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Risk factors in Australian bond returns

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Abstract

This study examines the risk factors in Australian bond returns. The study quantifies bond liquidity and estimates a liquidity risk factor in the Australian setting. We develop a three-factor asset pricing framework that uses term, default and liquidity risk factors to explain the variation of Australian bond returns. Our findings corroborate the US evidence on the pervasiveness of these risk factors faced by bond investors. The three-factor model developed in this study has practical applications when calculating the cost of debt, evaluating the performance of an active bond fund manager and hedging underlying risk in a bond portfolio.

Key words: Asset pricing; Bond pricing; Default and term beta; Liquidity risk

JEL classification: G12, G14, G15

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1. Introduction

The study examines the systematic risk factors that explain the variation of bond returns. This issue so far is unresolved in the Australian setting. Our understanding of asset pricing in bonds originates from the work of Fama and French (1993), who demonstrate that two systematic risk factors, the term and

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default premia, capture a significant proportion of the variation of US bond returns. The term premium reflects the common risk factor associated with unexpected changes in interest rates whereby investors demand compensation for holding bonds with longer maturities compared to those with shorter maturities. The default or credit premium reflects compensation for holding bonds with a nonzero probability of default.

More recently, Liu (2006), Mahanti *et al.* (2008), Chen *et al.* (2007) and Lin *et al.* (2011) suggest that liquidity is an additional systematic risk factor that can explain the behaviour of bond returns. The efficacy of an asset pricing model is whether it is robust out-of-sample in a country other than the USA, in our case, Australia, given its different institutional frameworks. We contribute to the global debate by identifying and examining the risk factors in Australian bonds.

The literature on bond asset pricing in Australia is scant, despite the size of this market. In fact, Australian non-government debt outstanding represents approximately 94 percent of Australian gross domestic product (GDP) compared to 144 percent for the US and 84 percent for Germany (Debelle, 2011). Black *et al.* (2012) estimate the face value outstanding of the Australian corporate bond market at $825 billion, or approximately two-thirds of the market capitalisation of the Australian Securities Exchange (ASX). As at December 2010, the Reserve Bank of Australia (RBA) reports $1420.8 billion of long-term debt securities outstanding.[1]

This study makes four contributions to the asset pricing debate. First, we quantify a term risk premium in Australia of 0.123 percent per month over the period 1999 through 2010. Second, we estimate a default risk premium of 0.024 percent per month over the same period. Third, we estimate the Australian bond liquidity risk premium at 0.036 percent per month over the period. Finally, we employ the term, default and liquidity risk premia as common factors in a multifactor bond asset pricing model. We find all three factors are statistically and economically significant in explaining Australian bond returns sorted by credit rating, duration or a combination of both.

The remainder of the study is organised as follows. Section 2 provides a brief survey of the literature. Section 3 outlines the data investigated in the study, with section 4 detailing the methodological approach. Section 5 presents the findings of the study, with concluding remarks in section 6.

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[1] The RBA Statistical Table D4 reports the following aggregate debt securities outstanding as at December 2010. Long-term non-government securities issued in Australia: $434.3 billion; government securities issued in Australia (long-term): $307.9 billion; non-government securities issued offshore: $511.0 billion; non-residents' A$ Eurobonds: $60.0 billion; and residential mortgage securities: $107.6 billion. These aggregate debt securities outstanding total $1420.8 billion.

2. Related literature

The identification of systematic risk factors in bond returns has important practical implications for asset pricing, valuation and investments. The contribution in the bond asset pricing literature from Fama and French (1993) reveals that two systematic risk factors, term and default premia, can capture the common variation of US investment grade bond returns. Moreover, Gebhardt *et al.* (2005) show that yield to maturity is a good proxy for explaining average bond returns, consistent with the theory of the term structure of interest rates. Related work has emphasised the importance of the expected default risk as a systematic risk factor in bond returns, with empirical support provided by Elton *et al.* (2001) and Longstaff *et al.* (2005).

Recently, the literature has introduced liquidity risk as a priced factor in explaining the cross-sectional variation of bond yield spreads and returns. Studies by Driessen (2005), Houweling *et al.* (2005) and Longstaff *et al.* (2005) find that liquidity is important in explaining a proportion of bond yield spreads. Earlier work, such as Amihud and Mendelson (1991), posits that investors demand a higher return for a less liquid security. It then follows that a liquidity premium may be a systematic risk factor in explaining bond yield spreads and, therefore, bond returns. This work measures the size of the bid–ask bond spread and shows that illiquid US Treasury Notes exhibit a higher yield and lower price than more liquid Treasury Note securities. Similar findings by Kamara (1994) and Warga (1992) support the notion of a US bond liquidity premium. Furthermore, Chen *et al.* (2007) demonstrate that illiquid bonds exhibit a higher yield to maturity and that changes in the liquidity measure explain some of the variation in US yield spreads. Most recently, Lin *et al.* (2011) use liquidity as a systematic risk factor, along with the Fama and French (1993) term and default risk premia, to show that all three factors are significant in explaining the variation of US bond returns.

In the case of Australia, the analysis of a two-factor, term and default, or three-factor bond asset pricing model, term, default and liquidity, is untested. Australian research has tended to focus on models that explain the variation of yield spreads (see Brown *et al.*, 2002; Batten and Hogan, 2003; Lepone and Wong, 2009; Darwin *et al.*, 2012) and the market efficiency of fixed interest markets (see Gallagher and Jarnecic, 2002 and Creighton *et al.*, 2007). While these studies contribute to an understanding of yield spreads and market efficiency, empirical research on the systematic drivers of Australian bond returns is lacking.[2]

[2] Davis (2005) is the closest related research to our study and finds evidence that Australian Commonwealth government bonds exhibit a nonzero beta with Australian stocks.

