bps), but a much lower liquidity premium between 2004 and 2007 (70 bps). The premium shoots up again beyond 200 bps during the crisis, and finally comes down to 70 bps after the crisis.

Our alternate specifications yield somewhat lower average values for liquidity premium at 71 bps (nonlinear estimate) and 89 bps (constrained estimate) but they show extremely similar time series variation. The nonlinear specification suggests that the liquidity premium in normal times might be as low as 40 bps and the liquidity premium during the initial period of TIPS might have been around 70 to 80 bps. However, all three specifications suggest that the liquidity premium reached prior unprecedented levels of over 200 bps during the financial crisis.

The time series of our liquidity premium is consistent with the findings in D'Amico, Kim and Wei (2008) but the level of the unconstrained linear estimate is a little higher. In recent work Fleckenstein, Longstaff and Lustig (2010) show that inflation swaps, which allow investors to trade on inflation without putting up any initial capital, appear to be mispriced relative to breakeven inflation in the cash market for TIPS and nominal Treasury bonds. Their series of average mispricing between synthetic and cash breakeven inflation resembles our series of differential financing costs $ASW_{n,t}^{spread}$ both in terms of level and time series variation. Our estimated liquidity premium could be interpreted as a measure of mispricing of TIPS relative to nominal Treasury bonds and we find this to be even larger than the mispricing relative to synthetic instruments.

The high liquidity premium in TIPS is puzzling given that bid-ask spreads on TIPS are small. As previously noted by Wright (2009) it seems implausible that the liquidity premium in TIPS yields simply serves to amortize transaction costs of a long-term investor. Haubrich, Pennachi and Ritchken (2010) report bid-ask spreads for TIPS between 0.5 bps up to a high of 10 bps during the financial crisis. As argued before, TIPS should typically be held by buy-and-hold investors. In a simple model of liquidity, such as given in Amihud, Mendelson

and Pedersen (2005), a transaction cost of 10 bps can only justify a liquidity premium of 1bp for a 10 year TIPS that is held by a buy-and-hold investor.

It is instructive to compare the liquidity premium for TIPS to the liquidity premium for off-the-run nominal Treasuries, adjusted for the likely time to convergence of the liquidity differential. The average off-the-run spread over our sample period is about 4 bps. However, the on-the-run off-the-run liquidity differential can be expected to converge when the new on-the-run nominal 10 year bond is issued. Therefore, convergence of the on-the-run off-the-run liquidity differential should take at most six months. Thus the annualized return on the liquidity differential between 10 year on-the-run and off-the-run nominal Treasury bonds is about 80 bps. On the other hand, the TIPS liquidity premium might only converge throughout the life of the bond and hence persist for 10 years for a 10 year TIPS. The annualized return on liquidity from 10-year zero-coupon TIPS then should be approximately equal to our estimate of the liquidity premium, i.e., between 40bps and 70bps during normal times. These simple calculations imply that the estimated liquidity premium in TIPS, though puzzlingly large when compared to bid-ask spreads, give rise to liquidity returns which are comparable in magnitude to those on off-the-run nominal Treasuries.

Figures 3 and 4 show liquidity-adjusted breakeven inflation and TIPS yields, respectively. The regression constant in Table II can be interpreted as the average liquidity-adjusted breakeven inflation for the respective specification of the liquidity premium. While the unconstrained estimation suggests an average liquidity-adjusted breakeven over our sample period of 3.3%, the nonlinear estimate suggests an average breakeven inflation of only 3.0%. We can also see that liquidity-adjusted breakeven inflation is much more stable than non-adjusted breakeven inflation. Table II , column 4 shows an R^2 of 67%, implying that the

variance of liquidity-adjusted breakeven is only one third of the variance of non-adjusted breakeven. Both specifications indicate that liquidity-adjusted breakeven inflation has been stable over our sample period and attribute the drop in breakeven inflation during the fall of 2008 to liquidity. Figure 4 shows that if TIPS had remained as liquid as nominal Treasuries their yields would have dropped dramatically in the fall of 2008. This has important implications for the interpretation of the dramatic reduction in breakeven inflation observed during the financial crisis as an indicator of massive expected deflation among bond market participants.

II Testing For Market Segmentation Effects

Pflueger and Viceira (2011) documented economically and statistically significant excess return predictability in inflation-indexed bonds and in the difference between nominal bonds and inflation-indexed bonds. In this section we explore whether shocks to the relative supply of nominal and inflation-indexed bonds can explain these findings.

The preferred-habitat hypothesis of Modigliani and Sutch (1966) states that the preference of certain types of investors for specific bond maturities might result in supply imbalances and price pressure in the bond market. In recent work Vayanos and Vila (2009) formalize this hypothesis in a theory where risk averse arbitrageurs do not fully offset the price imbalances generated by the presence of preferred-habitat investors in the bond market, leading to excess bond return predictability. Greenwood and Vayanos (2008) and Hamilton and Wu (2010) find empirical support for this theory using the relative supply of nominal Treasury bonds at different maturities as a proxy for supply shocks.

Following Greenwood and Vayanos (2008) we try to control for the potential segmentation between both markets and supply effects using the outstanding supply of real bonds relative to total government debt. If supply is subject to exogenous shocks while clientele demand is stable over time we would expect increases in the relative supply of inflation-indexed bonds to be correlated with contemporary decreases in breakeven inflation, as the price of inflation-indexed bonds falls in response to excess supply. Subsequently we would expect to see positive returns on inflation-indexed bonds as their prices rebound.

Alternatively, it could be the case that bond demand changes over time, and the government tries to accommodate changes in demand. This would be consistent with a debt management policy that tries to take advantage of interest rate differentials across both markets. In this case we would expect the relative supply of inflation-indexed bonds to be unrelated to subsequent returns, and possibly to be even positively correlated with contemporaneous breakeven inflation.

We measure the relative supply of inflation-indexed bonds in the US as the nominal amount of TIPS outstanding relative to US government TIPS, notes and bonds outstanding.[12] The relative supply variable for the UK is computed similarly, as the total amount of inflation-linked gilts relative to the total amount of conventional gilts outstanding. [13]

[12] The economic report of the president reports US Treasury securities by kind of obligation and reports T-bills, Treasury notes, Treasury bonds and TIPS separately. The data can be found in Table 85 for the reports until 2000 and in Table 87 in subsequent reports at http://www.gpoaccess.gov/eop/download.html. The face value of TIPS outstanding available in the data is the original face value at issuance times the inflation incurred since then and therefore it increases with inflation. The numbers include both privately held Treasury securities and Federal Reserve and intragovernmental holdings as in Greenwood and Vayanos (2008).

[13] We are deeply grateful to the UK Debt Management Office for providing us with the UK data. Conventional gilts exclude floating-rate and double-dated gilts but include undated gilts. The face value of index-linked gilts does not include inflation-uplift and is reported as the original nominal issuance value. Our results are not sensitive to including or excluding the inflation uplift.

Let D_t^{TIPS} denote the face value of inflation-indexed bonds outstanding and D_t the combined face value of nominal and inflation-indexed bonds outstanding at time t for either the US or the UK. We define the relative supply as

$$Supply_t = D_t^{TIPS}/D_t. \tag{13}$$

We also consider the relative issuance $\Delta Supply_t$, which we compute as

$$\Delta Supply_t = \left(D_t^{TIPS} - D_{t-1}^{TIPS}\right)/D_{t-1}^{TIPS} - \left(D_t - D_{t-1}\right)/D_{t-1}. \tag{14}$$

Figure 5A plots the relative supply of TIPS, D_t^{TIPS}/D_t, and 10 year breakeven inflation in the US. It illustrates the rapid increase in the relative amount of TIPS outstanding. Starting from less than 2% in 1997 TIPS increased to represent over 14% of the US Treasury coupon bond portfolio in 2008. Subsequently to the financial crisis the US government issued substantial amounts of nominal notes and bonds, leading to a drop in the relative TIPS share in 2009. At the same time the level of breakeven inflation remained relatively steady over this 11 year period with a large drop in the fall of 2008, as discussed earlier.

Figure 5B illustrates the history of the relative share of UK inflation-linked gilts outstanding. The relative share of linkers has increased over the period from about 8% in 1985 to over 17% in 2008. At the same time 20 year UK breakeven inflation has fallen in the period 1985-2009, reaching a low of 2.1% in 1998. The increase in inflation-linked bonds outstanding accelerated noticeably after 2004. Greenwood and Vayanos (2009) analyze this episode in light of the UK Pensions Act of 2004, which provided pension funds with a strong incentive to buy long-maturity and inflation-linked government bonds and subsequently led

the government to increase issuance of long-maturity and inflation-linked bonds.

Table II shows regressions of breakeven inflation onto the relative supply of inflation-indexed bonds. If markets are segmented and subject to exogenous supply shocks we would expect a negative coefficient on measures of relative supply of inflation-indexed bonds. In the US neither the relative supply nor relative issuance $\Delta Supply_t$ appear to be related to breakeven inflation. The results do not change when we add our liquidity proxies or a time trend as controls.

One might be concerned that the relative supply of TIPS has been very predictable and therefore does not represent an adequate measure of supply shocks. In the Appendix we conduct Dickey-Fuller tests to find that in the US we cannot reject a unit root in $Supply_t$ or in $\Delta Supply_t$. However, the year-over-year change in relative issuance appears stationary and we construct a supply shock ε_t^{Supply} as the residual from an autoregression of $\Delta Supply_t - \Delta Supply_{t-12}$ with twelve lags. In the UK we can reject stationarity in relative issuance $\Delta Supply_t$, potentially reflecting the less regular issuance cycle in the UK, and we construct a supply shock ε_t^{Supply} as the residual from an autoregression of $\Delta Supply_t$ with twelve lags. We add the residual shock ε_t^{Supply} as a potential explanatory variable to our regressions in Table II.

The US supply shock $\varepsilon_t^{Supply_t}$ by itself covaries positively with breakeven inflation and is marginally significant but this effect goes away when we add the liquidity controls. Those results suggest that the US government might react to yield differentials and moreover might react to differential liquidity between the nominal and inflation-indexed markets.

Table IIB shows regressions of UK breakeven inflation onto the relative supply. Due to

data constraints we are not able to control for liquidity. The results are very similar to the US results, even though the maturities of the bonds and the sample periods are different: The supply variable is significant but it switches sign as we include a time trend in the regression, while the change in supply does not enter significantly. The time trend is highly statistically significant and increases the R^2 from 26% to 65%. The supply shock variable ε_t^{Supply} does not appear to commove with breakeven inflation either positively or negatively.

Figure 5B helps to interpret the supply coefficient's sign change when adding a time trend. Since the mid-1980's the supply of inflation linkers in the UK has risen, while breakeven inflation has been generally declining. This secular decline in breakeven inflation likely reflects changes in monetary policy and declines in both realized and expected inflation (Campbell, Shiller, and Viceira 2009), rather than changes in bond supply. A simple regression of UK breakeven on the supply of inflation linkers therefore gives a negative slope. Introducing a time trend takes care of this common inverse trend, and switches the sign of the slope on the supply variable to positive. This positive partial correlation might again lend weight to the interpretation that the UK government reacts to increased demand for inflation-linked bonds by issuing more inflation-indexed bonds, an interpretation that would be consistent with the episode described in Greenwood and Vayanos (2009).

If markets are segmented we would expect a positive shock in the relative supply of inflation-indexed bonds to predict lower excess returns on nominal bonds over inflation-indexed bonds. Our left-hand-side variables in Table IV are the nominal, inflation-indexed and breakeven returns as defined in (3), (4) and (5). Pflueger and Viceira (2011) show that nominal, TIPS and breakeven term spreads are significant predictors of the corresponding excess returns and therefore we control for these spreads in our regressions. One might also

think that liquidity should predict bond excess returns and we therefore include it as an additional control.

