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Investors Valuation for Assets Liquidity and Safety and the Corporate-Treasury Yield Spread[1]

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Abstract

The present study seeks to explain the non-default component of corporate-U.S. Treasury yield spreads. This is done by assuming, along the lines of Krishnamurthy and Vissing-Jorgensen (2012), that investors' valuation for asset-specific liquidity and safety features is being priced. For that purpose I modify a standard asset pricing model by allowing certain groups of assets to directly contribute to utility. Empirical tests of the model's implications confirm that view and show that changes in the supply of more liquid and safe assets cause a stronger impact on corporate-Treasury yield spreads compared to changes in the supply of less liquid and safe assets. Finding this systematic pattern, points to the existence of a demand function for liquidity and safety attributes. Further I provide evidence that liquidity and safety are priced separately from commonly used controls for economic risk and default risk factors as well as liquidity risk controls.

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Keywords: Corporate-Treasury Bond Yield Spread, Liquidity and Safety adjusted CAPM, Asset Pricing, Credit Risk, Liquidity Premium

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1 Introduction

The study of determinants of corporate-Treasury yield spreads has been the subject of a large number of contributions in the corporate finance literature. Some recent papers by Elton et al. (2001), Delianedis and Geske (2001), Huang and Huang (2003), Eom, Helwege, and Huang (2004) find that variables, i.e. default risk and credit risk resp., that should in theory determine spreads between Treasury and corporate bond yields have rather limited explanatory power. Longstaff, Mithal, and Neis (2005) use information in credit default swaps to estimate a measure of the size of the default component within corporate-Treasury yield spreads and label the residual as non-default component. The latter is found to be time-varying and strongly related to macroeconomic measures of bond market liquidity.[3] Krishnamurthy and Vissing-Jorgensen (2012) (KVJ) provide evidence that the non-default component of the corporate bond spread is to a significant extent driven by the total amount of Treasuries outstanding. They argue that investors value certain features of Treasury securities, namely liquidity and "absolute security of nominal return", which affects prices of Treasuries and hence drives down their yields compared to assets that do not to the same extent share these features.

The present study seeks to investigate the robustness of the results presented by KVJ. In particular, I ask whether there is evidence for a systematic pattern in investors' valuation for asset-specific liquidity and safety features which is priced in corporate-Treasury yield spreads. For that purpose I follow the approach of KVJ by modifying a standard asset pricing model to allow for holdings of certain groups of assets to directly contribute to investors' utility. To test the theoretical implications I derive regression models where I compare the effects of changes in the aggregate supply of assets which are different in their respective degree of perceived liquidity and safety on alternative yield spread measures, thereby controlling for commonly used measures of default and liquidity risk.

U.S. Treasuries are of high liquidity and are considered to be default-free. From a theoretical point of view this should be reflected in the interest differential between Treasuries and any other debt security of the same maturity length. Standard controls are intended to capture spread determinants derived from a Consumption Capital Asset Pricing Model (CCAPM). Those credit risk factors are the expected loss in case of default on a corporate bond and the economic risk premium attached to default states, commonly named "default risk" and investors' demanded "risk premium" resp. Furthermore Amihud, Mendelson, and Pedersen (2005) and Acharya and Pedersen (2005) argue that time-varying differences in an assets' degree of liquidity contribute to make returns, i.e. future expected payment

[3] For example flows into money market mutual funds.

streams, risky and induce an additional "liquidity risk premium". For example, in times when investors would like to sell and the liquidity of a corporate bond deteriorates, risk averse investors will demand a liquidity risk premium for holding these bonds. Chen, Lesmond, and Wei (2007) show that measures which control for CCAPM and liquidity risk components can improve the ability of credit spread regressions to explain observed levels and variability of yield spreads. However explanatory power still remains relatively low.[4]

KVJ find for U.S. data a strong negative correlation between the corporate bond spread and the government Debt-to-GDP ratio (i.e. the ratio of the market value of publicly held U.S. government debt to U.S. GDP) over the period from 1926 to 2008. They argue that investors value certain features of Treasury securities, i.e. a high degree of liquidity and perceived safety, which is priced separately from the common CCAPM and the liquidity risk factors mentioned above.[5] This is motivated by assuming some services and gains in the subjective level of well-being which the holder of such an asset obtains.[6] KVJ summarize those benefits as "convenience yield" and lead Treasuries to have significantly lower yields than they otherwise would have in a standard asset-pricing framework. The strong negative correlation they find therefore reflects a Treasury demand curve or more specifically investors' demand for certain features of Treasuries. This implies that if the supply of Treasuries is low, the value that investors assign to convenience offered by Treasuries is high. As a result the yields on Treasuries are low relative to the yields on corporate bonds which offer less convenience yield. The opposite applies when the supply of Treasuries is high.

In this article I employ improved credit spread regression models extending the approach of KVJ by assuming that not only Treasuries may bear a convenience yield but also assets which are less or more liquid and safe compared to Treasuries. In addition to evaluating the effects that the factors which should implied by the structural model drive corporate-Treasury yield spreads, the present study is also intended to conduct an exploratory analysis. This is done by regressing bond spreads on measures that reflect on the investors' perceived liquidity risk of corporate debt securities relative to Treasuries and "flight-to-liquidity" episodes following authors such as Pflueger and Viceira (2011) and Longstaff (2004).

[4] For an overview of regressions including standard controls see Collin-Dufresne, Goldstein, and Martin (2001).

[5] The assumption of an asset's features providing specific services valued by investors is reminiscent of the rationale for the money-in-the-utility-function model.

[6] For a complete elaboration of the rationale for investors' valuation for liquidity and safety see Krishnamurthy and Vissing-Jorgensen (2012).

I find a significant association between changes in measures for the supply of money and near money assets, changes in Treasury supply, as well as for the supply changes of corporate debt securities and corporate-Treasury yield spreads. Thereby results indicate that yield spreads react the stronger the higher the respective measure's degree of liquidity. Further I find that this observation is robust across different model specifications including measures for credit and liquidity risk. Hence econometric evidence supports the convenience yield theory. Moreover I show that there is a systematic pattern in investors' valuation which points to the existence of a demand curve for assets' liquidity and safety features.