Our analysis of Australian bonds in an asset pricing framework provides new insights. Although the research contributions from Bilson *et al.* (2008) and Finlay and Chambers (2009) confirm the importance and pricing of the term structure of interest rates, whether one or all three of the systematic risk factors in US bond asset pricing models applies in the Australian market is unproven. Further, the information from our multifactor bond asset pricing model has important practical implications for the private sector, government, the central bank (Reserve Bank of Australia) and regulatory agencies.[3]

The body of knowledge regarding Australian liquidity is limited to equity markets. Early studies such as Gaunt (2004), Gharghori *et al.* (2007) and Brailsford *et al.* (2012) demonstrate the importance of the Fama and French (1993) size (SMB) and value (HML) premia in explaining the common variation of Australian equity returns. Subsequent work from Drew *et al.* (2006) finds that a liquidity proxy can improve the explanatory power of a multifactor equity asset pricing model. More recently, Vu *et al.* (in press) employ various definitions of liquidity and show that it is a priced factor in Australian stock returns. Limkriangkrai *et al.* (2008) find that equity liquidity as an additional factor to the Carhart (1997) four-factor asset pricing model increases the explanatory power of the variation of Australian stock returns; however, Chai *et al.* (2013) reveal that the liquidity risk factor adds marginal explanatory power only. While the equity literature provides insights on the behaviour of liquidity in the sharemarket, we are unaware of any studies measuring systematic risk factors and liquidity in an Australian bond asset pricing framework.

3. Data

There is no centralised repository or exchange for storing historical information on Australian bonds. To address this issue of data and price integrity in this market, this study examines the individual bond constituents of the Union Bank of Switzerland (UBS) Australia Composite Bond Index. Following Gallagher and Jarnecic (2002), the UBS Australia Composite Bond

[3] Multifactor bond asset pricing models are useful in numerous practical applications. The motivation of asset pricing models is to identify the systematic (or priced) risks versus the idiosyncratic (or unpriced) risks that explain the variation of returns of fixed interest securities and bond portfolios. Conventional studies suggest that the yield spread represents default risk; however, Chen *et al.* (2007) and Lin *et al.* (2011) reveal a liquidity component in the yield spread that is less related to default risk. A bond asset pricing model allows middle office risk managers to identify the systematic risks that deliver reward/risk to investors versus the idiosyncratic risk that remains unpriced and needs to be hedged out of the bond portfolio. In another setting, the front office bond portfolio manager can construct long/short positions in the term, default and liquidity factors (i.e. three positions) to efficiently hedge an entire bond portfolio (rather than hedging every individual bond position), if required.

Index (UBSACBI) is the preferred benchmark for Australian bond funds.[4] Using the bond constituents of the UBS, benchmark index ensures that the Australian bond price information collected by UBS is the best and most accurate data available.[5]

To be included in the UBSACBI, bonds must meet certain criteria. Credit Suisse (2009) states that the UBSACBI consists of nominal fixed rate bonds and mortgage-backed and asset-backed securities only. All bonds in the UBSACBI must have a minimum face value of $100 million on issue. They comprise several categories/sectors, including Commonwealth government securities, semi-government, investment grade credit, fixed mortgage-backed securities and fixed asset-backed securities. At the end of each month, the clean price, coupon rate and maturity for all semi-government, corporate and asset-backed bonds are collected from 1 January 1999 to 31 December 2010 to calculate total monthly returns. The index maintains a daily update cycle whereby bond constituents can enter or exit the index.[6]

The UBSACBI data set comprises 901 bond issues from 207 unique bond issuers over the full sample period. For our study, we remove 33 Australian Commonwealth government bonds from the sample (which are effectively the risk-free rate) resulting in 868 bonds available for further analysis. Then, we collate daily bond prices and returns of these securities to estimate a liquidity proxy in the Australian bond market.

We cross-reference the 868 bonds in the UBSACBI with their daily pricing information available in the Datastream database. A total of 228 bonds with no daily pricing information are removed from the data set yielding 640 bonds available for analysis. The credit ratings for these bonds are obtained from Moody's Investor Services and from Standard and Poor's for bonds not rated by Moody's. Any conflict in credit rating is resolved in favour of the Moody's Investor Services rating, consistent with Lin *et al.* (2011).

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[4] The UBS Australia Composite Bond Index originated in 1989 as the 'Dominguez Barry Samuel Montague (DBSM) All Composite Bond Index'. After the takeover of the DBSM merchant bank, the index was renamed the 'Swiss Bank Corporation (SBC) All Composite Bond Index'. In 1998, SBC merged with the Union Bank of Switzerland (UBS) and the index was renamed as the 'UBS Australia Composite Bond Index'. On 2 April 2014, it was announced that Bloomberg Indexes had completed the acquisition of the family of Australian bond indices from UBS and will be renamed as part of the 'Bloomberg AusBond Indexes'. Bloomberg will continue the calculation of this Australian bond index from 29 September 2014. Refer to the following media release: http://www.businesswire.com/news/home/20140402006764/en/Bloomberg-Indexes-Acquires-UBS-Australia-Bond-Indexes#.U3mEc457mrt

[5] We gratefully acknowledge and thank UBS Australia for providing the data employed in this study.

[6] These features provide the reader with information relating to the history and maintenance of the UBS Australia All Composite Bond Index; however, we do not use the index returns in this study, but rather, we analyse the bond constituents of the index.

Table 1
Bond issues and maturities in the UBS Australia composite bond data set

		All bonds		Corporate bonds	
Year	Avg. no. bond issues	Issues	Maturities	Issues	Maturities
2000	147.92	98	65	52	51
2001	174.67	79	67	25	49
2002	187.33	26	51	14	43
2003	190.08	63	59	44	47
2004	222.75	91	60	66	50
2005	304.92	141	50	121	41
2006	347.00	72	34	46	25
2007	372.83	46	39	42	28
2008	354.92	42	30	37	24
2009	335.50	56	35	43	27
2010	362.33	39	18	33	13

This table summarises the number of bonds on issue in the UBS bond data set for every calendar year from 2000 to 2010. Avg. no. bond issues denotes the mean number of bonds on issue. Columns three and four summarise the total number of bonds issued and maturities. The final two columns summarise the total number of corporate bonds issued and maturities.