Panel A in Table IV shows that in the US the supply variables do not help to predict bond excess returns. TIPS and breakeven term spreads still enter significantly and predict TIPS excess returns and breakeven excess returns, respectively, after including liquidity and supply effects. The liquidity premium enters significantly and in particular helps predict the breakeven return. The results are extremely similar for the UK.

Overall, we find no evidence of supply shocks predicting bond excess returns. In particular our measures of relative supply shocks cannot explain why term spreads predict excess returns on inflation-indexed bonds and on nominal bonds in excess of inflation-indexed bonds as found in Pflueger and Viceira (2011).

In summary, there is no evidence of relative supply shocks predicting bond excess returns in either the UK or the US. We find some weak evidence that relative supply of inflation-indexed bonds moves positively with breakeven inflation. These results do not seem consistent with segmented markets that are subject to exogenous supply shocks. Instead they might be consistent with the US and UK governments accommodating demand pressures from investors for nominal or inflation-indexed bonds. Panel A in Table III shows that liquidity is also a very strong predictor of breakeven excess returns in the US. We therefore proceed to analyze the role of liquidity more closely by decomposing breakeven inflation into a liquidity component and liquidity-adjusted breakeven inflation.

III Time-Variation of Real Interest Rate and Inflation Risk Premia

A Predictive regressions with liquidity-adjusted yields and returns

In this section we decompose return-predictability in nominal and inflation-indexed bonds. Inflation-indexed bond return predictability could be the result of either a time-varying real interest rate risk premium, a time-varying liquidity premium, or a combination of both—since supply effects do not seem to matter. Breakeven and nominal bond excess return predictability could be the result of a time-varying inflation-risk premium and time-varying liquidity.

We can use our estimates of liquidity effects on inflation-indexed bond prices and returns to disentangle these effects. We start by replacing the TIPS yield by the liquidity-adjusted TIPS yield (11) and breakeven by liquidity-adjusted breakeven (12) and use these to compute liquidity-adjusted TIPS and breakeven returns according to

$$xr_{n,t+1}^{TIPS-L} = ny_{n,t}^{TIPS,adj} - (n-1)\, y_{n-1,t+1}^{TIPS,adj} - y_{1,t}^{TIPS}, \tag{15}$$

$$xr_{n,t+1}^{b+L} = xr_{n,t+1}^{\$} - xr_{n,t+1}^{TIPS-L}. \tag{16}$$

We also examine whether there is evidence of a time-varying liquidity risk premium, by

looking at the predictability of the liquidity return. We define the liquidity return as

$$r_{n,t+1}^{L} = -\left(n-1\right) L_{n-1,t+1} + nL_{n,t}. \tag{17}$$

We can think of $r_{n,t+1}^{L}$ as the return on TIPS return due to time-varying liquidity.

Our estimates for the liquidity premium $L_{n,t}$ are based on the full-period regression allowing for a flexible regression coefficient on the asset-swap spread, reported in Table II, column 4 but our results are not sensitive to the particular specification of $L_{n,t}$, as we show in the Appendix.

Table V shows that conditional on our estimates of liquidity-adjusted yields and returns, the real yield spread forecasts positively inflation-indexed bond returns, and the breakeven inflation spread forecasts breakeven returns—or the return on nominal bonds in excess of the return on inflation-indexed bonds. This provides support for the hypothesis that real and nominal bond term spreads reflect time-varying real interest rate and inflation risk premia. Remarkably the liquidity variable does not predict liquidity-adjusted real bond excess returns or breakeven excess returns. The current level of the liquidity premium does not appear to be related to fundamental cash-flow risk as represented by the real interest rate risk premium or the inflation risk premium.

The results shown use excess returns on TIPS over our hypothetical real short rate. However, the return-predictability results in Table V hold up if instead we consider nominal returns on TIPS in excess of the nominal short rate, as shown in the Appendix.

The last column of Table V reports a regression of the liquidity return $r_{n,t+1}^{L}$ onto the liquidity-adjusted real term premium, the liquidity-adjusted breakeven spread, and $L_{n,t}$. We

find that the liquidity return is predictable from the liquidity premium with a large and highly significant regression coefficient, suggesting that the return-predictability in TIPS found in Pflueger and Viceira (2011) is at least partly due to a time-varying and predictable liquidity premium. The effect of the liquidity premium on returns is such that when liquidity in the TIPS market is scarce, TIPS enjoy a higher expected return relatively to nominal bonds, rewarding investors who are willing to invest into a temporarily less liquid market.

The results shown in Table V strongly suggest that return-predictability in inflation-indexed and nominal government bonds in Pflueger and Viceira (2011) is driven by a combination of factors. Our results offer support for a time-varying real interest rate risk premium and a time-varying liquidity premium in TIPS and for a time-varying inflation risk premium in nominal bonds.

B Historical Fitted Risk Premia and Systematic Risk

We next aim to better understand the economic significance of the different components of bond returns. Specifically, Table VI compares the market-loadings and predictability of the different bond return components. [14]

Our estimates attribute the negative average breakeven inflation returns over our sample period to the large liquidity effects in TIPS.[15] After adjusting for liquidity, we obtain a

[14] In Panel A we obtain liquidity-adjusted expected excess log returns and expected liquidity returns as fitted values from the regressions shown in columns 1, 3 and 4 in Table V. Our average return calculations are based on log returns with no variance adjustments for Jensen's inequality. We compute CAPM betas using the stock market as the proxy for the wealth portfolio. The US excess stock return is the log quarterly return on the value-weighted CRSP index, rebalanced annually, in excess of our log 3 month interest rate. The UK excess stock return similarly is computed as the log quarterly total return on the FTSE in excess of our log 3 month interest rate.

[15] In Panel A, the moments of non liquidity-adjusted excess log returns are for a slightly longer sample pe-

positive breakeven inflation return of 74 bps p.a. on average. The estimated average TIPS return due to time-variation in liquidity is large at 1.36% p.a.. At the same time our estimates imply that even controlling for liquidity the average return on TIPS has been positive at 2.87% p.a..

The second column in the panel investigates the extent to which excess returns are systematic. The upper half of the panel shows that over our sample period the CAPM beta of nominal bonds and breakeven inflation have been significantly negative, both economically and statistically, while the CAPM beta of TIPS has been essentially zero. The lower half of the panel shows that by contrast the CAPM beta on liquidity-adjusted breakeven inflation returns has been zero, and the CAPM beta liquidity-adjusted TIPS returns has been negative and highly significant at -0.46. We also estimate a positive and highly significant beta of 0.53 on the returns on the liquidity premium.[16]

Our estimates of CAPM betas of liquidity-adjusted returns suggest that liquidity risk explains most of the systematic variation in breakeven inflation returns. The positive beta on liquidity implies that TIPS tend to become illiquid relative to nominal Treasury bonds—or conversely, Treasury bonds become more liquid relative to TIPS—at times when the stock valuations fall. The strong positive covariation of our liquidity estimate with stock returns suggests that investors should expect to earn a premium on TIPS for bearing systematic variation in liquidity.

riod (1999.4-2009.12) than the moments of liquidity-adjusted returns and liquidity returns (1999.6-2009.12). This explains why the average liquidity-adjusted excess log return on TIPS and the log return on liquidity do not exactly add up to the average excess log return on TIPS.

[16] Our results are robust to excluding the financial crisis period from the estimation of CAPM betas. Excess log returns on TIPS, nominal Treasuries, breakeven inflation, and our measure of liquidity do not load significantly on Fama-French value and size factors. For details see the Appendix.

Nevertheless, systematic risk does not fully explain the returns on liquidity over our sample period. In the Appendix we show that after controlling for market returns the average return on TIPS liquidity is still positive. The market alpha of liquidity returns is statistically significant for the full time period but not for a more recent sub-period starting in 2002. Adding additional controls for size, value, and the Pastor-Stambaugh (2003) liquidity factor also renders the intercept insignificant. These results suggests that the positive alpha was at least partly related to the novelty of TIPS and due to particular market conditions during the first few years of TIPS issuance. Once TIPS were more solidly established the intercept was still positive but no longer statistically significant and it seems plausible to think that this positive intercept will be smaller going forward.

The negative beta of liquidity-adjusted TIPS returns imply a pro-cyclical behavior of real interest rates in the framework of Campbell, Sunderam, and Viceira (2011). Once we adjust for liquidity we find a breakeven inflation beta that is close to zero, so that systematic inflation risk appears to have been negligible during our sample period.[17] Procyclical behavior of real interest rates and low inflation risk makes all Treasury bonds, whether nominal or inflation-indexed, safe assets that provide investors with sizable diversification benefits relative to stocks.

In order to understand the economic significance of the estimated return predictability, we now calculate the volatilities of predicted returns and compare them to the variability of realized returns. We obtain the expected liquidity-adjusted breakeven returns, the expected liquidity-adjusted TIPS returns and expected liquidity returns from the return-predictive

[17] These results suggest that the negative inflation risk premium estimated by Campbell, Sunderam and Viceira (2010) over our sample period might have been partly caused by systematic variation in the relative liquidity of TIPS and nominal Treasury bonds.

regressions in Table V. We obtain the expected excess returns on nominal bonds, TIPS and breakeven inflation as in Pflueger and Viceira (2011). They specify the nominal risk premium at any point in time as the expected excess log return on nominal bonds predicted by the nominal term spread. They obtain TIPS and breakeven risk premia as fitted values of regressions analogous to those in Table V, column 1 and Table V, column 3 without any liquidity adjustments.

From the second column of Panel A in Table VI we see that expected liquidity returns were the most volatile component of predictable returns. Time-varying expected liquidity returns can account for 12% of the variance of realized TIPS returns, while time-variation in the expected returns on liquidity-adjusted TIPS explain 6% of the variance of realized TIPS returns. The time-variation in expected returns on liquidity-adjusted breakeven inflation and TIPS can account for 3% and 5% of the sample variability of realized nominal bond returns, respectively.

For the alternate estimates of the liquidity premium we obtain a lower but positive average liquidity returns and a lower but positive average liquidity-adjusted breakeven returns but betas and volatilities look similar. More details can be found in the Appendix.

Figure 6A illustrates the time series of the fitted US expected excess returns. We interpret the expected liquidity excess return as a liquidity return premium, the expected liquidity-adjusted breakeven return as an inflation risk premium and expected liquidity-adjusted TIPS returns as a real rate risk premium. It shows that during the period of 2000 to 2006 the inflation risk premium was small or negative. During the period of high oil prices in 2008 and during the peak of the financial crisis in late 2008 the inflation risk premium was positive but subsequently fell to almost -10% at the end of 2009, precisely at a time when the real

rate risk premium increased sharply. The liquidity risk premium on TIPS was large in the early 2000's, but declined steadily during the decade, with the exception of a pronounced spike during the financial crisis in the Fall of 2008.

Panel B in Table VI shows similar statistics for UK excess bond returns over the longer sample period 1985-2009. Due to data constraints we are not able to compute a liquidity-adjustment for the UK. However, arguably liquidity-adjustments in the UK bond market are likely to be less significant than in the US bond market. UK inflation-linked bonds have been issued for a significantly longer period and therefore it appears plausible that initial learning should affect only a small portion of their time series. Moreover, neither UK nominal nor inflation-indexed bonds are likely to enjoy the same extraordinary liquidity benefits as US nominal Treasury bonds, suggesting that "flight-to-liquidity" effects should be less significant in generating a liquidity differential between inflation-indexed and nominal bonds in the UK.

We find an average excess return on inflation-indexed bonds of 1.66% p.a., and an average excess return on inflation-indexed bonds of 1.81% per annum in UK bonds. If instead UK inflation-indexed bonds were less liquid than nominal UK bonds then the liquidity-adjusted breakeven excess return might be slightly higher and the excess return on inflation-indexed bonds might be slightly lower. Both of these components of UK bond risk premia appear economically significant. In particular, we estimate a slightly larger excess return on breakeven inflation for UK bonds than for US bonds.