The remainder of this article is organized as follows. Section 2 describes the model set-up and derives the yield spread regression model. Section 3 provides estimation results for testing the hypothesis of liquidity and safety being priced by investors. Finally, section 4 offers concluding remarks.

2 Theoretical framework

The corporate-Treasury yield spread regression models I use are derived from a theoretical framework which extends the standard asset pricing model by the concept of convenience yield as proposed by KVJ. This approach is based on a money-in-the-utility preference specification which is modified to derive a theoretical Treasury-pricing model by assuming that Treasuries enter the utility function as a separate argument. I extend the pricing equations derived by KVJ by allowing for holdings of close to money substitutes, Treasuries and corporate debt securities to contribute to household's utility[7].

2.1 Utility Function

Under the convenience yield hypothesis a representative agent's utility function is assumed to be of the form:

$$u_t = u\left(c_t, \nu\left(\Theta_t, X_t, \xi_t\right)\right)$$
$$\text{with } \Theta_t = \Theta\left(m_{t,} b_t, s_t\right)$$

The argument c_t is the agent's consumption at date t and $\nu(\cdot)$ denotes the agent's gained convenience yield which is a function of $\Theta(\cdot)$, an unknown aggregator function of the real

[7] This idea is based on Poterba and Rotemberg (1986) who use a utility function where so called liquidity services directly contribute to household's utility. The function's argument "liquidity services" is assumed to be a CES aggregate of demand deposits plus currency, short term plus savings deposits and Treasury Bill holdings.

holdings of money as well as close to money substitutes m_t, Treasuries b_t and corporate debt securities s_t and a set of other macroeconomic factors X_t. The term ξ_t in the convenience yield function is a preference shock which is intended to capture level-effects of utility derived from holdings of liquid and safe assets during times when exogenous shocks like a financial crisis, temporarily changes investors' valuation for convenient assets like Treasuries.[8]

The convenience yield function $\nu(\cdot)$ is assumed to capture unique services provided by liquid and safe assets which are valued by investors, where $\nu'(\cdot) > 0$ and $\nu''(\cdot) < 0$. For the purposes of this study I follow KVJ by assuming that X_t is mainly driven by U.S. Gross Domestic Product and that $\nu(\cdot)$ is homogeneous of degree one in GDP_t and Θ_t. Hence $\nu(\cdot)$ can be transformed to

$$\nu(\Theta_t, GDP_t, \xi_t) \equiv \nu\left(\frac{\Theta_t}{GDP_t}, \xi_t\right) GDP_t \tag{1}$$

For simplicity I further assume that for the unknown aggregator function $\Theta(\cdot)$ as well holds that

$$\frac{\Theta_t}{GDP_t} = \Theta\left(\frac{m_t}{GDP_t}, \frac{b_t}{GDP_t}, \frac{s_t}{GDP_t}\right)$$

The convenience yield function (1) is concave as it is assumed that $\nu(\cdot)$ is increasing in $\frac{\theta_t}{GDP_t}$,with $\theta_t = \{m_t,b_t,s_t\}$, but the marginal convenience benefit is decreasing in $\frac{\theta_t}{GDP_t}$ and has the property $\lim_{\frac{\theta_t}{GDP_t}\to\infty} \nu'\left(\frac{\Theta_t}{GDP_t}, \xi_t\right) = 0$. This captures the idea that holding more convenience assets reduces the marginal value of an extra unit of convenience assets. Further this marginal value approaches zero if the agent is holding a large amount of convenience spending assets. Moreover under the hypothesis that investors value liquidity and safety, holding one more unit of an asset that is more convenient compared to another asset should c.p. generate more convenience yield than holding one more unit of the latter i.e.

$$\frac{\partial \nu(\cdot)}{\partial m_t} > \frac{\partial \nu(\cdot)}{\partial b_t} > \frac{\partial \nu(\cdot)}{\partial s_t}$$

Thereby it is important to note that long-term Treasuries carry a higher interest rate and default risk than short-term bonds. Therefore at least the "short-term" safety property

[8] Longstaff (2004) finds evidence for what he calls „flight to liquidity/quality" premium episodes by examining the spread between government agency bonds and U.S. Treasury bonds. In a flight to liquidity episode market participants suddenly prefer highly liquid securities, such as Treasuries, rather than less liquid securities.

of a Treasury Bill will differ from the "long-term" safety property of a Treasury bond.[9] Hence the marginal convenience yield of holding an additional unit of Treasury Bonds will differ from the additional convenience yield of a Treasury Bill. This should be reflected in the functional forms of $\nu(\cdot)$ and $\Theta(\cdot)$. However for the present study it is sufficient to use this general specification to motivate the empirical analysis.

2.2 Household's Problem

A representative household is assumed to maximize the expected sum of a discounted stream of utilities

$$E_0 \sum_{t=0}^{\infty} \beta^t u\left(c_t, \nu\left(\Theta\left(m_{t,} b_t, s_t\right), GDP_t, \xi_t\right)\right)$$

Subject to the budget constraint

$$P_t c_t + P_t^M m_t + P_t^B b_t + P_t^S s_t \leq P_t y_t + P_t^M m_{t-1} + P_t^B b_{t-1} + P_t^S s_{t-1}\left(1-\delta_t\right)$$

Where E_0 is the expectation operator conditional on the information set in the initial period, $\beta \in (0,1)$ is the subjective discount factor. The price level at date t is denoted by P_t. P_t^M, P_t^B, P_t^S are the nominal prices for one-period investments into close to money substitutes and money, Treasuries and corporate debt securities. Note that for the price of one unit of m_t it should hold that $P_t^M = 1$ which is one nominal unit of currency. An investment increases real holdings of convenience assets Θ_t by $\Theta'(\cdot)\frac{P_t^\theta}{Q_t}$, where $P_t^\theta = \{P_t^M, P_t^B, P_t^S\}$. Further y_t is an endowment income.[10] Assume that the agent buys zero coupon discount bonds which pay out one unit of currency when being hold to maturity[11]. For a corporate debt security with face value of one the repayment is $(1-\delta_t)$ where δ_t is the default rate which is $\delta_t = 0$ in the absence of default and $\delta_t > 0$ if there is default on the bond. The first order conditions for consumption c_t and investments into money and close to money substitutes m_t, Treasuries b_t and corporate bonds s_t are given by

$$u'\left(c_t, \nu(\cdot)\right) = \lambda_t \tag{2}$$

[9] Further one can argue that Treasury Bonds will carry a higher Liquidity Premium compared to Treasury Bills.