The short-term and long-term estimates of the risk-free rate in this analysis are sourced from the RBA. We follow Brailsford *et al.* (2008) using the composite 10-year Australian Commonwealth government bond rate as the long-term risk-free rate and the Australian 90-day bank accepted bill rate as the short-term risk-free rate. The Brailsford *et al.* (2008) methodology removes the need to estimate an Australian Commonwealth government risk-free rate for a significant period of the analysis.[7]

Table 1 summarises the number of bond issues and maturities in the data set for all bonds in the sample and corporate bonds only. The average number of securities in the data set increases every calendar year except in 2008 and 2009 when bond markets were in the midst of the Global Financial Crisis (GFC). There are higher levels of aggregate bond issues than maturities in all years except in 2002. There are more corporate bond issues than maturities in all years except in 2001 to 2003.

Table 2 provides the summary statistics of the data sample sorted by their bond issuer classifications as defined by UBS. It shows that the Australian semi-government bond issuers are the largest constituents in the data sample

[7] Following the election of the John Howard Government in 1996, there was a policy decision to reduce federal government debt levels. The Australian Commonwealth (federal) government delivered numerous budget surpluses in consecutive years, thereby reducing government debt, and as a consequence, there were no Treasury Notes (i.e. the proxy for the risk-free rate) on issue from 2003 to 2008. http://www.aofm.gov.au/content/_download/Historical_tables/Historical_07_08/TableH14.pdf

Table 2
Summary statistics

Industry classification	Avg. YTM (%)	Avg. Cpn (%)	Avg. FV ($)	Avg FV (%)	Mean return (%)	Mean maturity	Mean number of issuers
Autos	6.17	6.32	138.1	1.77	0.47	1.46	1.98
Bank sub	8.50	6.72	271.7	3.49	0.48	2.71	10.25
Banks	6.13	6.29	444.0	5.71	0.48	2.56	49.97
Capital goods	6.59	6.63	227.5	2.92	0.55	2.68	1.17
CMBS	6.35	6.19	146.7	1.89	0.52	1.46	3.12
CMBS call	5.99	5.88	290.0	3.73	0.48	0.90	1.00
Commercial services	6.81	6.84	229.7	2.95	0.47	3.23	2.39
Diversified financials	7.12	6.28	285.7	3.67	0.50	2.86	28.28
Energy	6.82	6.36	127.0	1.63	0.51	3.56	1.72
Food beverage and tobacco	6.13	6.75	140.0	1.80	0.50	2.02	0.85
Food and drug retailing	6.55	6.07	263.3	3.38	0.55	2.86	2.16
Hotels restaurants and leisure	7.07	6.50	385.0	4.95	0.53	3.70	1.00
Insurance	6.26	6.39	232.3	2.99	0.56	2.38	7.56
Materials	6.67	6.56	302.8	3.89	0.56	2.36	2.30
Media	6.99	6.76	200.7	2.58	0.49	2.73	1.56
Other	8.87	6.71	205.2	2.64	0.18	9.11	1.00
Other abs	6.48	6.33	287.2	3.69	0.45	4.23	7.90
Real estate	6.61	6.52	171.1	2.20	0.54	2.74	19.52
RMBs conf	5.99	5.97	290.2	3.73	0.46	0.86	1.03
Semi-government	5.65	7.00	1582.6	20.34	0.47	5.99	39.65
Supranational/Sovereign	5.81	5.80	719.2	9.24	0.47	4.00	39.63
Telecommunications	6.33	8.59	416.5	5.35	0.52	4.16	6.12
Transportation	6.98	6.57	208.3	2.68	0.41	6.36	8.80
Utilities	6.61	6.67	215.8	2.77	0.48	3.33	10.96

This table presents the summary statistics of the bonds employed in the analysis from January 1999 to December 2010, sorted by their UBS bond issuer classifications. Avg. YTM denotes the average yield to maturity. Avg. Cpn denotes the average coupon rate. Avg. FV ($) denotes the average face value outstanding per A$10 000 000 on issue. Avg. FV (%) denotes the Avg. FV ($) expressed as a percentage of all bonds outstanding. Mean return denotes the equal-weighted average return per month. Mean maturity denotes the average number of years to maturity. Mean number of issuers denotes the average number of bond issuers.

and are followed by other bond issuers. Of the corporate bond issuers, the banks, telecommunications and hotel restaurant and leisure industries report the highest average amount of bonds outstanding in the sample. From a credit ratings perspective, Table 3 presents the data sample sorted by Moody's credit ratings. It shows a large proportion of bonds in the sample have an Aaa, Aa or A credit rating, and all bonds are investment grade in nature, given the institutional requirement of the UBSACBI.

Table 3
Bond sample sorted by credit ratings

Aaa	Aa	A	Baa	Ba	B
44.01%	25.75%	24.27%	5.96%	0.00%	0.01%

This table reports the percentage of bonds in the data sample sorted by credit rating. It is important to note that only Moody's credit ratings are reported in this table.

4. Methodology

Our research design to identify and measure term, default and liquidity premia follows the standard convention for studies in the field. Therefore, it uses a market value-weighted return for all bond portfolios to ensure investability of the estimated bond returns. We calculate bond returns using price and yield data obtained on the last day of each month as follows:

$$r_{i,t} = \frac{\left(P_{i,t} + \mathrm{AI}_{i,t}\right) + C_{i,t} - \left(P_{i,t-1} + \mathrm{AI}_{i,t-1}\right)}{\left(P_{i,t-1} + \mathrm{AI}_{i,t-1}\right)} \tag{1}$$

where the subscript '$_{i,t}$' refers to bond i at time t; P_t is the clean price of the bond at the end of month t; AI_t is the accrued interest for the bond at the end of month t; C_t is any coupon paid during month t; $\mathrm{P}_{t\text{-}1}$ is the clean price of the bond at the end of month t-1, and $\mathrm{AI}_{t\text{-}1}$ is the accrued interest for the bond at the end of month t-1.