The CAPM beta of UK inflation-indexed bonds at 0.15 is positive and statistically significant, while the CAPM beta of breakeven inflation is essentially zero over the full sample. The betas on UK bonds indicate that on average inflation-indexed bonds, and to some degree nominal bonds, have been risky over the time period under consideration. On the other

hand, breakeven inflation has not exhibited any systematic risk. However, the UK betas hide important variation across sub-periods. In the Appendix we show that the beta of UK breakeven inflation was positive in the period prior to 1999 and turned negative and significant in the post-1998 period, suggesting that inflation risk in nominal bonds was much more pronounced in the first half of the sample.

Interestingly, Figure 6B suggests that the UK breakeven risk premium shot up during the financial crisis and in contrast to the US has remained high. In the framework of Campbell, Sunderam, and Viceira (2010) this could indicate that while investors in the UK fear that further economic deterioration will go along with inflation, US investors are concerned about low growth accompanied by low inflation or even deflation.

IV Conclusion

This paper explores the sources, magnitude, and time variation in bond risk premia in US and UK inflation-indexed and nominal bonds. We find strong empirical evidence for two different potential sources of excess return predictability in inflation-indexed bonds: real interest rate risk and liquidity. We also provide empirical evidence that nominal bond return predictability is related to both time variation in the real interest rate risk premium and time variation in the inflation risk premium.

Using a variety of liquidity indicators, we find that the liquidity premium on TIPS yields relative to nominal Treasury bond yields exhibits strong time-variation, with a large premium in the vicinity of 70 to 120 bps early in the life of TIPS, a significant decline to a lower premium of 40 to 70 bps after 2004, and a sharp increase to over 200 bps during the height

of the financial crisis in the fall of 2008 and winter of 2009. Since then, the premium has declined back to 50 to 80 bps.

Time-varying liquidity explains up to 67% of the time-series variance of breakeven inflation. Once we adjust breakeven inflation for liquidity effects, we find it to be stable over our sample period around 3%, suggesting that bond investors' long-term inflation expectations in the US have not moved significantly, even during the financial crisis.

In our analysis of price pressures due to supply shocks in the inflation-indexed bond market we find no evidence for a supply channel in either the US or in the UK. If anything, our results are consistent with the government trying to accommodate shifts in the demand for nominal bonds, relative to inflation-indexed bonds.

A high liquidity return can explain why US TIPS have exhibited higher excess returns than nominal Treasuries over the 1999-2009 period. Returns due to liquidity appear to be highly systematic and are correlated with aggregate stock returns, indicating that investors should expect to be paid a return premium for bearing this risk.

Variation in expected liquidity excess returns explains a substantial 12% of the observed variation in TIPS returns. The liquidity premium does not predict liquidity-adjusted returns on TIPS or on breakeven, so that it does not seem to proxy for any real interest rate risk or inflation risk. Hence, while we find that the liquidity differential between nominal bonds and TIPS moves with the aggregate market, it bears no relationship to the real cash flow risks of the specific securities, a conclusion that should be important in guiding future models of liquidity.

Our liquidity premium is correlated with other liquidity spreads in fixed income markets,

particularly the off-the-run spread (Krishnamurthy, 2002), and it exhibits an economically and statistically significant positive CAPM beta, suggesting that the liquidity premium is at least partly systematic in nature. A simple calculation also suggests that the liquidity returns on TIPS during normal times are comparable to the liquidity returns on off-the-run nominal Treasury bonds.

A possible interpretation of this result is that we partly identify a liquidity premium or convenience yield on nominal Treasury bonds (Krishnamurthy and Vissing-Jorgensen, 2010), rather than a liquidity discount specific to TIPS. Under this interpretation TIPS are not undervalued securities; instead investors appear to be willing to pay a liquidity premium on nominal Treasury bonds. The Treasury could take advantage of this premium by issuing more nominal Treasury bonds, but it would still be issuing TIPS at their fair value. If investors appropriately value TIPS, taking them off the market might have adverse welfare consequences for investors in need of the real interest rate hedge and inflation hedge offered by TIPS (Campbell and Viceira 2002).

Our results suggest several directions for future research. First, inflation expectations are a major input into monetary policy. One could adjust breakeven inflation for the forms of inflation risk premia and liquidity premia found in this paper to obtain a measure of long-term expected inflation. It would be informative to see whether this is a good predictor of future inflation and other macroeconomic variables. Second, different classes of investors have different degrees of exposure to time-varying liquidity, real interest rate risk and inflation risk. It would be interesting to understand the implications for portfolio management and pension investing and how these implications vary by investment horizon and the investor's share of real and nominal liabilities. Third, our analysis of supply effects in the inflation-indexed

market suggests to further explore strategic behavior by the government in accommodating shifts in the demand for nominal and real bonds.

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Table I
Summary Statistics

US data is monthly 1999.4-2009.12 and UK data is monthly 1985.4-2009.12. The US Asset-Swap Spread (ASW) is monthly 2007.7-2009.4. The nominal government bond yield $y^{\$}_{n,t}$, TIPS yield $y^{TIPS}_{n,t}$, breakeven inflation $b_{n,t} = y^{\$}_{n,t} - y^{TIPS}_{n,t}$, Off-the-Run Spread, GNMA Spread and ASW are expressed in annualized % units. The summary statistics for quarterly overlapping nominal excess log returns $xr^{\$}_{n,t+1}$, TIPS excess log returns $xr^{TIPS}_{n,t+1}$ and breakeven excess log returns $xr^{b}_{n,t+1}$ are in annualized %. Transaction volume refers to the log of TIPS transaction volume relative to the transaction volume of all government coupon securities with at least 6 years to maturity.

	Panel A: US 10 YR				**Panel B: UK 20 YR**			
	Mean	Std	Min	Max	Mean	Std	Min	Max
$y^{\$}_{n,t}$	4.80	0.80	1.25	6.70	6.38	1.94	3.79	9.93
$y^{TIPS}_{n,t}$	2.55	0.85	1.25	4.29	2.79	1.14	0.56	4.57
$b_{n,t}$	2.25	0.40	0.45	2.87	3.59	0.94	2.07	5.50
$xr^{\$}_{n,t+1}$	3.26	8.57	−41.89	56.62	3.47	14.67	−104.94	109.32
$xr^{TIPS}_{n,t+1}$	4.16	7.67	−65.02	56.26	1.66	9.25	−67.90	64.47
$xr^{b}_{n,t+1}$	−0.91	7.22	−39.52	74.24	1.81	11.97	−103.21	84.79
Off-the-run Spr.	0.04	0.14	−0.41	0.59	NA			
GNMA Spr.	0.90	0.17	0.15	1.92	NA			
Transaction Vol.	−0.57	0.45	−1.44	0.00	NA			
ASW	0.64	0.37	0.44	1.30	NA			

Table II
Breakeven onto Liquidity Proxies US

We regress the difference between nominal bond yields and TIPS (breakeven inflation) onto liquidity proxies. π^{SPF} denotes the 10 year CPI- inflation forecast from the Survey of Professional Forecasters. Monthly (quarterly) regressions provide Newey-West standard errors with three (four) lags in parentheses. The p-value of the F-test for no predictability is shown. * and ** denote significance at the 5% and 1% level, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
				$y^{\$}_{n,t} - y^{TIPS}_{n,t}$				$y^{\$}_{n,t} - y^{TIPS}_{n,t} - \pi^{SPF}$
Off-the-run Spr.	-0.63^{**}	-0.49^{**}	-0.53^{**}	-0.59^{**}	-0.48^{**}	-0.56^{**}	-0.75^{**}	-0.75^{**}
	(0.23)	(0.18)	(0.18)	(0.17)	(0.14)	(0.15)	(0.19)	(0.20)
GNMA Spr.		-0.46^{**}	-0.37^{**}	-0.19	0.56^{**}	-0.21	-0.24	-0.32^{*}
		(0.08)	(0.12)	(0.11)	(0.27)	(0.16)	(0.15)	(0.15)
Transaction Vol.			0.16	0.28^{**}	0.30^{**}	0.32^{**}	0.23^{**}	0.22^{*}
			(0.09)	(0.08)	(0.08)	(0.12)	(0.08)	(0.09)
Asset-Swap-Spr.	set -1	set -1	set -1	-1.59^{**}	-1.31^{**}		-1.66^{**}	-1.56^{**}
				(0.20)	(0.15)		(0.21)	(0.23)
$(\text{Off-the-run Spr.})^2$					-488.7^{*}			
					(189.9)			
$(\text{GNMA Spr.})^2$					-171.9^{**}			
					(63.3)			
const.	$2..71^{**}$	3.12^{**}	3.13^{**}	3.30^{**}	2.95^{**}	2.72^{**}	3.38^{**}	0.92^{**}
	(0.04)	(0.08)	(0.08)	(0.09)	(0.11)	(0.09)	(0.12)	(0.12)
p-value	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
R^2	0.44	0.56	0.64	0.67	0.70	0.47	0.71	0.70
Sample			$1999.3 - 2009.12$			$1999.3 - 2006.12$	$1999.Q1 - 2009.Q4$	

Table III
Breakeven Inflation onto Relative Supply

We regress the difference between nominal bond yields and inflation-indexed yields (breakeven inflation) onto measures of relative supply We control for liquidity measures as in Table II and a time trend. $Supply_t$ denotes the amount of inflation-indexed bonds outstanding relative to all nominal and inflation-indexed bonds outstanding. $\Delta Supply_t$ denotes the issuance of inflation-indexed bonds relative to all nominal and inflation-indexed bonds issuance. ε_t^{Supply} is obtained as the residual in a 12-lag monthly autoregression of $\Delta Supply_t - \Delta Supply_{t-12}$ ($\Delta Supply_t$) in the US (UK). Newey-West standard errors with three lags are provided in parentheses. The p-value of the F-test for no predictability is shown. * and ** denote significance at the 5% and 1% level, respectively.

Panel A: US						**Panel B: UK**				
$Supply_t$	0.01		−0.01			−0.27**		0.29**		
	(0.02)		(0.04)			(0.06)		(0.05)		
$\Delta Supply_t$		0.03	0.00				0.01	−0.01		
		(0.02)	(0.01)				(0.01)	(0.01)		
ε_t^{Supply}				0.04	0.00				0.00	0.00
				(0.02)	(0.01)				(0.02)	(0.01)
Off-the-run Spr.			−0.57**		−0.60**					
			(0.17)		(0.15)					
GNMA Spr.			−0.19		−0.20					
			(0.11)		(0.09)					
Transaction .			0.40**		0.39**					
			(0.15)		(0.11)					
Asset-Swap-Spr.			−1.55**		−1.53**					
			(0.22)		(0.17)					
$month \times 10^{-5}$			−0.11		−0.42			−3.43		−1.96**
			(0.92)		(0.32)			(0.29)		(0.21)
p-value	0.69	0.14	0.00	0.09	0.00	0.00	0.42	0.00	0.69	0.00
R^2	0.01	0.04	0.68	0.04	0.70	0.26	0.00	0.66	0.00	0.53
Sample	1999.3 − 2009.12			2000.2 − 2009.12		1985.1 − 2009.12			1986.1 − 2009.12	

Table IV
Excess Bond Returns onto Relative Supply of Inflation-Indexed Bonds

We regress log excess bond returns of TIPS, nominal bonds and nominal bonds over TIPS onto measures of relative supply as defined in Table III. We control for the nominal term spread, the TIPS term spread and the breakeven term spread as well as TIPS liquidity as estimated in Table II (4) and a time-trend. We use quarterly overlapping returns. Newey-West standard errors with three lags are provided in parentheses. The p-value of the F-test of no predictability is shown. * and ** denote significance at the 5% and 1% level, respectively.