[10] Here I neglect the non-negativity constraints for $m_{t,} b_t$ and s_t as well as the no-Ponzi game condition.

[11] Derivation of pricing expressions takes place for zero-coupon Treasury and corporate bonds. In the empirical part coupon bonds are examined. However it can be argued that the impact of Treasury supply on coupon bond spreads is qualitatively similar to effect on zero-coupon bond spreads.

$$u'(c_t,\nu(\cdot))\,\nu'\left(\frac{\Theta_t}{GDP_t},\xi_t\right)\frac{\partial\Theta(\cdot)}{\partial m_t}\frac{1}{P_t}+\beta E_t\left[\lambda_{t+1}\frac{1}{P_{t+1}}\right]=\lambda_t\frac{1}{P_t} \tag{3}$$

$$u'(c_t,\nu(\cdot))\,\nu'\left(\frac{\Theta_t}{GDP_t},\xi_t\right)\frac{\partial\Theta(\cdot)}{\partial b_t}\frac{P_t^T}{P_t}+\beta E_t\left[\lambda_{t+1}\frac{P_{t+1}^T}{P_{t+1}}\right]=\lambda_t\frac{P_t^T}{P_t} \tag{4}$$

$$u'(c_t,\nu(\cdot))\,\nu'\left(\frac{\Theta_t}{GDP_t},\xi_t\right)\frac{\partial\Theta(\cdot)}{\partial s_t}\frac{P_t^S}{P_t}+\beta E_t\left[\lambda_{t+1}\frac{P_{t+1}^S}{P_{t+1}}(1-\delta_{t+1})\right]=\lambda_t\frac{P_t^S}{P_t} \tag{5}$$

Define the pricing kernel and stochastic discount factor resp. for nominal payoffs as,

$$M_{t+1}=\beta\frac{u'(c_{t+1},\nu(\cdot))}{u'(c_t,\nu(\cdot))}\frac{P_t}{P_{t+1}}$$

so that

$$P_t^M=1=\frac{E_t[M_{t+1}]}{1-\nu'(\Theta_t/GDP_t,\xi_t)\frac{\partial\Theta(\cdot)}{\partial m_t}} \tag{6}$$

$$P_t^T=\frac{E_t\left[M_{t+1}P_{t+1}^T\right]}{1-\nu'(\Theta_t/GDP_t,\xi_t)\frac{\partial\Theta(\cdot)}{\partial b_t}} \tag{7}$$

$$P_t^S=\frac{E_t\left[M_{t+1}P_{t+1}^S(1-\delta_{t+1})\right]}{1-\nu'(\Theta_t/GDP_t,\xi_t)\frac{\partial\Theta(\cdot)}{\partial s_t}} \tag{8}$$

Conditions for $P_t^M = 1 > P_t^T > P_t^S$ can easily be found which actually is what we can expect to observe in the data. Equations (6) - (8) demand that under the assumption of convenience yield being an argument of the investor's utility function, increasing the amount of convenience assets hold will lower the investor's willingness to pay for another unit of liquid and safe assets. This is due to the assumption of $\nu(\cdot)$ being concave. Therefore one can interpret $\nu'(\cdot)$ as a demand function for certain features of assets namely their degree of liquidity and safety. Further note that by assuming $\frac{\partial\nu(\cdot)}{\partial m_t} > \frac{\partial\nu(\cdot)}{\partial b_t} > \frac{\partial\nu(\cdot)}{\partial s_t}$, increasing the amount of m_t hold should decrease prices P_t^M, P_t^T and P_t^S which reflect the investors willingness to pay for an additional unit of the respective asset to a larger extent than increasing the amount of b_t and s_t. The same reasoning analogously holds for increasing the amount of b_t compared to increasing s_t.

2.3 Corporate-Treasury Yield Spread Model

In this section I derive a theoretical model for explaining spreads between yields of Treasuries and corporate debt securities with each having identical lengths to maturity. The intention of this section is to motivate a model specification which can be transferred to an empirical regression model for explaining corporate-Treasury yield spreads.

First define

$$i_t^T = -\frac{1}{\tau} lnP_t^T \text{ and } i_t^S = -\frac{1}{\tau} lnP_t^S$$

as the period t yields for a Treasury and a corporate debt security where τ is the number of periods to maturity. By applying this transformation the price of a zero coupon bond is converted into a continuously compounded zero coupon bond yield. Therefore for discount bonds with $P_\tau^T = P_\tau^S = 1$ the corporate-Treasury yield spread for bonds with any number of periods to maturity τ an be expressed as

$$\begin{aligned} i_t^S - i_t^T &= -\frac{1}{\tau}\left(lnP_t^T - lnP_t^S\right) \\ &= -\frac{1}{\tau}\left(ln\left(\frac{E_t\left[M_{t+\tau}\right]}{1-\nu'(\cdot)\frac{\partial\Theta(\cdot)}{\partial b_t}}\right) - ln\left(\frac{E_t\left[M_{t+\tau}\left(1-\delta_{t+\tau}\right)\right]}{1-\nu'(\cdot)\frac{\partial\Theta(\cdot)}{\partial s_t}}\right)\right) \\ &\approx -\frac{1}{\tau}\left(E_t\left[M_{t+\tau}\right] + \nu'(\cdot)\frac{\partial\Theta(\cdot)}{\partial b_t} - E_t\left[M_{t+\tau}\left(1-\delta_{t+\tau}\right)\right] - \nu'(\cdot)\frac{\partial\Theta(\cdot)}{\partial s_t}\right) \end{aligned}$$