4.1 Estimation of term and default risk premia

Following Fama and French (1993), we calculate term and default as the two common risk factors in these bond returns. The proxy for the term risk factor is calculated as the difference between the monthly value-weighted returns of Australian government bonds with a maturity greater than ten years and the 90-day bank accepted bills. The proxy for the default risk factor is calculated as the difference in monthly returns of a value-weighted portfolio of all bonds in the UBSAACBI with a maturity longer than five years (excluding the Australian Commonwealth and semi-governments) and a value-weighted portfolio of Australian Commonwealth government bonds with a maturity longer than five years.[8]

[8] The Fama and French (1993) definition of the default premium employs government and corporate bonds with 10 years to maturity. Our Australian bond data set has too few corporate bonds with 10 years to maturity; therefore, we calculate the Australian default premium by employing government and corporate bonds with 5 years to maturity.

4.2 Estimation of bond liquidity

To evaluate liquidity as a potential risk factor in Australian bond returns, we must first estimate the liquidity of every individual bond in the sample. For the purposes of this analysis, we use the Chen *et al.* (2007) liquidity measure adapted for the Australian setting.[9] Chen *et al.* (2007) assume that bond returns follow a return generating process given as:

$$R^*_{j,t} = \beta_{j1}\text{Duration}_{j,t} \times \Delta R_{f,t} + \beta_{j2}\text{Duration}_{j,t} \times \Delta \text{S\&P ASX Index}_t + \varepsilon_{j,t} \tag{2}$$

where $R^*_{j,t}$ is the 'real' unobserved return for bond j on day t that an investor would earn before transaction costs; $\Delta R_{f,t}$ is the daily change in the 10-year risk-free interest rate; ΔS&P ASX Index$_t$ is the daily return of the S&P ASX 200 Accumulation Index; and Duration$_{j,t}$ is the Macaulay duration of bond j at time t. Chen *et al.* (2007) state that the observed return $R_{j,t}$ is related to the unobserved return $R^*_{j,t}$ by the following equation:

$$R_{j,t} = R^*_{j,t} - \alpha_{i,j} \tag{3}$$

where $R_{j,t}$ is the observed clean price bond returns, and $\alpha_{i,j}$ is the effective liquidity cost for transacting in the instrument. Chen *et al.* (2007) state that the effect of liquidity on bond prices can be modelled by employing the following system of equations:

$$R_{j,t} = R^*_{j,t} - \alpha_{1,j} \quad \text{if } R^*_{j,t} < \alpha_{1,j} \text{ and } \alpha_{1,j} < 0 \tag{4}$$

$$R_{j,t} = 0 \quad \text{if } \alpha_{1,j} \leq R^*_{j,t} \leq \alpha_{2,j} \tag{5}$$

$$R_{j,t} = R^*_{j,t} - \alpha_{2,j} \quad \text{if } R^*_{j,t} > \alpha_{2,j} \text{ and } \alpha_{2,j} > 0 \tag{6}$$

where $\alpha_{1,j}$ is the effective buy side cost involved in trading the bond instrument, and $\alpha_{2,j}$ is the effective sell side cost. We derive estimates of $\alpha_{1,j}$, $\alpha_{2,j}$, $\beta_{j,1}$ and $\beta_{j,2}$ by maximising the following log-likelihood function. The following estimation technique follows Maddala (1983) and the bond literature of Lesmond *et al.* (1999) and Chen *et al.* (2007):

[9] The Chen *et al.* (2007) methodology employed in Equation (2) assumes that bond returns are riskier than the risk-free rate but are less risky than stock market returns due to the conventional capital structure of a firm and the higher ranking of bonds over equity in the event of a corporate failure.

$$\begin{aligned}
\mathrm{LnL} = {} & \sum_1 \mathrm{Ln}\frac{1}{(2\pi\sigma_j^2)^{1/2}} \\
& -\sum_1 \frac{1}{2\sigma_j^2}(R_j + \alpha_{1,j} - \beta_{j1}\mathrm{Duration}_{j,t} \times \Delta R_{f,t} - \beta_{j2}\mathrm{Duration}_{j,t} \\
& \times \Delta \mathrm{S\&P\ ASX\ Index}_t)^2 + \sum_2 \mathrm{Ln}\frac{1}{(2\pi\sigma_j^2)^{1/2}} \\
& -\sum_2 \frac{1}{2\sigma_j^2}(R_j + \alpha_{2,j} - \beta_{j1}\mathrm{Duration}_{j,t} \times \Delta R_{f,t} - \beta_{j2}\mathrm{Duration}_{j,t} \\
& \times \Delta \mathrm{S\&P\ ASX\ Index}_t)^2 + \sum_0 \mathrm{Ln}(\Phi_{2,j} - \Phi_{1,j})
\end{aligned} \tag{7}$$

where $\Phi_{\mathrm{i,j}}$ is the cumulative distribution function expressed as:

$$(\alpha_{i,j} - \beta_{j1}\mathrm{Duration}_{j,t} \times \Delta R_{f,t} - \beta_{j2}\mathrm{Duration}_{j,t} \times \Delta \mathrm{S\&P\ ASX\ Index}_t)/\sigma_j \tag{8}$$

$\sum_1$(region 1) represents the negative nonzero measured returns, $\sum_2$(region 2) represents the positive nonzero measured returns, and $\sum_0$(region 0) represents the zero measured returns. As in Chen *et al.* (2007), the difference between the buy side and sell side costs $\alpha_{2,j}$ - $\alpha_{1,j}$ is the bond liquidity estimate used in this study.