Panel A: US						**Panel B: UK**				
	$xr^{\$}_{n,t+1}$	$xr^{TIPS}_{n,t+1}$	$xr^{b}_{n,t+1}$	$xr^{b}_{n,t+1}$	$xr^{b}_{n,t+1}$	$xr^{\$}_{n,t+1}$	$xr^{TIPS}_{n,t+1}$	$xr^{b}_{n,t+1}$	$xr^{b}_{n,t+1}$	$xr^{b}_{n,t+1}$
$y^{\$}_{n,t} - y^{\$}_{1,t}$	2.35					3.23				
	(1.52)					(1.76)				
$y^{TIPS}_{n,t} - y^{TIPS}_{1,t}$		3.30**		−1.81	−1.78		2.17		−3.02	−2.58
		(1.23)		(1.19)	(1.25)		(1.41)		(1.95)	(2.19)
$b_{n,t} - b_{1,t}$			5.67	6.44*	7.00*			7.39**	8.97**	9.00**
			(2.88)	(2.75)	(3.47)			(2.27)	(2.65)	(2.85)
$L_{n,t}$	−3.27	9.61	−13.10**	−9.78*	−10.49*					
	(6.49)	(6.02)	(3.78)	(4.65)	(4.27)					
$Supply_t$	0.26	0.14	−0.01	−0.21		−2.98	−2.72	−0.51	−1.75	
	(0.70)	(0.75)	(0.62)	(0.61)		(2.30)	(1.78)	(2.25)	(2.18)	
$\Delta Supply_t$	0.17	0.10	0.17	0.04		−0.14	−0.12	0.00	−0.05	
	(0.45)	(0.36)	(0.28)	(0.25)		(0.49)	(0.34)	(0.39)	(0.41)	
ε^{Supply}_t					−0.47					0.02
					(0.37)					(0.53)
$month \times 10^{-4}$					−1.27	0.73	1.83*	−1.69	−1.33	−2.05**
					(−1.38)	(1.41)	(0.89)	(1.13)	(1.09)	(0.69)
p-value	0.60	0.01	0.00	0.00	0.00	0.09	0.01	0.01	0.01	0.02
R^2	0.04	0.16	0.21	0.22	0.23	0.06	0.07	0.10	0.11	0.10
Sample		1999.3 − 2009.12					1985.4 − 2009.12			1986.4 − 2009.12

Table V
Liquidity-Adjusted Return Predictability US

We regress liquidity-adjusted excess log bond returns of TIPS and of nominal bonds in excess of TIPS onto the liquidity-adjusted TIPS term spread, the liquidity-adjusted breakeven term spread and the liquidity premium on TIPS $L_{n,t}$. $L_{n,t}$ is estimated as the fitted value less the constant from the regression in Table II (4). $r^L_{n,t+1}$ is the return on TIPS due to liquidity. We use quarterly overlapping returns. Newey-West standard errors with three lags appear in parentheses. The p-value of the F-test for no predictability is shown. * and ** denote significance at the 5% and 1% level, respectively.

	(1) $xr^{TIPS-L}_{n,t+1}$	(2) $xr^{b+L}_{n,t+1}$	(3) $xr^{b+L}_{n,t+1}$	(4) $r^L_{n,t+1}$
$(y^{TIPS}_{n,t} - L_{n,t}) - y^{TIPS}_{1,t}$	3.53*		−1.66	−0.03
	(1.41)		(1.12)	(0.77)
$(b_{n,t} + L_{n,t}) - b_{1,t}$		2.94	3.42*	−2.62
		(1.57)	(1.53)	(3.09)
$L_{n,t}$	−6.05	0.73	2.00	19.81**
	(11.09)	(6.23)	(6.86)	(6.18)
p-value	0.05	0.17	0.11	0.02
R^2	0.06	0.04	0.07	0.26
Sample			1999.6 − 2009.12	

Table VI
Moments of Realized and Fitted Bond Returns

We show summary statistics for realized excess log returns $xr_{n,t}$ and historical fitted risk premia $E_t\left(xr_{n,t+1}\right)$. We show realized sample moments $\hat{E}\left(xr_{n,t}\right)$ and $\hat{\beta}\left(xr_{n,t}\right)$ for excess log returns on nominal bonds, TIPS, breakeven, liquidity-adjusted breakeven, liquidity-adjusted TIPS and liquidity returns. Betas are with respect to excess log stock returns including dividends. We obtain US expected excess log returns for liquidity-adjusted breakeven, liquidity-adjusted TIPS and liquidity over 1999.6-2009.12 as fitted values from Tables V (1), V (3) and V (4). Expected nominal, TIPS and breakeven excess log returns breakeven were obtained in Pflueger and Viceira (2011) from analogous return-predictive regressions using no liquidity-adjustment over 1999.4-2009.12 (US) and 1985.4-2009.12 (UK). Numbers shown are annualized (%). Newey-West standard errors for $\hat{\beta}$ are computed with 3 lags. * and ** denote significance at the 5% and 1% level for $\hat{\beta}$, respectively.

Panel A: US	$\hat{E}\left(xr_{n,t}\right)$	$\hat{\beta}\left(xr_{n,t}\right)$	$\sigma\left(E_t xr_{n,t+1}\right)$	$\frac{\sigma^2(E_t xr_{n,t+1})}{\sigma^2\left(xr^{\$}_{n,t}\right)}$	$\frac{\sigma^2(E_t xr_{n,t+1})}{\sigma^2\left(xr^{TIPS}_{n,t}\right)}$
Excess Log Return Nominal	3.26	-0.40^{**}	1.56	3%	
Excess Log Return TIPS	4.16	0.06	2.70	10%	12%
Excess Log Return BEI	-0.91	-0.47^{*}	3.24	14%	
Liq.-Adj. Exc. Log Ret. BEI	0.74	0.07	1.38	3%	
Liq.-Adj. Exc. Log Ret. TIPS	2.87	-0.46^{**}	1.90	5%	6%
Log Return Liquidity	1.36	0.53^{**}	3.15		12%

Panel B: UK	$\hat{E}\left(xr_{n,t}\right)$	$\hat{\beta}\left(xr_{n,t}\right)$	$\sigma\left(E_t xr_{n,t+1}\right)$	$\frac{\sigma^2(E_t xr_{n,t+1})}{\sigma^2\left(xr^{\$}_{n,t}\right)}$	$\frac{\sigma^2(E_t xr_{n,t+1})}{\sigma^2\left(xr^{TIPS}_{n,t}\right)}$
Excess Log Return Nominal	3.47	0.16	3.13	5%	
Excess Log Return TIPS	1.66	0.15^{**}	1.84	2%	4%
Excess Log Return BEI	1.81	0.01	2.55	3%	

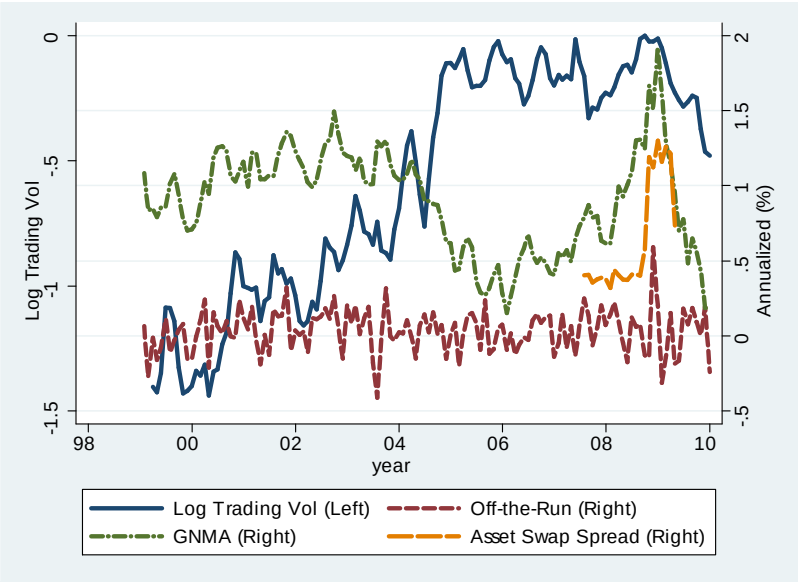

Figure1. US Liquidity Proxies 1999-2009. Relative TIPS Trading Volume from New York Federal Reserve survey FR-2004; GNMA spread from Bloomberg; 10 Year On-the-Run Off-the-Run spread from the Federal Reserve and Bloomberg; TIPS-Nominal Asset-Swap-Spread from Barclays Live.

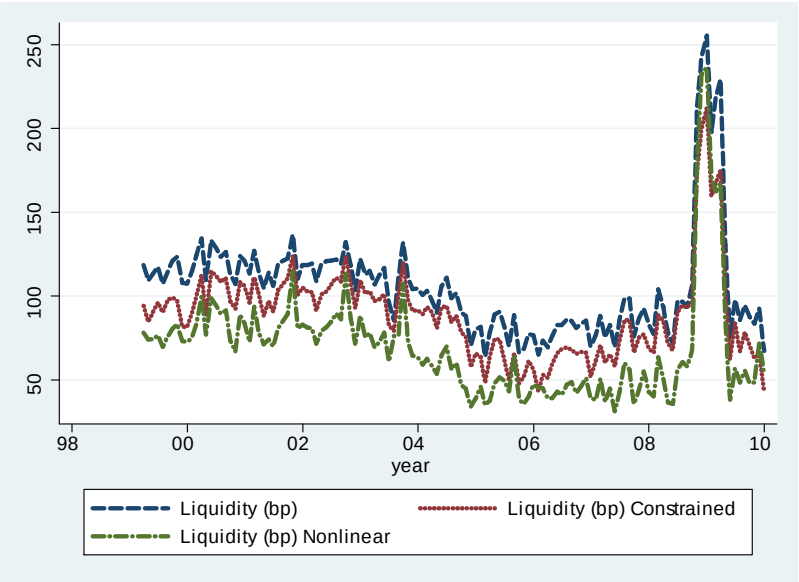

Figure 2. Estimated US Liquidity Premium. 10 Year TIPS Liquidity Premium estimated in Table I (4). The constrained liquidity premium constrainsthe coefficient onto the Asset-Swap-Spread to -1 as in Table I (3).The nonlinear liquidity premium with quadratic terms is estimated in Table I (5).

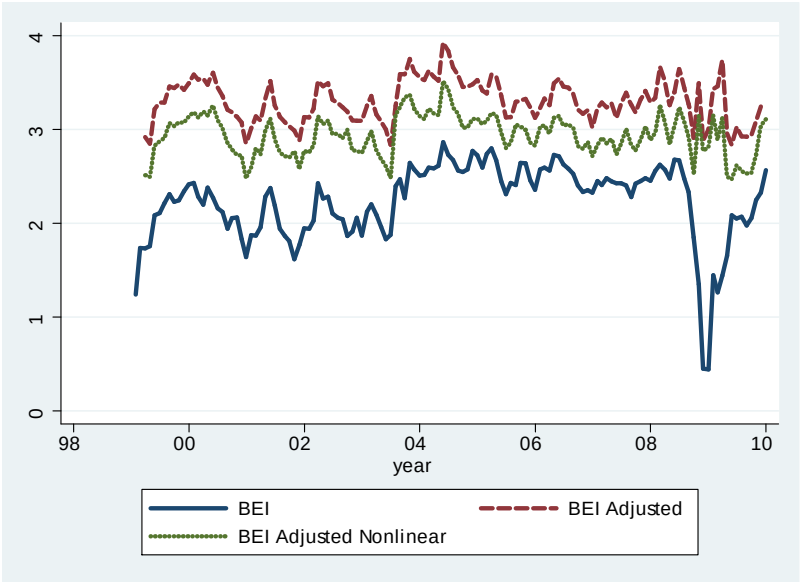

Figure 3. Liquidity-Adjusted US 10 Year Breakeven Inflation. We adjust breakeven inflation (the difference between nominal and TIPS yields) for liquidity premia shown in Figure 2.