This approximation uses that $\ln(1+x) \approx x$ for small x. This is an imperfect approximation, however this suffices to motivate the empirical specification of the corporate-Treasury yield spread regression. Define the corporate-Treasury yield spread as $\Delta i_t = i_t^S - i_t^T$ and rearrange

$$\Delta i_t = \frac{1}{\tau}E_t\left[M_{t+\tau}\right]E_t\left[\delta_{t+\tau}\right] + \frac{1}{\tau}cov_t\left(M_{t+\tau},\delta_{t+\tau}\right) + \frac{1}{\tau}\nu'\left(\frac{\Theta_t}{GDP_t},\xi_t\right)\left(\frac{\partial\Theta(\cdot)}{\partial b_t} - \frac{\partial\Theta(\cdot)}{\partial s_t}\right) \tag{9}$$

The first two terms on the right hand side of equation (9) are identical to the standard approach of asset pricing theory's CCAPM accounting for the theoretical variables that should drive corporate-Treasury yield spreads. The first term on the right-hand side reflects the expected losses in case of default on corporate commercial papers and bonds. The common label for this expression is "default risk". A higher expected probability of default in the business sector leads investors to demand a higher premium and hence to a higher yield spread. The second term on the right-hand side reflects the economic "risk premium" related to variation in default probabilities. This premium investors demand reflects in how far expected default rates covary with expected levels of the agent's marginal utility of consumption. The third term captures the modification of the standard asset pricing model by the assumption of convenience yields. The marginal convenience yield of holding money m_t, Treasuries b_t and corporate bonds s_t widens the spread compared to the standard model. Increasing the investors' holdings of m_t, b_t and s_t should decrease bond spreads with the ordering of marginal impacts by

$$\frac{\partial \Delta i_t(\cdot)}{\partial m_t} > \frac{\partial \Delta i_t(\cdot)}{\partial b_t} > \frac{\partial \Delta i_t(\cdot)}{\partial s_t}$$

This is due to the assumption that by offering liquidity and safety to a higher degree an additional unit of m_t holdings will yield more convenience in terms of utility than holding an additional unit of b_t and s_t. The same reasoning analogously holds for increasing the amount of b_t compared to increasing s_t.

For this model I assume that "flight-to-liquidity" episodes and liquidity risk premia resp. are captured in the shock parameter ξ_t. Both types of shocks can be interpreted as temporary shock to investors' demand for liquidity $\nu'(\cdot)$. The term "flight-to-liquidity" was coined by Longstaff (2004) who defines this as an episode where we can observe on the markets that some participants suddenly prefer to hold highly liquid securities such as U.S. Treasuries rather than less liquid securities like corporate bonds and commercial papers. Therefore in a "flight-to-liquidity" episode investors will have an increased willingness to pay for another unit of b_t which will drive up prices and in turn decrease yields and respective yield spreads compared to corporate debt securities. Following Amihud, Mendelson, and Pedersen (2005) Liquidity risk premia are due to time-varying changes in an asset's liquidity, as increasing the time span of a transaction as well as increasing bid-ask-spreads contribute to make future expected payment streams risky. For example, in times when investors would like to sell and the liquidity of a corporate bond deteriorates, risk averse investors will demand a liquidity risk premium for holding these bonds.

Further to note is that one should not expect to find by comparing the implications of equation (9) for short-term and log-term spreads, that changing both, $\frac{\Theta_t}{GDP_t}$ and ξ_t, will have the same impact on short-term and long-term spreads. Therefore theory leaves the possibility for a different priced value of short-term and long-term liquidity and safety.

2.4 Estimation Strategy

The present study estimates regression models derived from (9) for short-term and long-term spreads between yields of corporate debt securities and Treasuries by using Ordinary Least Squares (OLS) technique. The intention is to investigate whether the third term on the right-hand side of (9) reflects the unexplained share and the non-default component resp. which appears to be found in common credit spread regression models. Further this approach poses a test for the convenience yield hypothesis i.e. for the existence of investors' valuation for assets' specific liquidity and safety features which are priced separately from economic risk factors as well as from default and liquidity risk. This is done by estimating whether changes in the aggregate supply of assets that are presumed to bear less or more convenience yield than Treasuries will drive spreads in the predicted way. Therefore I test the hypothesis whether an increase in the supply of assets that are more (less) liquid and safe than Treasuries reduces observed spreads stronger (weaker) than an increase in the supply of Treasuries.

The dependent variables in each of the corporate-Treasury spread regressions is a month's average bond yield spread measured in percentage terms. The explanatory variables of interest are the face value of the outstanding stock of U.S. Treasuries scaled by U.S. GDP, denoted as the log of $Debt_t/GDP_t$, which proxies b_t/GDP_t, the empirical measure for the supply of money and near monies, the monetary base aggregate and total currency resp., scaled by U.S. GDP, $\log\left(MB_t/GDP_t\right)$, which proxies m_t/GDP_t, and the face value of corporate bonds and commercial papers outstanding scaled by U.S. GDP, $\log\left(CD_t/GDP_t\right)$, which proxies s_t/GDP_t. A log functional form is used because it provides a good fit and requires estimation of only one parameter.[12] Further, interpretation of the regression coefficient of a log independent variable which is a percentage share on a dependent variable in percentage terms is more convenient.

To control for default risk I use a measure for stock return volatility, named $Volatility$. The volatility measure for a given month is computed as the standard deviation of weekly log returns on the value-weighted S&P 500 index up to the end of a month. Then this is multiplied by the square root of 4 to derive the standard deviations on quarterly basis. As proxy for the risk premium the slope of the yield curve is taken. *Slope* is measured as the spread between the 10-year Treasury yield and the 3-month Treasury yield. The slope of the yield curve is regarded as a measure of the state of the business cycle. It is known to predict the excess returns on stocks and may also pick up time-varying risk premia on corporate bonds. For example if investors are more risk averse in a recession, when the slope is high, they will demand a higher risk premium to hold corporate bonds. Thus the slope of the yield curve serves as a measure of variation in the risk premium component of the bond spread, i.e. the term involving $cov_t\left(\cdot\right)$ in (9). Also note that to the extent that corporate default risk is likely to vary with the business cycle the *Slope* variable can furthermore contribute to control for the default risk in the yield spread.