4.3 Test of bond liquidity

As a robustness test, we examine whether the liquidity measure in the previous section can explain the changes in Australian bond yields. Chen *et al.* (2007) hypothesise that the yield to maturity of a bond is positively related to the illiquidity of a bond because investors demand a higher rate of return due to higher liquidity risk. To test this, we follow Chen *et al.* (2007) and model yield spread changes with the following panel regression based on first differences:

$$\begin{aligned}
\Delta\mathrm{Yield\ Spread}_{i,t} = {} & \beta_0 + \beta_1\Delta \mathit{Liquidity}_{i,t} + \beta_2\Delta \mathit{Rating}_{i,t} \\
& + \beta_3\Delta \mathit{Treasury\ Rate}_{i,t} + \beta_4\Delta \mathit{10\,Yr - 2\,Yr\ Treasury}_{i,t} \\
& + \varepsilon_{i,t}
\end{aligned} \tag{9}$$

where ΔYield $\mathrm{Spread}_{i,t}$ is the monthly change in yield spread, $\Delta\mathrm{Liquidity}_{i,t}$ is the monthly change in the liquidity proxy, $\Delta \mathit{Rating}_{i,t}$ is the monthly change in the Moody's credit rating, $\Delta \mathit{Treasury\ Rate}_{i,t}$ is the monthly change in the 90-day bank accepted bill rate, $\Delta \mathit{10\,Yr}$ - $\mathit{2\,Yr\ Treasury}_{i,t}$ is the monthly change in the difference between the ten-year and two-year Australian government bond rates and $\varepsilon_{i,t}$ are the error terms.

4.4 Test of market-wide bond liquidity

After examining the efficacy of the liquidity measure in explaining bond yield spreads, the next step tests whether a market-wide liquidity risk premium exists in the Australian bond market. To measure the presence of a market-wide liquidity factor in Australian bonds, we employ the approach of Liu (2006). In investigating the systematic liquidity risk factor in stocks, Liu (2006) ranks firms according to their liquidity to form decile portfolios. In this study, we take the same ranking and decile portfolio approach. To determine whether liquidity is a market-wide risk factor in the Australian market, the returns of the highest liquidity decile and the lowest liquidity decile are calculated.

Decile bond portfolios are formed based on the Chen *et al.* (2007) estimate of liquidity. We extend this methodology by varying the formation period used in our calculation of the liquidity proxy. We employ the Chen *et al.* (2007) 12-month formation period approach; however, we also calculate the liquidity proxy based on 1- and 6-month formation periods.

4.5 Bond multifactor model

To evaluate the explanatory power of these independent variables, we form several bond portfolios based on credit rating and duration. We follow Fama and French (1993), Gebhardt *et al.* (2005) and Lin *et al.* (2011) by including the liquidity risk factor in the following regression[10] :

$$R_{i,t} - R_{f,t} = \alpha_i + \beta_1 Term_{i,t} + \beta_2 Default_{i,t} + \beta_3 Liquidity_{i,t} + \varepsilon_{i,t} \quad (10)$$

where $R_{i,t}$ is the realised return of bond portfolio i at time t; $R_{f,t}$ is the risk-free proxy which is the 90-day bank accepted bill rate; $Term_{i,t}$ is the difference between the monthly value-weighted returns of Australian government bonds with a maturity greater than ten years and the 90-day bank accepted bill; $Default_{i,t}$ is the difference in monthly returns of a value-weighted portfolio of all bonds (except Australian Commonwealth government and semi-government bonds) with a maturity greater than five years and a value-weighted portfolio of Australian Commonwealth government

[10] This study also examined Australian SMB and HML proxies as potential systematic risk factors in explaining the variation of bond returns. The preliminary analysis reveals the Australian SMB and HML factors are insignificant at explaining the variation of bond returns in this study. We do not report these results; however, they are available upon request.

bonds with a maturity greater than five years; and $Liquidity_{i,t}$ is the market-wide proxy of liquidity calculated earlier in this study orthogonalised to the term and default factors; and $\varepsilon_{i,t}$ are the error terms.[11] The data sample is for the period January 1999 to December 2010. We use a liquidity proxy with a 12-month formation period to estimate the regressions from January 2000 to December 2010. In the case of Baa bonds, the regressions employ a commencement date of February 2005 due to the lack of data for these lower credit-rated securities prior to this period.

5. Results

We present the results in three sections. First, we report the estimates of the Australian term, default and liquidity risk premia over the sample period. Second, we explore the proxy for liquidity risk in Australian bonds in more detail. Finally, we report the efficacy of these independent variables using the multifactor model approach.

5.1 Term, default and liquidity factors

Table 4 summarises the Australian term, default and liquidity risk factor estimates (with Figures 1–3 illustrating the time-varying nature of the premia). From the outset, it is important to acknowledge that the mean returns of all three risk factors are positive and insignificant (as reported in their *t*-tests), which is consistent with US studies. Panel A reports the Australian term factor is estimated at 0.123 percent per month, with the long-term component of the term factor showing higher return and risk characteristics than the short-term component. Figure 1 illustrates the sharp increase in the term premium from 2008 to 2009, which is consistent with similar increases in the US term premium reported in Gil-Alana and Moreno (2012).

Panel B reports the Australian default factor at 0.024 percent per month. The corporate bond component exhibits higher return and risk characteristics than the government bond component for all summary statistics except the standard deviation. The marginally higher standard deviation of the government bond portfolio is due to its average duration of 6.46 years while the corporate bond component reports a shorter average duration of 6.17 years. Figure 2 illustrates the relative consistency of the Australian default premium in the pre-GFC period, followed by the increased volatility during the 2007 credit crunch, the 2008 GFC, and the subsequent reduction in market stress in 2009–2010.

The next step in the analysis is constructing a proxy for the Australian liquidity risk factor. Following Chen *et al.* (2007), the liquidity risk factor is

[11] The liquidity factor exhibits a correlation with the term and default factors of 0.84 and 0.05, respectively (see Table 3). To remove potential collinearity effects between these variables, we estimate an orthogonalised liquidity factor.