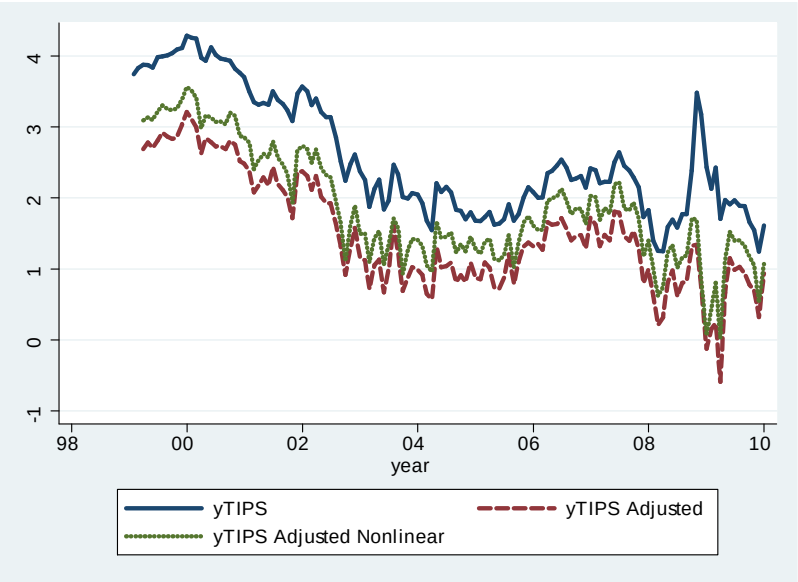

Figure 4. Liquidity-Adjusted US TIPS. We adjust US 10 Year TIPS yields for liquidity premia shown in Figure 2.

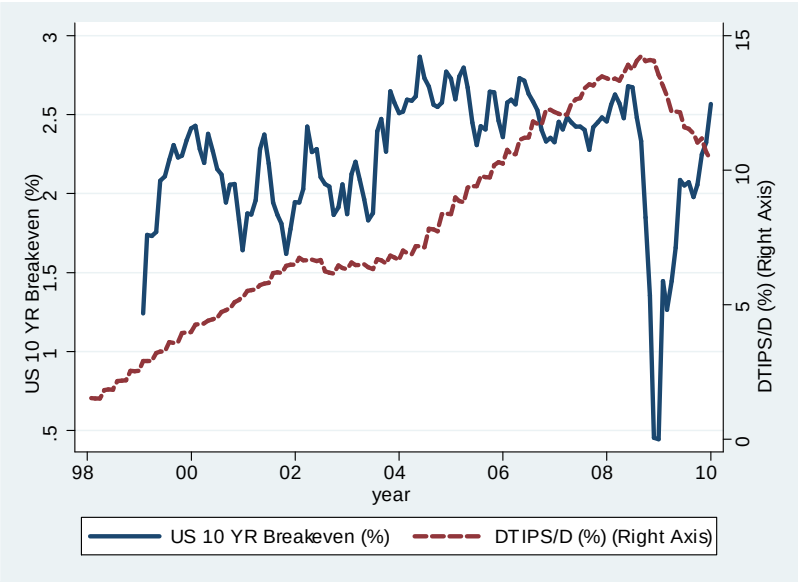

Figure 5A. US Relative Supply and 10 Year Breakeven Inflation.
Relative supply shows the total amount of TIPS relative
to the total amount of TIPS and nominal bonds outstanding.

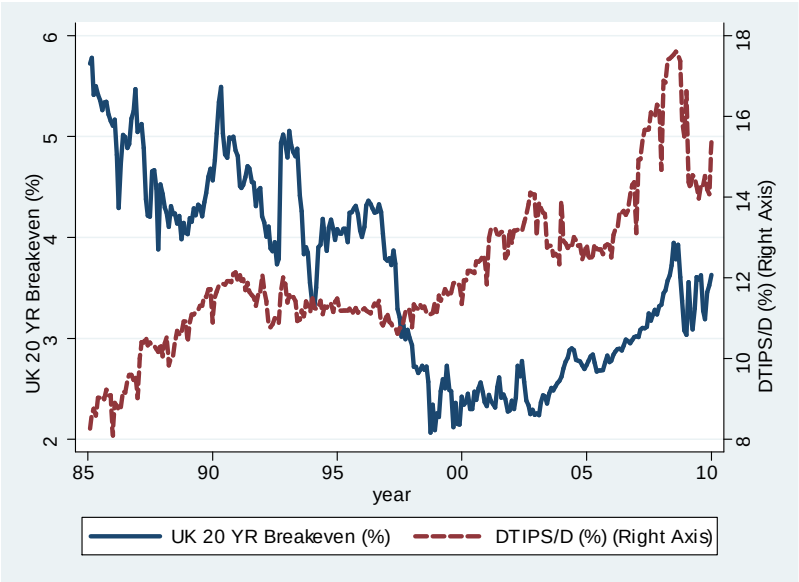

Figure 5B. UK Relative Supply and 20 Year Breakeven.
Relative supply shows the total amount of inflation-linked gilts relative to nominal and inflation-linked gilts outstanding.

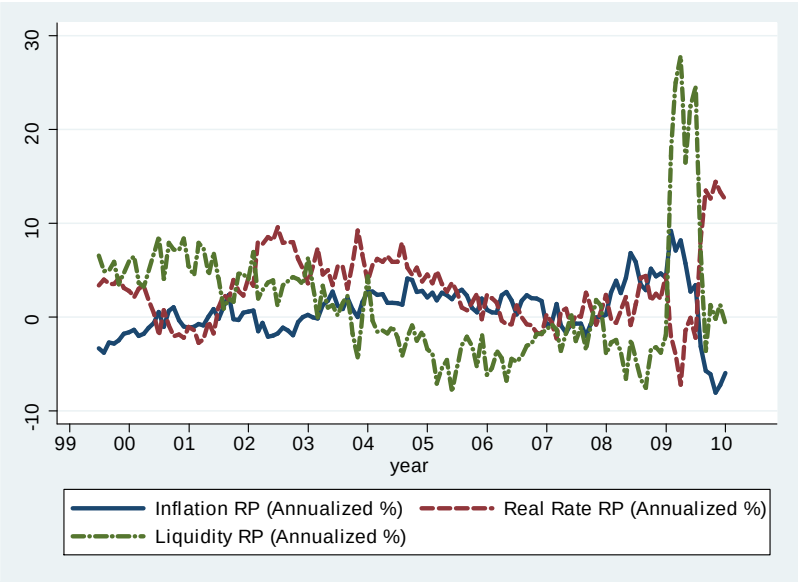

Figure 6A. Estimated US Risk Premia. The real rate risk premium, inflation risk premium and liquidity return premium are obtained as the fitted expected excess returns for liquidity-adjusted TIPS, liquidity-adjusted breakeven and liquidity from Tables IV (1), IV (3) and IV (4).

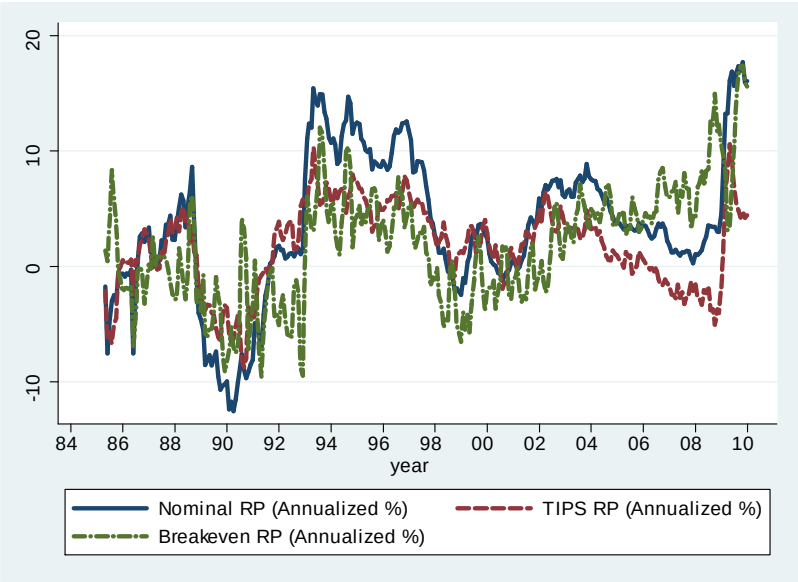

Figure 6B. Estimated UK Bond Risk Premia. The nominal risk premium, TIPS risk premium and breakeven risk premium were obtained for 1985.4-2009.12 in Pflueger and Viceira (2011). They were obtained as expected excess returns on nominal bonds, inflation-indexed bonds and breakeven in return-predictive regressions analogous to Table IV without liquidity-adjustments.

Appendix: An Empirical Decomposition of Risk and Liquidity in Nominal and Inflation-Indexed Government Bonds

A.I The Deflation Floor in TIPS Yields

In order to better understand the value of the deflation option in 10 year TIPS during the crisis we compare our data series of 10 year TIPS yields with 10 year TIPS issued in 2007 and 2008. While in 2008 and 2009 these TIPS had very similar times to maturity they differed in their reference CPIs. During the financial crisis the July 2018 was the most recently issued 10 year TIPS and was fully protected against deflation over its 10 year time to maturity. The January 2017 TIPS on the other hand has a reference CPI that is 7% lower than the reference CPI of the July 2018 TIPS. Hence, while the deflation option on the July 2018 TIPS was going to pay off if inflation was zero over the next 10 years the deflation option on the January 2017 TIPS was only going to pay off if the price level declined substantially over the next ten years and therefore it should reflect a much smaller deflation option or none at all.

In Figure A.1 we show our series of 10 year TIPS yields together with the yields of the 10 year TIPS maturing in July 2018 with a reference CPI of 215.63997, the 10 year TIPS maturing in January 2018 with a reference CPI of 209.49645 and the 10 year TIPS maturing in January 2018 with a reference CPI of 201.66452 between 4/30/2008 and 4/9/2009. The yields of individual TIPS issuances are from Bloomberg. We can see that during the financial crisis the yield of the July 2018 TIPS was indeed lower than the yields of the January 2018 and January 2017 TIPS, possibly reflecting a deflation option. One could however also imagine that, having been issued very recently, this issuance might have had a more active investor base and therefore enjoyed better liquidity.

We can also see that the GSW zero-coupon ten year TIPS yields, which we use for our

main analysis, are much closer to the January 2018 and January 2017 TIPS yields during the crisis than to the July 2018 TIPS yields, reflecting the parametric approach of GSW, which smooths out idiosyncratic movements of yields of individual TIPS issuances.

A.II Nonlinear and Constrained Specifications for L

In this section we report additional robustness checks of our results for different specifications of the liquidity premium L.

One might be concerned that our estimation of the liquidity premium L relies on extrapolation outside the range of historically observed data. The effect of our liquidity proxies on the liquidity premium in TIPS might not be linear and this might lead to significant errors in the extreme values of the estimated liquidity premium. The results in this section are thought to complement the results in Table I in the paper, where we reported results including quadratic terms.

We show the regressions including the squared terms for the off-the-run spread and for the GNMA spread in Table A.I. The asset-swap-spread and the transaction volume exhibit too little variation over time and their squared terms do not enter significantly when added together with the linear terms. The squared off-the-run spread and the squared GNMA spread enter significantly.

One might also think that interaction terms could matter. For example, one could imagine that while transaction volume was low, TIPS were more affected by market-wide flight-to-liquidity episodes and therefore the interaction term between transaction volume and the

off-the-run spread should enter negatively. However, we see in our regressions in Table A.I that the interaction terms between transaction volume, the off-the-run spread and the GNMA spread do not enter significantly.

Figures A.1 and A.2 show the liquidity-adjusted breakeven and liquidity-adjusted TIPS yields with the liquidity premium estimated as in Table A.I (2) and in Table I (5). As an additional robustness check we also show the corresponding quantities estimated as in Table I (3), that is with the regression coefficient on the asset swap spread constrained to equal -1.