Longstaff (2004) provides evidence for a flight-to-liquidity premium in the prices for U.S. Treasuries which is captured by the spread between yields of bonds issued by Resolution Funding Corporation (Refcorp), a U.S. government agency which is guaranteed by

[12] For the present study I find that for quarterly and monthly time series data Debt-to-GDP ratio is non-stationary but the log of the variable is stationary.

the Treasury, and Treasury bonds. By full repayment being guaranteed, Refcorp bonds therefore have literally the same credit risk as Treasuries. Since Treasuries are more liquid and more popular than Refcorp bonds a widening (deterioration) of this yield spread reflects investors' preference to hold more (less) highly liquid assets. The reason behind such changes in preferences lies in changing conditions of financial markets e.g. financial market turmoil would suddenly increase investors' preference for highly liquid assets. Therefore I use the spread between Refcorp bond U.S. Treasury bond yields to control for flight-to-liquidity episodes. This variable is named *Agency*.

To proxy for liquidity risk premia I follow Pflueger and Viceira (2011) by employing the difference between asset-swap spreads (ASW) for corporate debt securities and Treasury securities. Consider an investor owning a bond and entering into an an asset swap contract. The payer of the bond cash flows can hedge by holding the bond and financing the position on the short term debt market. Hence the asset-swap spread reflects the current and expected financing costs of holding the long bond position. Therefore the difference between the asset-swap spreads for corporate bonds and commercial papers resp. and Treasuries is a measure for the relative cost of financing a long position in the corporate debt securities market versus financing in the Treasuries market. A widening of this difference indicates a decreasing relative liquidity of corporate debt securities.

To ensure comparability of empirical results where possible, the same data as in the regressions by KVJ is used for construction of model variables. Details on the data used as well as data sources are in the data appendix[13]. Differently from KVJ, for the present study I use data at a monthly frequency in the regression models. Increasing the number of observations in the data set will make regression results more precise and more sound. Further the specification on monthly data will lead to a stronger emphasis of coefficients measuring market volatility and risk in the results. Therefore, if the impact of Debt-to-GDP ratio on spreads is robust across annual and monthly data, in terms of sign and magnitude, this would be strong evidence in favor of the presumed convenience yield theory.

3 Empirical results

Since data on the liquidity risk measures *Agency* and ASW are only available from 1987 onwards the empirical results are split into two parts: In the first part the standard CCAPM credit spread regression model is augmented by the measures for supplies of liquid and safe assets where monthly time series are going back to the second quarter

[13] See appendix B.

of 1971. The dependent variables are long-term and short-term bond yield spreads. In the second part the liquidity risk measures are included whereas only a short-term yield spread is the dependent variable.[14] To derive monthly GDP data I used a cubic spline interpolation on the time series of quarterly U.S. GDP.

Further note that for Tables I-VI I report t-statistics with adjusted standard errors, after finding an AR(1), AR(2) and AR(3) resp. error structure in most regressions. The AR(n) structure is motivated by a standard Box-Jenkins analysis of the autocorrelation function and partial autocorrelation function of the error terms. The first-order AR coefficients are included in the table. Serial correlation is especially pronounced in the long-term spread regressions. I use the Newey-West estimator to correct the t-statistics and standard errors for autcorrelation in the error terms.

3.1 Impact of asset supply changes on price measures

Table I presents results for the regressions of long-term and short-term spreads on the measure for Treasury supply, $\log(Debt_t/GDP_t)$, the measure for default risk, $Volatility$, and the proxy for the economic risk premium, $Slope$. A constant term is included as well. Panel A of Table I summarizes the coefficient estimates for the long-term spread as dependent variable, which is here the spread between the yields on Aaa rated corporate bonds and the yields on Treasury bonds. The mean value of the Aaa-Treasuries spread is at 96 basis points for the period of 1971 - 2008. The coefficient of -0.784 on the $\log(Debt_t/GDP_t)$ variable implies that a decrease of one standard deviation in the Debt-to-GDP ratio, from its mean value of 0.498 to 0.364, increases the Aaa-Treasury spread by 25 bp (0.25%) via the convenience yield channel from equation (9). This is consistent with the expectations and statistically significant. KVJ find for the same period with annual data an increase in 22 bp. Further $Volatility$ is found to be significantly related to the spread. The magnitude of the respective coefficient implies that default risk is an important component of long term bond spreads. While KVJ estimate for a one standard deviation increase in their default risk measure an increase of 10 bp in the Aaa-Treasuries spread, the present study finds an increase by 13 bp and a regression coefficient of 5.588.[15] Though evidence in Panel A of Table I indicates that $Slope$ does not exhibit a significant impact on the Aaa-Treasuries spread.

In Panel B of Table I results for the same regression model are shown with a short-

[14] The covariates *Agency* and *ASW* are expected to capture sudden short-term flight-to-liquidity episodes and short-term liquidity risk. In fact regression results do not show a significant impact on long-term spreads.

[15] For the sample of 1971-2008 this study finds a mean value of 0.035 and a standard deviation of 0.023 for $Volatility$.

term bond spread as dependent variable, which is the spread between the yields of highest rated commercial paper and Treasury bills, both with 3-month maturity length. Short and long-term spreads may be driven by different short and long-term convenience attributes, hence it should not be expected to find coefficients on $\log(Debt_t/GDP_t)$ to be the same across the two panels. Nonetheless, the effect of changes in aggregate Treasury supply on the short-term spread is estimated to be of fairly similar magnitude as the effect on long-term spreads. The mean value of the commercial paper-T-Bills spread is at 62 basis points for the period of 1971 - 2008. A decrease of one standard deviation in the Debt-to-GDP ratio from its mean increases the commercial paper-T-Bills spread by 22 bp compared to 23 bp in KVJ. Further this study finds evidence for a statistically significant impact of $Volatility$ on short-term spreads. An increase of $Volatility$ by one standard deviation increases the respective spread by 13 bp. KVJ however find no significant effect of their default risk measure on short-term spreads for the period 1969-2007. Panel B further shows that the measure for the economic risk premium *Slope* exhibits a significant but rather small impact on the commercial paper-T-Bills spread.[16]

From the results presented in Table I there is evidence in favour of the predictions by the theoretical pricing model which also confirms the findings of KVJ for annual data. Increasing the number of observations by changing frequency from annual to monthly data, leads for the same time horizon to similar results regarding the coefficient on $\log(Debt_t/GDP_t)$, and $Volatility$. Whereas for monthly data the non-default component proxied by the Debt-to-GDP ratio as well as the default risk component proxied by stock market volatility play a more pronounced role compared to the respective measures on annual data basis.