Table 4
Summary statistics of term, default and liquidity risk premia (with components)

Panel A: Term factor

	Term risk premium	Short term portfolio	Long term portfolio
Mean	0.123%	0.451%	0.574%
Median	−0.037%	0.454%	0.497%
Maximum	5.405%	0.658%	5.716%
Minimum	−5.527%	0.258%	−5.256%
Standard deviation	2.043%	0.090%	2.049%
t-test	0.689		

Panel B: Default factor

	Default risk premium	Corporate bond portfolio	Government bond portfolio
Mean	0.024%	0.567%	0.543%
Median	0.009%	0.624%	0.415%
Maximum	1.882%	4.846%	4.730%
Minimum	−2.343%	−4.168%	−3.996%
Standard deviation*	0.469%	1.518%	1.600%
t-test	0.123		

Panel C: Liquidity factor

	Liquidity risk premium	Illiquid portfolio	Liquid portfolio
Mean	0.036%	0.537%	0.501%
Median	0.045%	0.577%	0.444%
Maximum	2.661%	3.792%	1.783%
Minimum	−3.752%	−3.622%	−0.879%
Standard deviation	1.080%	1.343%	0.405%
t-test	0.293		

Panel D: Correlations

	Term risk premium	Default risk premium	Liquidity risk premium
Term	1.000		
Default	−0.319	1.000	
Liquidity	0.841	0.050	1.000

Panel A presents the Fama and French (1993) term risk premium and associated short-term and long-term portfolio components. Short-term portfolio denotes the monthly average of the 90-day bank accepted bill rate. Long-term portfolio denotes the monthly value-weighted returns of Australian Commonwealth government bonds with a maturity greater than ten years. Panel B reports the Fama and French (1993) default risk premium and the associated corporate and government bond portfolio components. Corporate bond portfolio denotes the value-weighted monthly returns of all bonds (except Commonwealth government and semi-governments) with a maturity greater than five years. Government bond portfolio denotes the monthly returns of a value-weighted portfolio of Australian Commonwealth government bonds with a maturity greater than five years. Panel C presents the Chen *et al*. (2007) value-weighted proxy for the bond liquidity premium and the associated illiquid and liquid portfolio components. Illiquid portfolio denotes the monthly returns of the 30% least liquid bonds using a 12-month formation. Liquid portfolio denotes the 30% most liquid bonds using a 12-month formation period. Panel D reports the correlation coefficients of the term, default and liquidity risk premia.

*In Panel B, the average durations of the corporate bond portfolio and the government bond portfolio components of the default factor are 6.17 and 6.46 years, respectively. The interest rate volatility of the corporate bond portfolio is marginally lower than the government bond portfolio. The duration difference in these components explains why the corporate bond portfolio exhibits a marginally lower standard deviation of returns than the government bond portfolio.

estimated by calculating the difference in monthly returns between the 30 percent most illiquid bonds and the 30 percent most liquid bonds. The 12-month formation period is used to estimate bond liquidity, which is

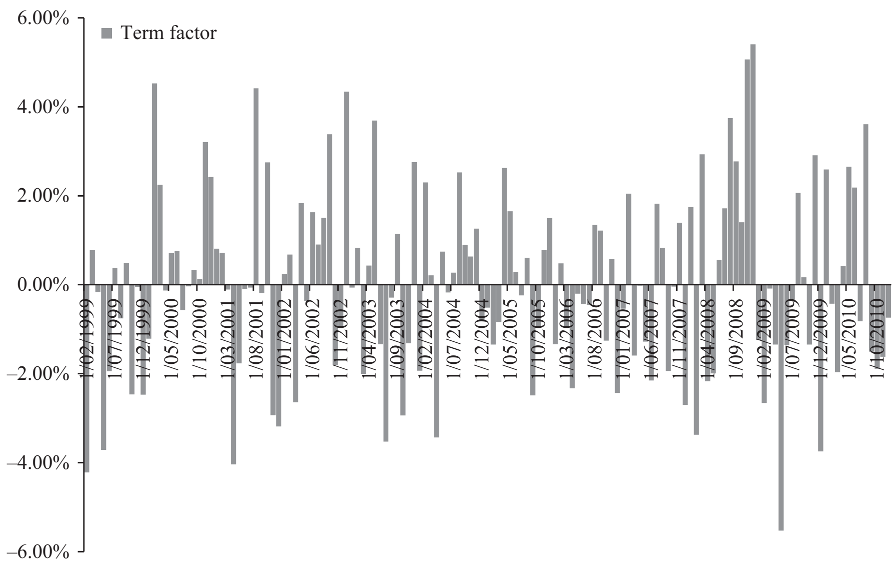

Figure 1 Australian term risk premium.

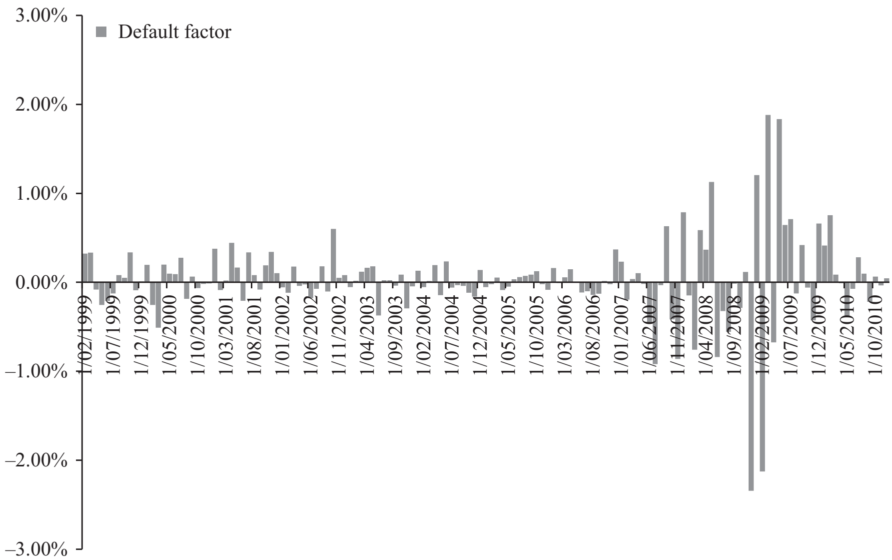

Figure 2 Australian default risk premium.