Tables A.II and A.III report our return-predictive regressions from Table IV in the paper using the nonlinear and the constrained estimate of L, respectively. Return-predictability appears unaffected by the choice of specification.

Table A.IV reports means and standard deviations of inflation risk premia, real interest-rate risk premia and liquidity premia. The inflation risk premia reported in Table A.IV are slightly lower than in Table V in the paper, the liquidity premium is slightly lower and the real interest rate risk premium is slightly higher but the general results are similar.

A.III Tradeable Excess Returns on TIPS

In our main analysis we consider the excess returns on TIPS over the return on the hypothetical real 3-month T-bill in order to capture real rate risk premia on long-term real bonds over short-term real bonds. However, a real 3-month T-bill does not exist and one might therefore interested in knowing whether the return-predictability regressions in Table

IV continue to hold when computing TIPS excess returns as nominal TIPS returns over the nominal returns on a nominal 3-month T-bill and breakeven returns as the nominal TIPS returns over the nominal return on a nominal bond. As one can see in Table A.V the results are almost unchanged.

A.IV Newey-West Standard Errors with 12 Lags

Table A.VI reports the same regressions as Table IV in the paper but with Newey-West standard errors with 12 lags in brackets. If anything the additional lags increase the significance of our coefficients.

A.V Alternative Measures of Supply Shocks

In this section we construct an additional measures of supply shocks for the US and the UK. One might think that governments aim for a long-term target value for the relative supply of TIPS relative to nominals. In that case transitory deviations around a trend in relative supply might be more appropriate measures of supply shocks.

Table A.VII reports Dickey-Fuller unit root tests for the relative supply $Supply_t$, relative issuance $\Delta Supply_t$ and changes in relative issuance over the previous year $\Delta Supply_t - \Delta Supply_{t-12}$ for both the US and the UK. We include 12 lags in order to be able to capture the annual issuance cycle.

In the US we cannot reject that the relative supply $Supply_t$ follows a unit root process.

The same is true for relative issuance $\Delta Supply_t$. This presumably indicates the regular annual issuance schedule of nominal and inflation-indexed bonds in the US. The annual change in the relative issuance $\Delta Supply_t - \Delta Supply_{t-12}$, however, does not follow a unit root process. This indicates that over our sample period in the US the issuance schedules are relatively stable with shocks around a regular issuance schedule.

Table A.VIII reports the autoregressions for $\Delta Supply_t$ and $\Delta Supply_t - \Delta Supply_{t-12}$ with twelve lags. While the coefficients in the autoregression of relative issuance sum to greater than one the coefficients of the change in relative issuance sum to less than one.

Our analogous analysis in the UK reveals that we can reject a unit root process in relative issuance $\Delta Supply_t$. That is, over our sample period in the UK relative supply appears to fluctuate around a target level and with shocks to relative issuance. This agrees well with the irregular issuance schedule of inflation-indexed gilts in the UK. We focus on data for $Supply_t$ and $\Delta Supply_t$ starting in 1985. Data is available before 1985 but it is subject to very large shocks during the first years of inflation-indexed gilt issuance and our yield data only starts in 1985.

From this analysis we conclude that an appropriate measure of supply shocks in the US should be the residual of the twelve month autoregression of $\Delta Supply_t - \Delta Supply_{t-12}$. We take our measure of relative supply shocks in the UK to be the residual in the twelve month autoregression of relative issuance $\Delta Supply_t$. We find that these supply shocks do not enter significantly either in Table II or in Table III. If instead we use the residuals from the other autoregressions reported in Table A.VIII the results in Tables II and III remain unchanged.

A.VI Sub-Period Betas

In Table V in the paper we reported betas for the different components of bond returns. One might be interested whether these betas look similar over sub-periods that exclude the financial crisis. In Table A.IX we therefore report betas for US returns over the shorter period ending at the end of 2006. We also report the corresponding alphas for completeness. We find that while the non liquidity-adjusted TIPS beta changes depending on whether the financial crisis is included or not, the liquidity-adjusted betas are unaffected by the inclusion of the financial crisis. These results confirm the importance of decomposing TIPS returns into a liquidity component and a real interest rate return.

Over the full sample period liquidity returns appear to have a positive alpha that is statistically significant from zero. However, one can also see that this alpha becomes statistically insignificant over the more recent sub-period starting in 2002. This suggests that the positive alpha was at least partly related to the novelty of TIPS and due to particular market conditions during the first few years of TIPS issuance. Once TIPS were more solidly established the intercept was still positive but no longer statistically significant.

For the UK we similarly report nominal, TIPS and breakeven betas for the periods 1985.3-2006.12 and 1999.1-2009.12. The bond betas appear robust to the inclusion or exclusion of the financial crisis period, consistent with our intuition that relative liquidity between inflation-linked and nominal gilts should play less of a role in the UK. We look at the shorter sub-period starting in 1999 as a way of checking whether UK government bond betas are likely to have changed over time, as discussed in Campbell, Sunderam and Viceira (2011) and Campbell, Shiller and Viceira (2009). Indeed we find that the government bond betas of

UK bonds look different over the shorter time period, the breakeven beta being negative over the most recent decade and the TIPS beta being smaller and insignificant but still positive.

A.VII Factor Betas

Having seen that our liquidity variable exhibits systematic exposure to market returns, one might be interested in whether it loads onto either the size factor (SMB) or the value factor (HML) of Fama and French (1993) or onto the Pastor-Stambaugh liquidity factor of Pastor and Stambaugh (2003). We obtain monthly data for the SMB, HML and Pastor-Stambaugh factors from CRSP. For the Pastor Stambaugh factor we use the innovations series. We construct quarterly overlapping returns by summing over the past three months.

We first regress our bond excess returns onto market excess returns and the Pastor-Stambaugh factor, which is a measure of changes in stock market liquidity. In Table A.X we find that both nominal and inflation-indexed excess returns are negatively related to the Pastor-Stambaugh factor. This holds for the full sample period and when we exclude the financial crisis. Liquidity-adjusted TIPS returns also appear negatively related to the Pastor-Stambaugh factor. One possible explanation is that when stock market liquidity decreases investors rush into government bonds, driving up the prices of both nominal and inflation-indexed Treasuries. Liquidity returns do not appear related to the Pastor-Stambaugh factor.

In Table A.XI we add the value and size factors to the regressions. Liquidity returns do not appear related to either value or size. Even though both of these factors are enter insignificantly, the Pastor-Stambaugh factor now becomes significant but not if we exclude the financial crisis period. Given the results in Table A.X the relationship between liquidity

returns and the Pastor-Stambaugh factor does not appear robust.

A.VIII Correlations of Returns and Spreads

One might be interested in how correlated are the returns and right-hand side variables in Table V. These correlations are reported in Table A.XI. As one can see, the correlations of our right-hand side variables in Table V are only weakly correlated, suggesting that collinearity of regressors should not need to be a concern.

Table A.I
Liquidity Regression with Interaction Terms

We add interaction terms to the regressions in Table II. Newey-West standard errors with three lags in parentheses. The p-value of the F-test for no predictability is shown. * and ** denote significance at the 5% and 1% level.

$y^{\$}_{n,t} - y^{TIPS}_{n,t}$	(1)	(2)	(3)	(4)	(5)
Off-the-run Spr.	-0.49^{**}	-0.48^{**}	-0.20	-0.54^{*}	-0.46^{**}
	(0.14)	(0.14)	(0.33)	(0.24)	(0.14)
GNMA Spr.	-0.18	0.56^{**}	0.52	0.56^{*}	0.58^{*}
	(0.11)	(0.27)	(0.27)	(0.28)	(0.28)
Transaction Vol.	0.28^{**}	0.30^{**}	0.29^{**}	0.30^{**}	0.131
	(0.09)	(0.08)	(0.08)	(0.08)	(0.26)
Asset-Swap-Spr.	-1.49^{**}	-1.31^{**}	-1.32^{**}	-1.30^{**}	-1.39^{**}
	(0.18)	(0.15)	(0.15)	(0.15)	(0.15)
$(\text{Off-the-run Spr.})^2$	-560.9^{**}	-488.7^{**}	-438.7^{*}	-464.2^{*}	-499.0^{*}
	(171.7)	(189.9)	(160.2)	(205.3)	(192.7)
$(\text{GNMA Spr.})^2$		-171.9^{**}	-162.1^{**}	-174.8^{**}	-157.8^{**}
		(63.3)	(63.93)	(64.17)	(56.19)
Off-the-run Spr.×GNMA Spr.			-110.7		
			(108.6)		
Off-the-run Spr.×Transaction Vol.				-45.45	
				(124.0)	
GNMA Spr.×Transaction Vol.					73.34
					(100.9)
const.	3.27^{**}	2.94^{**}	2.95^{**}	2.94^{**}	2.94^{**}
	(0.08)	(0.11)	(0.11)	(0.11)	(0.11)
$p - value$	0.00	0.00	0.00	0.00	0.00
R^2	0.69	0.70	0.70	0.70	0.71
Sample			1999.3 − 2009.12		

Table A.II
Liquidity-Adjusted Predictability US
Nonlinear Liquidity Estimate

We run liquidity-adjusted return-predictive regressions as in Table V. Variables are defined as in Table V. We adjust for the liquidity premium with nonlinear terms as estimated in Table II(5). Newey-West standard errors with three lags appear in parentheses. The p-value of the F-test for no predictability is shown. * and ** denote significance at the 5% and 1% level, respectively.

	$xr_{n,t+1}^{TIPS-L}$	$xr_{n,t+1}^{b+L}$	$xr_{n,t+1}^{b+L}$	$r_{n,t+1}^{L}$
$\left(y_{n,t}^{TIPS} - L_{n,t}\right) - y_{1,t}^{TIPS}$	4.07^{**}		-2.12^{*}	-0.51
	(1.48)		(0.99)	(0.80)
$(b_{n,t} + L_{n,t}) - b_{1,t}$		3.07	3.63^{*}	-2.41
		(1.58)	(1.51)	(3.40)
$L_{n,t}$	-8.47	2.26	3.57	21.74^{**}
	(8.11)	(3.77)	(4.35)	(4.62)
$p - value$	0.01	0.10	0.03	0.00
R^2	0.08	0.07	0.12	0.28
Sample		1999.6 – 2009.12		

Table A.III
Liquidity-Adjusted Predictability US
Constrained Liquidity Estimate

We run liquidity-adjusted return-predictive regressions as in Table V. Variables are defined as in Table V. We adjust for the liquidity premium estimated in Table II (3) with coefficient on the asset-swap spread constrained to -1. Newey-West standard errors with three lags appear in parentheses. The p-value of the F-test for no predictability is shown. * and ** denote significance at the 5% and 1% level, respectively.

	$xr_{n,t+1}^{TIPS-L}$	$xr_{n,t+1}^{b+L}$	$xr_{n,t+1}^{b+L}$	$r_{n,t+1}^{L}$
$\left(y_{n,t}^{TIPS} - L_{n,t}\right) - y_{1,t}^{TIPS}$	3.22^{*}		-1.70	0.40
	(1.49)		(1.15)	(0.79)
$(b_{n,t} + L_{n,t}) - b_{1,t}$		3.92^{*}	4.30^{*}	-2.38
		(1.80)	(1.74)	(2.34)
$L_{n,t}$	-3.56	-1.63	0.53	16.87^{**}
	(9.48)	(5.42)	(6.39)	(4.90)
$p - value$	0.10	0.09	0.07	0.01
R^2	0.05	0.07	0.10	0.23
Sample		1999.6 – 2009.12		

Table A.IV
Moments of Realized and Fitted Bond Returns
Nonlinear and Constrained Estimates

We show summary statistics for expected and realized excess returns as in Table VI for different specifications of the liquidity premium. We obtain expected excess returns 1999.6-2009.12 as fitted values from Tables A.II (1), (3) and (4) and Tables A.III (1), (3) and (4), respectively. Numbers shown are annualized (%).