Table II reports OLS estimations of (9) where in the first column the impact of $\log(CD_t/GDP_t)$, $Volatility$ and *Slope* on the AAA-Treasury spread is measured. In the second column the $\log(Debt_t/GDP_t)$ regressor replaces the proxy for the supply of corporate debt securities from the first column. The proxy for money supply, $\log(MB_t/GDP_t)$, replaces the former in the third column. From the theoretical corporate-Treasury yield spread model described in the section above one would expect to find under the hypothesis of convenience yield being a priced attribute, that estimated coefficients would be in absolute terms ordered by $\beta_{\log(MB/GDP)} > \beta_{\log(Debt/GDP)} > \beta_{\log(CD/GDP)}$.

In Table II the coefficient on the proxy for aggregate supply of corporate debt is estimated to be smaller in absolute terms than the coefficient on the proxy for the aggregate Treasury supply which is in line with the expectations. This coefficient implies an increase

[16] These regressions were also conducted for quarterly data but are not provided for reasons of brevity. Results imply that a decrease in the Debt-to-GDP ratio by one standard deviation increases the long term spread by 26 bp and the short-term spread by 21 bp. An increase in $Volatility$ by one standard deviation increases the long-term spread by 14 bp and the short-term spread by 17 bp.

of 7 bp in the Aaa-Treasuries spread by a decrease of the corporate debt-to-GDP ratio by one standard deviation from its mean value. The coefficient on $\log(MB_t/GDP_t)$ is insignificant while the respective regression model has a relatively low R^2 of 0.154. The finding of an insignificant coefficient on the proxy for money supply does not seem to support the hypothesis that changes in the supply of assets that should deliver more convenience yield than Treasuries will cause a stronger impact on long-term spreads than changes in supply of the latter. However it is not surprising that the comparison of the effect of additional money holdings with the effect of additional long-term Treasury bond holdings will yield such evidence for the long-term spread regression. Money holdings are in general motivated by investors' short-term considerations whereas Treasury and corporate bond holdings are motivated by matching investor's long-term objectives. Including a different measure of money supply, namely the difference of M3-M2 scaled by GDP, instead of monetary base scaled by GDP, yields a regression coefficient which is in line with the hypothesis under consideration. Column 4 of Table II reports a coefficient of -1.718 on the measure $\log((M3_t - M2_t)/GDP_t)$ which implies an increase in the Aaa-Treasuries spread by 75 bp following a decrease in the M3-M2-to-GDP ratio by one standard deviation from its mean value. Note that M3-M2 covers the positions of large time deposits, institutional money market funds, repurchase agreements and other larger liquid assets. Regarding the motives of investors, these close to money substitutes capture mostly long term investment horizons for highly liquid assets. Hence the insignificance of $\log(MB_t/GDP_t)$ seen against the background of evidence presented in the fourth column of Table II points to a difference in long and short-term convenience yields and to the existence of different investment motives. This implies investors' separate pricing of short and long-term liquidity and short and long-term safety and further poses reasoning for the existence of market segmentation for long-term and short-term convenience assets. All the other variables included, but the four of interest mentioned, provide roughly the same evidence as explained in the paragraph above.

In Column 1 of Table III output for estimations of the short term spread regression on the $\log(CD_t/GDP_t)$, $Volatility$ and $Slope$ measures is reported. In Column 2 the proxy for the aggregate supply of corporate debt securities is replaced by the proxy for the supply of Treasury debt, $\log(Debt_t/GDP_t)$, and in Column 3 by the proxy for money supply, $\log(MB_t/GDP_t)$. Results presented in Table III are in line with expectations and generally statistically significant where $\beta_{\log(MB/GDP)} > \beta_{\log(Debt/GDP)} > \beta_{\log(CD/GDP)}$ in absolute terms. Expressed in terms of basis points coefficients imply 26 bp, 22 bp and 5 bp increases of the commercial paper-T-Bills spread by decreases of the respective asset-to-GDP ratio by a one standard deviation from the respective mean. Further comparing sign and magnitude of the coefficients on the proxies for money supply in column 3 and 4 with accordant results from Table II, there is further support for the implication of market segmentation and a difference in the short and long-term convenience yield. Coefficients on $\log((M3_t - M2_t)/GDP_t)$ and $\log(MB_t/GDP_t)$ imply that changes in the supply of long-term close to money substitutes do not exert such a strong impact on short-term yields as changes in the base money supply. All variables included, except the three mentioned of interest, here also provide the same evidence as explained in the paragraphs above.

Table IV reports regression results for estimations of (9) including the liquidity risk measures. The data sample covers the period from April 1987 to September 2008. In Column 1 estimated coefficients of the commercial paper-T-Bills yield spread regression on $\log(Debt_t/GDP_t)$, $Volatility$, $Slope$ and a constant are shown. Column 2 reports results for the same regression model where as well the covariates $Agency$ and ASW are added. By using the same approach, regressions are estimated for models that use $\log(CD_t/GDP_t)$ and $\log(MB_t/GDP_t)$ resp. instead of $\log(Debt_t/GDP_t)$. Accordant results are summarized in Columns 3 and 4 and Columns 5 and 6 resp.