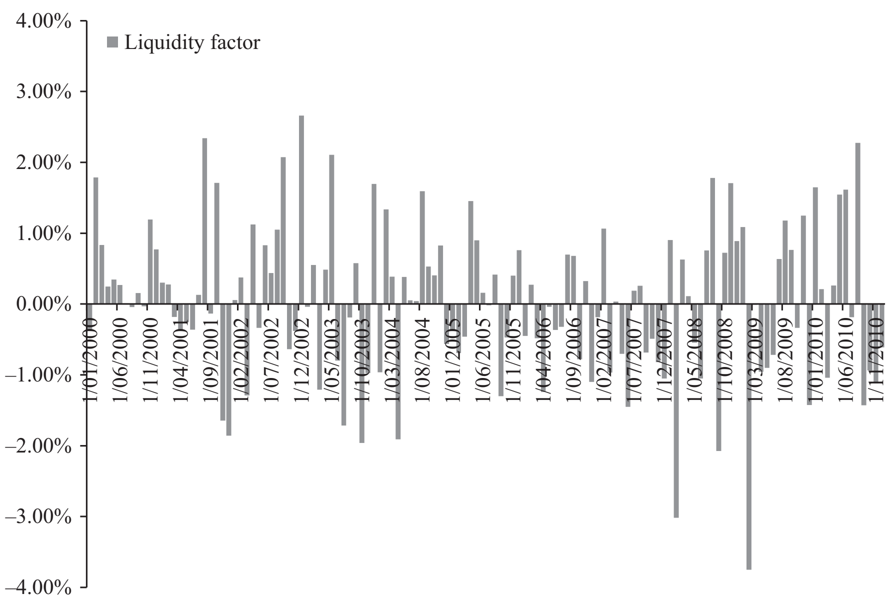

Figure 3 Australian liquidity risk premium.

consistent with the Chen *et al.* (2007) methodology. Similar methodologies have been applied in the equity liquidity literature in the Australian market by Limkriangkrai *et al.* (2008) and in the US market by Liu (2006). Monthly returns were selected to reflect the transitory nature of liquidity, and therefore, a one-month holding period is used in the analysis.

Panel C in Table 4 reports the mean liquidity factor of 0.036 percent and the median liquidity factor of 0.045 percent per month. The mean, maximum, minimum and standard deviation of the liquidity risk factor proxy are all larger than the default risk premium but less risky than the term risk premium. Despite the differences in research methodology and country setting, the liquidity statistics in Panel C corroborate the Amihud liquidity factor estimated in Lin *et al.* (2011). Figure 3 illustrates the monthly liquidity risk factor returns during the sample period. We can observe that the liquidity risk factor is particularly noisy with sharp upturns and downturns. Again, the liquidity risk factor reports large dispersion in returns, which correspond with the 2007 credit crunch, the collapse of Lehman Brothers and the subsequent 2008 GFC.

5.2 *Bond liquidity premium*

To calculate whether Australian bond liquidity is a potential risk premium, we first use equations (1) to (6) from Chen *et al.* (2007) to estimate the liquidity of all bonds within our sample. We then use the liquidity calculation to examine whether liquidity can explain the changes in Australian bond yields. Table 5 presents the panel regression results of Equation (9) with bond issue and year fixed effects. Changes in liquidity, credit rating and the 90-day bank bill rate are positively related to changes in bond yield spreads. The liquidity, credit rating and 90-day bank bill rate coefficients are statistically significant across the four panel regression specifications (using conventional and clustered standard errors).[12]

The term slope (*10y – 2y Treasury*) is also positively related to yield spread changes; however, it loses significance when we control for year fixed effects. In results not reported here, the 2008 calendar year fixed effect is significant and positively related to yield spread changes. Conversely, the 2009 calendar year fixed effect is also significant but negatively related to changes in yield spreads. These results suggest that the term slope is insignificant in explaining changes in yield spreads after controlling for the effects of the GFC. From a liquidity perspective, the overall findings demonstrate that the Chen *et al.* (2007) liquidity measure is statistically significant in explaining the change in Australian bond yield spreads.

To test the presence of a market-wide liquidity premium, we employ the Liu (2006) method that sorts Australian bonds into decile portfolios based on

[12] The clustering methodologies of Petersen (2009) and Thompson (2011) were employed to correct the standard errors in the panel regressions.

Table 5
Liquidity regressions on yield spread changes

Variables	Bond Issue Fixed Effects	Year Fixed Effects	Bond issue Fixed effects With bond Issue clustered Standard errors	Year Fixed effects With bond Issue clustered Standard errors
Intercept	0.000	0.000	0.000	0.000
	(0.0000)	(0.000)	(0.000)	(0.000)
	[3.77]^	[0.85]^	[10.03]^	[6.20]^
Δ *Liquidity*	0.107	0.086	0.107	0.086
	(0.008)	(0.008)	(0.035)	(0.039)
	[13.96]^	[10.97]^	[3.05]^	[2.22]**
Δ *Rating*	0.005	0.005	0.005	0.005
	(0.000)	(0.000)	(0.002)	(0.002)
	[12.82]^	[12.88]^	[2.47]^	[2.41]**
Δ *Treasury rate*	0.104	0.136	0.104	0.136
	(0.021)	(0.021)	(0.039)	(0.039)
	[4.92]^	[6.33]^	[2.63]^	[3.49]^
Δ *10y – 2y Treasury*	0.001	−0.000	0.001	−0.000
	(0.000)	(0.000)	(0.000)	(0.000)
	[2.59]^	[−0.35]	[2.43]**	[−0.27]
Adjusted r-square	0.037	0.059	0.037	0.059
F-statistic	95.21	48.34	3.38	31.22