Panel A: Nonlinear Liquidity Estimate

	$\hat{E}\left(xr_{n,t}\right)$	$\hat{\beta}\left(xr_{n,t}\right)$	$\sigma\left(E_t xr_{n,t+1}\right)$	$\frac{\sigma^2(E_t xr_{n,t+1})}{\sigma^2\left(xr^{\$}_{n,t}\right)}$	$\frac{\sigma^2(E_t xr_{n,t+1})}{\sigma^2\left(xr^{TIPS}_{n,t}\right)}$
Liq.-Adj. Exc. Log Ret. BEI	0.23	0.06	3.37	4%	
Liq.-Adj. Exc. Log Ret. TIPS	3.38	-0.46^{**}	4.69	7%	9%
Log Return Liquidity	0.86	0.52^{**}	6.99		19%

Panel B: Constrained Liquidity Estimate

	$\hat{E}\left(xr_{n,t}\right)$	$\hat{\beta}\left(xr_{n,t}\right)$	$\sigma\left(E_t xr_{n,t+1}\right)$	$\frac{\sigma^2(E_t xr_{n,t+1})}{\sigma^2\left(xr^{\$}_{n,t}\right)}$	$\frac{\sigma^2(E_t xr_{n,t+1})}{\sigma^2\left(xr^{TIPS}_{n,t}\right)}$
Liq.-Adj. Exc. Log Ret. BEI	0.57	-0.04	3.25	4%	
Liq.-Adj. Exc. Log Ret. TIPS	3.04	-0.36	3.29	4%	4%
Log Return Liquidity	1.20	0.42^{**}	4.74		9%

Table A.V
Return Predictability Liquidity US
Tradeable Excess Returns

We run liquidity-adjusted return-predictive regressions as in Table V. We consider liquidity-adjusted log nominal bond returns on TIPS over nominal returns on the nominal T-bill rate $r_{n,t}^{TIPS-L} - r_t^{Tbill}$ as a tradeable version of liquidity-adjusted log excess returns of TIPS. We also consider liquidity-adjusted log nominal bond returns on TIPS over log nominal bond returns on nominal bonds $r_{n,t}^{TIPS-L} - r_{n,t}^{nom}$ as a tradeable version of liquidity-adjusted breakeven returns. Newey-West standard errors with three lags appear in parentheses. The p-value of the F-test for no predictability is shown. * and ** denote significance at the 5% and 1% level, respectively.

	$r_{n,t}^{TIPS-L} - r_t^{Tbill}$	$r_{n,t}^{TIPS-L} - r_{n,t}^{nom}$	$r_{n,t}^{TIPS-L} - r_{n,t}^{nom}$
$(y_{n,t}^{TIPS} - L_{n,t}) - y_{1,t}^{TIPS}$	3.56*		−1.71
	(1.44)		(1.21)
$(b_{n,t} + L_{n,t}) - b_{1,t}$		3.06	3.56**
		(1.76)	(1.71)
$L_{n,t}$	−7.67	2.26	3.57
	(10.77)	(6.27)	(7.00)
$p - value$	0.05	0.17	0.14
R^2	0.06	0.05	0.07
Sample		1999.6 − 2009.12	

Table A.VI
Return Predictability Liquidity US
Newey-West Standard Errors with 12 Lags

We run liquidity-adjusted return-predictive regressions as in Table V. Newey-West standard errors with twelve lags appear in parentheses. The p-value of the F-test for no predictability is shown. * and ** denote significance at the 5% and 1% level, respectively.

	$xr_{n,t+1}^{TIPS-L}$	$xr_{n,t+1}^{b+L}$	$xr_{n,t+1}^{b+L}$	$r_{n,t+1}^{L}$
$(y_{n,t}^{TIPS} - L_{n,t}) - y_{1,t}^{TIPS}$	3.53*		−1.66	−0.03
	(1.43)		(0.92)	(0.9)
$(b_{n,t} + L_{n,t}) - b_{1,t}$		2.94*	3.42*	−2.62
		(1.41)	(1.31)	(3.52)
$L_{n,t}$	−6.05	0.73	2.00	19.81**
	(6.80)	(3.98)	(4.46)	(5.27)
$p - value$	0.04	0.07	0.05	0.00
R^2	0.06	0.04	0.07	0.26
Sample		1999.6 − 2009.12		

Table A.VII
Dickey-Fuller Unit Root Tests

We report Dickey-Fuller test for the null-hypothesis of a unit root with twelve lags. $Supply_t$ denotes the amount of inflation-indexed bonds outstanding relative to all nominal and inflation-indexed bonds outstanding. $\Delta Supply_t$ denotes the relative issuance of inflation-indexed bonds relative to all nominal and inflation-indexed bonds issuance. $\Delta Supply_t - \Delta Supply_{t-12}$ is the change in relative issuance over the past 12 months. * and ** denote significance at the 5% and 1% level respectively.

Panel A: US

	$Supply_t$	$\Delta Supply_t$	$\Delta Supply_t - \Delta Supply_{t-12}$
	-2.03	-1.72	-3.05^{*}
Sample	$1999.1 - 2009.12$	$1999.2 - 2009.12$	$2000.2 - 2009.12$

Panel B: UK

	$Supply_t$	$\Delta Supply_t$	$\Delta Supply_t - \Delta Supply_{t-12}$
	-1.67	-4.33^{**}	-1.88
Sample	$1986.1 - 2009.12$	$1986.1 - 2009.12$	$1987.1 - 2009.12$

Table A.VIII
Supply Autoregression

We regress relative issuance $\Delta Supply_t$, as described in Table III onto its own twelve lags. We also regress the 12-month change in relative issuance onto its own twelve lags. We report the sum of the twelve autoregressive coefficients.

	Panel A: US		**Panel B: UK**	
	$\Delta Supply_t$	$\Delta Supply_t - \Delta Supply_{t-12}$	$\Delta Supply_t$	$\Delta Supply_t - \Delta Supply_{t-12}$
Sum of Coeff.	1.10	0.92	0.47	1.05
const.	0.00	0.00	0.00	0.00
	(0.00)	(0.00)	(0.00)	(0.00)
R^2	0.69	0.30	0.15	0.28
Sample	$1999.2 - 2009.12$	$2000.2 - 2009.12$	$1986.1 - 2009.12$	$1987.1 - 2009.12$

Table A.IX
Sub-Period Betas US

We regress liquidity-adjusted and non liquidity-adjusted excess log government bond returns onto excess log stock returns. All variables are described in Table VI. Newey-West standard errors are computed with 3 lags. * and ** denote significance at the 5% and 1% level for $\hat{\alpha}$ and $\hat{\beta}$, respectively.

Panel A: US	1999.4-2009.12		1999.4-2006.12		2002.1-2009.12	
	$\widehat{\beta}$	$\widehat{\alpha}$	$\widehat{\beta}$	$\widehat{\alpha}$	$\widehat{\beta}$	$\widehat{\alpha}$
Excess Log Return Nominal	-0.40^{**}	2.52	-0.51^{*}	2.47	-0.38^{**}	3.46
Excess Log Return TIPS	0.06	4.28^{*}	-0.34^{*}	3.74^{*}	0.11	4.50
Excess Log Return BEI	-0.47^{*}	-1.76	-0.17	-1.28	-0.49^{*}	-1.03
	1999.6-2009.12		1999.6-2006.12		2002.1-2009.12	
	$\widehat{\beta}$	$\widehat{\alpha}$	$\widehat{\beta}$	$\widehat{\alpha}$	$\widehat{\beta}$	$\widehat{\alpha}$
Liq.-Adj. Exc. Log Ret. BEI	0.07	0.87	0.02	0.72	0.09	0.97
Liq.-Adj. Exc. Log Ret. TIPS	-0.46^{**}	1.96	-0.51^{**}	2.17	-0.47^{*}	2.49
Log Return Liquidity	0.53^{**}	2.40^{*}	0.17^{**}	1.62^{**}	0.58^{**}	2.00

Panel B: UK	1985.3-2009.12		1985.3-2006.12		1985.3-1998.12		1999.1-2009.12	
	$\widehat{\beta}$	$\widehat{\alpha}$	$\widehat{\beta}$	$\widehat{\alpha}$	$\widehat{\beta}$	$\widehat{\alpha}$	$\widehat{\beta}$	$\widehat{\alpha}$
Excess Log Return Nominal	0.16	2.98	0.19	3.25	0.31	3.96	-0.06	0.41
Excess Log Return TIPS	0.15^{**}	1.21	0.14^{*}	1.13	0.17^{*}	0.09	0.13	2.40
Excess Log Return BEI	0.01	1.78	0.05	2.12	0.13	3.87	-0.19^{*}	-1.98

Table A.X
Loadings onto the Market and the Pastor-Stambaugh Factor

US liquidity-adjusted and non liquidity-adjusted excess log government bond returns onto excess log stock returns xr_t^{equity} and the innovations in the Pastor-Stambaugh liquidity factor. Annualized (%). Newey-West standard errors with 3 lags in brackets. * and ** denote significance at the 5% and 1% level.

Panel A: 1999.6-2009.12	$xr^{\$}_{n,t+1}$	$xr^{TIPS}_{n,t+1}$	$xr^{b}_{n,t+1}$	$xr^{TIPS-L}_{n,t+1}$	$xr^{b+L}_{n,t+1}$	$r^{L}_{n,t+1}$
xr^{equity}_{t+1}	-0.28^{*}	0.19	-0.47^{*}	-0.40^{*}	0.12	0.59^{**}
	(0.13)	(0.24)	(0.19)	(0.16)	(0.12)	(0.16)
Pastor-Stambaugh	-0.09^{**}	-0.10^{**}	0.01	-0.05^{*}	-0.04	-0.05
	(0.03)	(0.03)	(0.04)	(0.03)	(0.02)	(0.02)
const.	2.42	3.91^{*}	-1.49	1.73	0.70	2.18
	(1.69)	(1.52)	(1.35)	(1.52)	(1.24)	(1.12)
Panel B: 1999.6-2006.12	$xr^{\$}_{n,t+1}$	$xr^{TIPS}_{n,t+1}$	$xr^{b}_{n,t+1}$	$xr^{TIPS-L}_{n,t+1}$	$xr^{b+L}_{n,t+1}$	$r^{L}_{n,t+1}$
xr^{equity}_{t+1}	-0.39	-0.27	-0.13	-0.45^{**}	0.06	0.18^{**}
	(0.22)	(0.14)	(0.14)	(0.13)	(0.13)	(0.04)
Pastor-Stambaugh	-0.11^{**}	-0.08^{**}	-0.03	-0.06^{*}	-0.05	-0.01
	(0.03)	(0.02)	(0.02)	(0.02)	(0.02)	(0.01)
const.	2.81	3.74^{**}	-0.93	2.12	0.69	1.61^{**}
	(2.01)	(1.34)	(1.36)	(1.28)	(1.43)	(0.50)

Table A.XI
Four Factor Regressions

We add the Fama-French factors SMB and HML to the regression in TableA.X. Annualized (%). Newey-West standard errors with 3 lags in brackets. * and ** denote significance at the 5% and 1% level.