By comparing estimated coefficients on the proxies for money supply, Treasury supply and the supply of corporate debt securities in columns 1, 3 and 5 the expected ordering of $\beta_{\log(MB/GDP)} > \beta_{\log(Debt/GDP)} > \beta_{\log(CD/GDP)}$ is preserved for the underlying data sample. Including the liquidity risk proxies $Agency$ and ASW yields statistically significant regression coefficients with the expected signs for all regression models under consideration. For the regression results reported in Column 2 of Table IV where $\log(Debt_t/GDP_t)$ is included as a covariate an increase of ASW by one standard deviation from its mean of 0.441 to 0.644 increases the short term yield spread by 22 bp. This poses evidence in favor of the hypothesis that the commercial paper-T-Bill spread captures an investors' demanded liquidity risk premium. Further if the measure $Agency$ increases by one standard deviation from its mean of 1.054 to 1.997 the short-term spread decreases by 20 bp which provides evidence for a flight to liquidity premium in the commercial paper-T-Bill spread. The corresponding numbers for regression output in the fourth column of Table IV are 23 bp and 21 bp resp., for Column 6 of Table IV I calculate 20 bp and 15 bp resp. Compared to the columns 1, 3 and 5 regression coefficients of the proxies for Treasury supply, money supply and the supply of corporate debt securities decrease sharply. Coefficients now imply that decreases of the respective measure by one standard deviation from its mean value, increase spreads by 3, 8 and 1 bp resp.[17] This implies that in regression models

[17] For the time period 1987 to 2008 the mean of $Debt_t/GDP_t$ is 0.603 with a standard deviation of 0.051. For the same period MB/GDP has a mean of 0.056 and a standard deviation of 0.005. The mean of CD/GDP is 0.225and the standard deviation is 0.031 for the respective time span.

excluding measures for liquidity risk and flight-to-liquidity episodes, the coefficients on the proxies for the amount of convenience assets outstanding capture sizeable information contained in the former. However seen against the background of the commercial paper-T-Bills spread's mean being at 46 bp for the period of 1987 - 2008 still priced convenience yield can be regarded as a significant driving force. In addition to that, the theoretically implied ordering is kept with $\beta_{\log(MB/GDP)} > \beta_{\log(Debt/GDP)} > \beta_{\log(CD/GDP)}$ in absolute terms. Further R^2 measures for all three regression models rise to values of roughly 0.8 and Durbin-Watson statistics increase significantly by including liquidity risk measures which points to a better model fit and a lager share of the spread's variance being explained by the models.

4 Conclusion

The present study provides empirical evidence supporting the finding that the non-default component of the corporate bond spread is to a significant extent driven by the supply of liquid and safe assets. Thereby robustness of results was tested by using different data samples and model specifications. I showed that changes in the aggregate supply of assets that are presumed to bear less or more convenience yield than Treasuries will effect spreads in the way predicted by the convenience yield theory. Finding this systematic pattern points to the existence of a demand function for liquidity and safety attributes. Moreover results imply market segmentation for long and short term bonds as a difference in long and short-term convenience yields points to the existence of different investment motives. Evidence shows that convenience yield theory explains a significant part of the non-default component in corporate-Treasury yield spread regressions. Results further show that investors price convenience yield separately from measures for default risk, flight-to-liquidity episodes and liquidity risk. Compared to commonly used credit spread regression models the present study uses model specifications which yield a better fit and a lager share of the spread's variance is explained. Further, finding empirical evidence for convenience yield being priced by investors poses a challenge to standard asset pricing theory models.

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A Regression variables

Aaa-Treasury yield spread: This variable is constructed as the monthly percentage spread between Moody's Aaa-rated long maturity corporate bond yield and the average yield on long term Treasury bonds. The Moody's Aaa index is constructed from a sample of long maturity ($\geq$ 20 years) industrial and utility bonds (industrial only from 2002 onward). The yield on long maturity Treasury bonds is the average yield on long-term government bonds. The Treasury bonds included are due or callable after 10 years for the period 1971-1999. For 2000-2008 the yields on 20-year maturity Treasuries are used. All three data series are from the Federal Reserve's FRED database (series AAA, LTGOVTBD, and GS20). Monthly data for April 1971 up to September 2008 is used leaving out the sub prime crisis market turmoil and fiscal and GDP response.

CP-Bills yield spread: The percentage yield spread between commercial paper and Treasury bills. For the whole period 1971-2008 the commercial paper yield is from the FRED database. The period 1971-1996 is covered by the series CP3M (the average of offering rates on 3-month commercial paper placed by several leading dealers for firms whose bond rating is AA or equivalent) and for 1997-2008 by the series CPN3M (the 3-month AA nonfinancial commercial paper rate). The Treasury bill yield is for 3-month Treasury bills from 1971-2008 (FRED series TB3MS).

Debt/GDP: This variable is intended to proxy the supply of Treasuries scaled by GDP. This variable is calculated from April 1971 until September 2008. I use time series data on the total amount of Treasury securities outstanding from Datastream (series USSECMNSA). Quarterly GDP data is from Federal Reserve's FRED database (series GDP). To derive monthly GDP data I used a cubic spline interpolation on the time series of quarterly U.S. GDP. Unlike KVJ I do not calculate Debt/GDP at market value. However KVJ show that over the period 1949-2008 the correlation between Debt/GDP at face value and Debt/GDP at market value is 0.992.

MB/GDP: This variable is intended to proxy for the supply of money and close to money substitutes scaled by GDP. From FRED I use the series BOGAMBSL, "Board of Governors Monetary Base, Adjusted for Changes in Reserve Requirements". Therefore notes and coins (currency) in circulation (outside Federal Reserve Banks, and the vaults of depository institutions), currency in bank vaults, and Federal Reserve Bank credit (minimum reserves and excess reserves) are included which is widely interpreted as base money or total currency. MB/GDP hence is derived from the most liquid measure of money supply actually leaving out close to money assets like demand and savings deposits.

(M3-M2)/GDP: This variable is intended to proxy for the supply of long-term close to money substitutes and long-term assets with the highest possible degree of liquidity and safety resp. scaled by GDP. M3-M2 covers the positions of large time deposits, institutional money market funds, repurchase agreements and other larger liquid assets. Data on the two empirical measures for aggregate money supply, M3 and M2, are from FRED (series M3SL and M2SL). Data for M3 is only available until February 2006. Hence this variable is calculated for the period April 1971 until February 2006.

CD/GDP: This variable is intended to proxy for the supply of corporate debt securities scaled by GDP. I use the FRED series CPLBSNNCB, "Commercial Paper - Liabilities - Balance Sheet of Nonfarm Nonfinancial Corporate Business", for the face value of outstanding commercial paper and the series CBLBSNNCB, "Corporate Bonds - Liabilities - Balance Sheet of Nonfarm Nonfinancial Corporate Business", for the face value of outstanding corporate bonds. The sum of both series is assumed to measure the total supply of corporate debt securities.

Volatility: This measure is based on standard deviations of weekly log stock returns on the S&P500 index. Weekly returns are calculated on the value-weighted S&P500 index based on daily returns obtained from Federal Reserve's FRED database (series SP500). As a volatility measure for a given month, the standard deviation of the weekly log returns are calculated up to the end of the month. The standard deviation of weekly log returns is then multiplied by the square root of 4.

Slope: The slope of the Treasury yield curve measured as the spread between the 10-year Treasury yield and the 3-months Treasury bill yield. The interest rate on Treasuries with 10 year maturity is from FRED (series GS10). The interest rate on Treasuries with 3 month maturity is from FRED as well (series TB3MS).

ASW: The measure for the difference in asset-swap spreads between corporate debt securities and Treasury securities. From Datastream the time series ICUSS2Y is used which captures the asset-swap rate of benchmark securities over the 2-year Treasury rate.

Agency: This is the measure for the spread between yields of Refcorp bonds and Treasury bonds. Time series data on yields of Freddie Mac bonds due after one year and bond yields on Treasuries with the same maturity length are from Datastream (series USMIA1 and FRTCM1Y).

Table I

Impact of Treasury Supply on Bond Spreads: Log specification

	Panel A: Aaa-Tresaury	**Panel B: CP-Bills**
Period	Apr. 1971 – Sep. 2008	
log(Debt/GDP)	-0.784	-0.620
	[-7.596]	[-8.732]
Volatility	5.588	5.819
	[4.005]	[6.567]
Slope	0.006	-0.136
	[0.327]	[-8.825]
Intercept	0.387	0.156
	[5.319]	[2.790]
R^2	0.419	0.350
Durbin-Watson	0.282	0.536
ρ	0.646	0.658
N	**453**	**453**

Table II
Impact of MB/GDP, Debt/GDP, CD/GDP

	Aaa-Treasury			
Period		Apr. 1971 – Sep. 2008		Apr. 1971 – Jan. 2006
	(1)	(2)	(3)	(4)
log(MB/GDP)			0.303	
			[1.122]	
log((M3-M2)/GDP)				-1.718
				[-4.018]
log(Debt/GDP)		-0.784		
		[-7.596]		
log(CD/GDP)	-0.277			
	[-4.369]			
Volatility	6.554	5.588	6.337	5.879
	[4.803]	[4.005]	[4.596]	[4.007]
Slope	-0.017	0.006	-0.027	-0.038
	[-0.799]	[0.327]	[-1.309]	[-1.767]
Intercept	-0.741	0.387	1.846	1.399
	[-1.902]	[5.319]	[2.329]	[12.352]
R^2	0.288	0.458	0.140	0.240
Durbin-Watson	0.287	0.418	0.225	0.239
ρ	0.589	0.646	0.611	0.615
N	**453**	**453**	**453**	**418**

Table III

Impact of MB/GDP, Debt/GDP, CD/GDP

	CP-Bills			
Period	Apr. 1971 – Sep. 2008			Apr. 1971 – Jan. 2006
	(1)	(2)	(3)	(4)
log(MB/GDP)			-1.267	
			[-6.638]	
log(MB/GDP)				-0.254
				[-3.582]
log(Debt/GDP)		-0.620		
		[-8.732]		
log(CD/GDP)	-0.198			
	[-5.538]			
Volatility	6.581	5.819	7.339	5.748
	[7.130]	[6.567]	[7.995]	[2.670]
Slope	-0.155	-0.136	-0.158	-0.177
	[-9.784]	[-8.825]	[-10.069]	[-5.451]
Intercept	-0.607	0.156	-3.085	0.132
	[-2.745]	[2.790]	[-5.535]	[0.975]
R^2	0.288	0.350	0.308	0.295
Durbin-Watson	0.521	0.536	0.566	0.486
ρ	0.646	0.658	0.624	0.674
N	**453**	**453**	**453**	**418**

Table IV
Impact of Debt/GDP, liquidity risk

	CP-Bills					
Period	Apr. 1987 – Sep. 2008					
	(1)	(2)	(3)	(4)	(5)	(6)
log(MB/GDP)			-2.313	-0.953		
			[-8.713]	[-4.356]		
log(Debt/GDP)	-1.495	-0.379				
	[-5.077]	[-3.436]				
log(CD/GDP)					-1.029	-0.068
					[-6.908]	[-5.325]
Volatility	2.862	2.104	4.007	3.822	5.216	2.737
	[1.916]	[3.266]	[3.711]	[3.822]	[4.671]	[4.646]
Slope	-0.050	0.077	-0.045	0.054	-0.069	0.079
	[-2.734]	[5.240]	[-3.156]	[3.549]	[-4.788]	[5.342]
ASW		1.095		0.945		1.146
		[9.094]		[9.658]		[13.609]
Agency		-0.209		-0.161		-0.227
		[-12.144]		[-8.190]		[-13.331]
Intercept	-0.301	-0.175	-0.620	-0.034	-1.170	-0.198
	[-2.064]	[-1.320]	[-8.192]	[-4.092]	[-4.977]	[-0.716]
R^2	0.287	0.671	0.505	0.715	0.402	0.684
Durbin-Watson	0.396	0.762	0.610	0.862	0.547	0.816
ρ	0.762	0.602	0.685	0.566	0.679	0.535
N	**258**	**258**	**258**	**258**	**258**	**258**