Panel A: 1999.6-2009.12	$xr^{\$}_{n,t+1}$	$xr^{TIPS}_{n,t+1}$	$xr^{b}_{n,t+1}$	$xr^{TIPS-L}_{n,t+1}$	$xr^{b+L}_{n,t+1}$	$r^{L}_{n,t+1}$
xr^{equity}_{t+1}	−0.25	0.21	−0.47*	−0.37*	0.12	0.58**
	(0.13)	(0.25)	(0.20)	(0.17)	(0.11)	(0.16)
HML	0.05	−0.00	0.05	−0.01	0.06	0.00
	(0.05)	(0.08)	(0.06)	(0.06)	(0.04)	(0.03)
SMB	−0.13*	−0.10	−0.03	−0.10	−0.03	0.01
	(0.06)	(0.06)	(0.05)	(0.06)	(0.05)	(0.03)
Pastor-Stambaugh	−0.09**	−0.10**	0.00	−0.05	−0.04*	−0.05*
	(0.03)	(0.03)	(0.03)	(0.03)	(0.02)	(0.02)
const.	3.08	4.67**	−1.59	2.56	0.52	2.11
	(1.73)	(1.72)	(1.42)	(1.58)	(1.11)	(1.17)

Panel B: 1999.6-2006.12	$xr^{\$}_{n,t+1}$	$xr^{TIPS}_{n,t+1}$	$xr^{b}_{n,t+1}$	$xr^{TIPS-L}_{n,t+1}$	$xr^{b+L}_{n,t+1}$	$r^{L}_{n,t+1}$
xr^{equity}_{t+1}	−0.33	−0.23	−0.10	−0.42**	0.09	0.18**
	(0.23)	(0.15)	(0.14)	(0.14)	(0.13)	(0.04)
HML	0.06	0.09*	−0.03	0.09	−0.03	0.01
	(0.06)	(0.04)	(0.04)	(0.04)	(0.04)	(0.02)
SMB	−0.10	0.01	−0.10*	0.00	−0.10	0.01
	(0.06)	(0.04)	(0.05)	(0.04)	(0.05)	(0.02)
Pastor-Stambaugh	−0.11**	−0.08**	−0.03	−0.06*	−0.04	−0.01
	(0.03)	(0.03)	(0.02)	(0.03)	(0.02)	(0.01)
const.	3.22	2.86	0.36	1.35	1.87	1.51**
	(2.28)	(1.58)	(1.20)	(1.43)	(1.28)	(0.54)

Table A.XII
Sample Correlations of Returns and Spreads

Monthly data of quarterly overlapping returns and inflation 1999.6-2009.12.
Annualized (%). All data are described in Table V.

Correlations Returns

	$xr_{n,t+1}^{TIPS-L}$	$xr_{n,t+1}^{b+L}$	$r_{n,t+1}^{L}$
$xr_{n,t+1}^{TIPS-L}$	1	-0.24	-0.44
$xr_{n,t+1}^{b+L}$	.	1	0.21
$r_{n,t+1}^{L}$	.	.	1

Correlations Spreads

	$\left(y_{n,t}^{TIPS} - L_{n,t}\right) - y_{1,t}^{TIPS}$	$(b_{n,t} + L_{n,t}) - b_{1,t}$	$L_{n,t}$
$\left(y_{n,t}^{TIPS} - L_{n,t}\right) - y_{1,t}^{TIPS}$	1	0.25	0.18
$(b_{n,t} + L_{n,t}) - b_{1,t}$	.	1	0.27
$L_{n,t}$	.	.	1

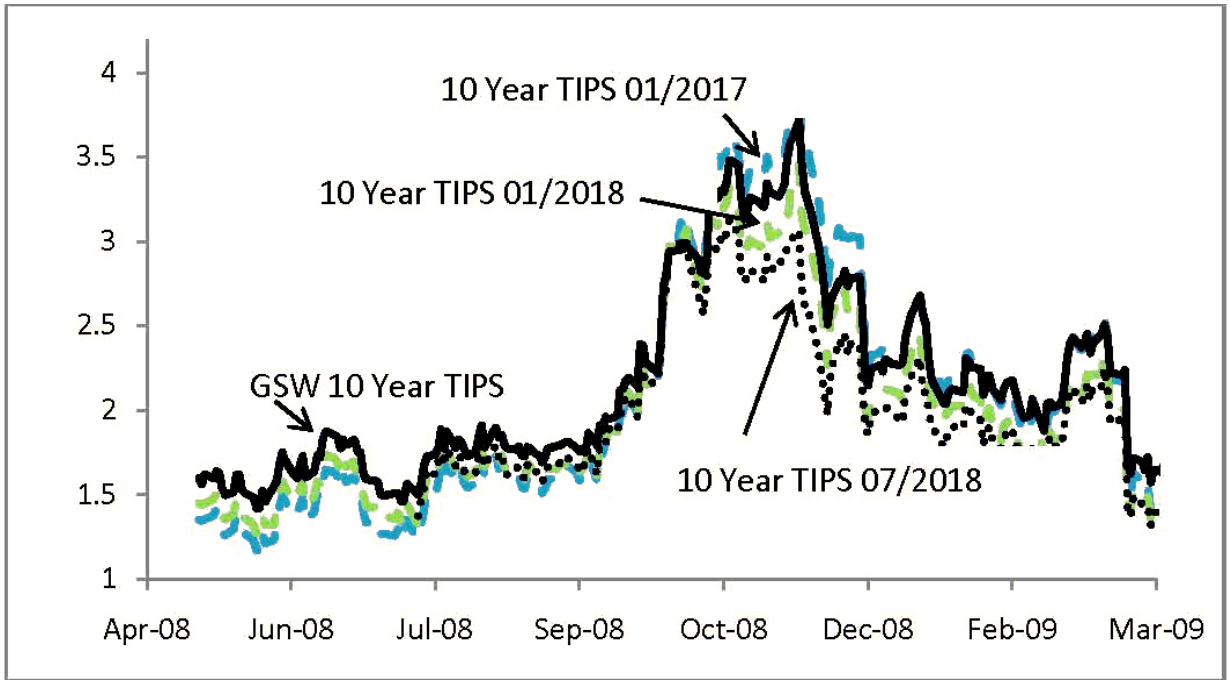

Figure A.1. Recently Issued and Less Recently Issued 10 Year TIPS. GSW 10 Year TIPS yields from Gurkaynak, Sack and Wright (2010); 10 Year TIPS maturing in 07/2018 (reference CPI 215.7), 01/2018 (reference CPI 209.5) and 01/2017 (reference CPI 201.7) from Bloomberg.

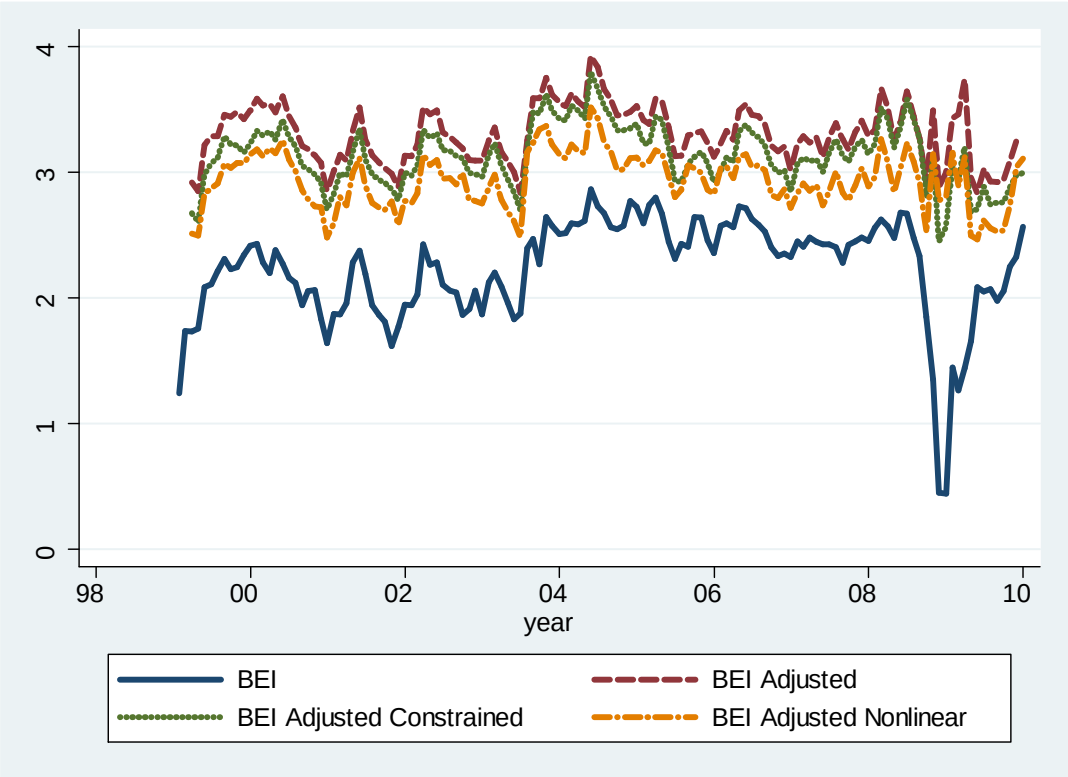

Figure A.2. Constrained and Nonlinear Liquidity Adjustments to Breakeven. We adjust breakeven inflation (the difference between nominal and TIPS yields) for liquidity premia shown in Figure 2. Relative to Figure 3 we add breakeven inflation adjusted for the constrained liquidity estimate.

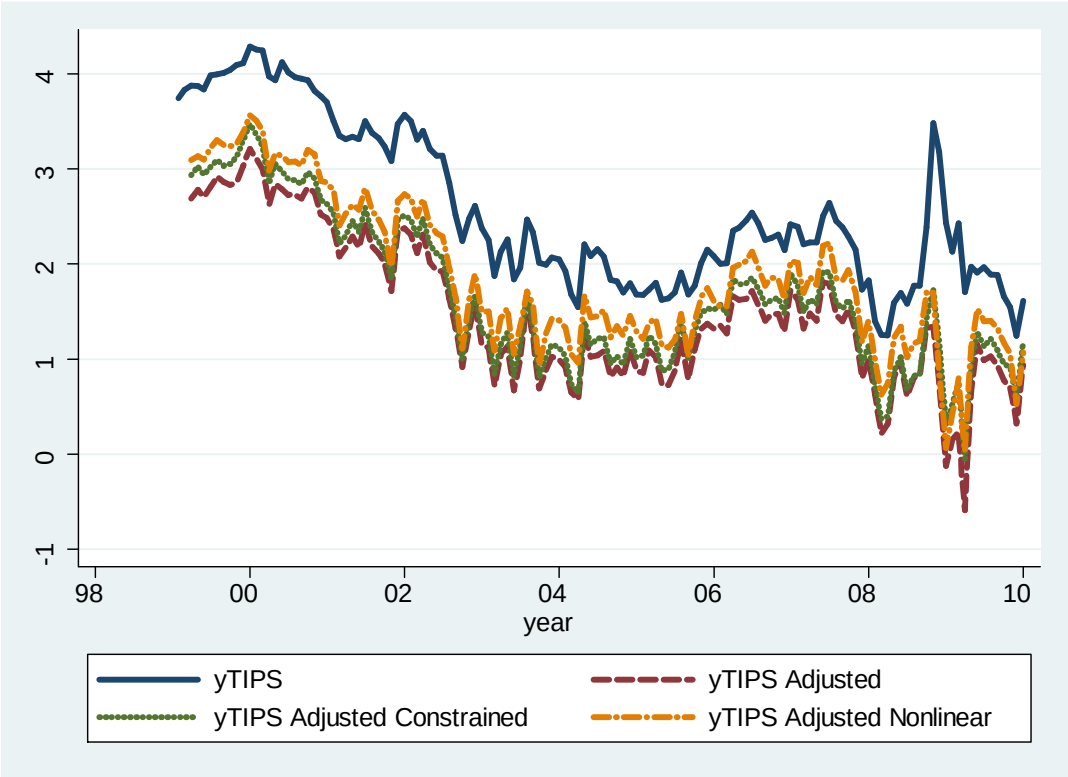

Figure A.3. TIPS Yields Adjusted for Constrained and Nonlinear Liquidity Specifications. We adjust US 10 Year TIPS yields for liquidity premia shown in Figure 2. Relative to Figure 4 we add TIPS yields adjusted for the constrained liquidity estimate.