This table presents the results of the following panel regression:

$$\Delta\text{Yield Spread}_{i,t} = \beta_0 + \beta_1\Delta Liquidity_{i,t} + \beta_2\Delta Rating_{i,t} + \beta_3\Delta Treasury\ Rate_{i,t} + \beta_4\Delta\ 10y\text{ - }2y\ Treasury_{i,t} + \varepsilon_{i,t}$$

where ΔYield Spread$_{i,t}$ is the change in the spread between the yield to maturity of the corporate bond and the closest matched maturity Australian Government bond, $\Delta Liquidity_{i,t}$ is the change in the Chen *et al.* (2007) calculated liquidity proxy, $\Delta Rating_{i,t}$ is the change in the Moody's credit rating, $\Delta Treasury\ Rate_{i,t}$ is the change in the 90-day bank accepted bill rate, $\Delta 10y\text{-}2y\ Treasury_{i,t}$ is the change in the difference between the composite 10-year and 2-year Australian government bond rate. Bond credit ratings are numbered from one (Aaa rated bonds) to six (B rated bonds). We report the regression coefficients with standard errors in parentheses and *t*-statistics in brackets. The panel regressions are estimated using (i) bond issue fixed effects, (ii) year fixed effects, (iii) bond issue fixed effects with bond issue clustered standard errors and (iv) year fixed effects with bond issue clustered standard errors. The analysis is for the period January 2000 to December 2010. The panel regressions are estimated using 469 cross sections with 13,801 observations. *, ** and ^ denote statistical significance at the 10%, 5% and 1% levels, respectively.

liquidity. The returns of the highest liquidity decile and the lowest liquidity decile are calculated. We hypothesise that liquidity risk can explain Australian bond returns when the lowest liquidity decile portfolio earns a higher rate of return than the highest liquidity decile portfolio.

Decile bond portfolios are formed based on the liquidity estimates of Chen *et al.* (2007), which have been calculated in the previous section of this study. This study differs from Chen *et al.* (2007) because we calculate the market-wide

Table 6
Returns by liquidity sorted deciles

L	D2	D3	D4	D5	D6	D7	D8	D9	H	L-H
Panel A: One-month formation period										
One-month holding period										
0.622%	0.570%	0.543%	0.533%	0.547%	0.551%	0.525%	0.528%	0.493%	0.470%	0.152%
[3.883]^	[5.008]^	[5.746]^	[6.887]^	[7.912]^	[9.550]^	[11.402]^	[14.458]^	[17.418]^	[18.465]^	[1.019]
(24)	(25)	(25)	(25)	(25)	(25)	(25)	(25)	(25)	(25)	
Six-month holding period										
0.610%	0.581%	0.540%	0.539%	0.533%	0.542%	0.532%	0.518%	0.494%	0.487%	0.123%
[10.015]^	[12.823]^	[13.926]^	[15.463]^	[17.530]^	[20.432]^	[22.448]^	[26.563]^	[30.016]^	[30.397]^	[2.139]**
(24)	(25)	(25)	(25)	(25)	(25)	(25)	(25)	(25)	(25)	
Twelve-month holding period										
0.593%	0.548%	0.517%	0.523%	0.520%	0.537%	0.525%	0.513%	0.499%	0.487%	0.107%
[14.151]^	[16.967]^	[19.147]^	[22.628]^	[24.301]^	[27.463]^	[29.757]^	[34.115]^	[38.069]^	[36.336]^	[2.680]^
(24)	(25)	(25)	(25)	(25)	(25)	(25)	(25)	(25)	(25)	
Panel B: Six-month formation period										
One-month holding period										
0.578%	0.593%	0.559%	0.561%	0.548%	0.551%	0.551%	0.519%	0.503%	0.455%	0.122%
[3.526]^	[4.852]^	[6.338]^	[7.386]^	[7.945]^	[9.614]^	[12.634]^	[14.615]^	[20.540]^	[20.221]^	[0.782]
(24)	(25)	(25)	(25)	(25)	(25)	(25)	(25)	(25)	(25)	
Six-month holding period										
0.619%	0.546%	0.546%	0.554%	0.546%	0.561%	0.534%	0.522%	0.498%	0.482%	0.137%
[9.484]^	[12.752]^	[14.433]^	[16.533]^	[17.445]^	[19.721]^	[22.650]^	[26.025]^	[31.445]^	[33.559]^	[2.099]**
(24)	(25)	(25)	(25)	(25)	(25)	(25)	(25)	(25)	(25)	

(continued)

Table 6 (continued)

L	D2	D3	D4	D5	D6	D7	D8	D9	H	L-H
Twelve-month holding period										
0.593%	0.549%	0.528%	0.536%	0.539%	0.545%	0.529%	0.522%	0.506%	0.486%	0.108%
[12.662]^	[17.112]^	[19.096]^	[21.839]^	[24.381]^	[28.209]^	[29.552]^	[33.812]^	[37.893]^	[39.864]^	[2.225]**
(24)	(25)	(25)	(25)	(25)	(25)	(25)	(25)	(25)	(25)	
Panel C: Twelve-month formation period										
One-month holding period										
0.566%	0.557%	0.550%	0.578%	0.556%	0.550%	0.528%	0.523%	0.491%	0.440%	0.126%
[3.293]^	[5.159]^	[6.313]^	[7.535]^	[8.219]^	[9.850]^	[2.326]^	[15.258]^	[21.209]^	[21.404]^	[0.756]
(24)	(25)	(25)	(25)	(25)	(25)	(25)	(25)	(25)	(25)	
Six-month holding period										
0.595%	0.527%	0.535%	0.564%	0.556%	0.537%	0.523%	0.519%	0.497%	0.468%	0.127%
[9.084]^	[12.541]^	[13.524]^	[15.521]^	[17.897]^	[18.147]^	[22.615]^	[25.035]^	[31.832]^	[38.312]^	[1.904]*
(24)	(25)	(25)	(25)	(25)	(25)	(25)	(25)	(25)	(25)	
Twelve-month holding period										
0.556%	0.512%	0.515%	0.539%	0.547%	0.541%	0.514%	0.511%	0.503%	0.465%	0.091%
[2.363]^	[16.994]^	[17.917]^	[22.396]^	[24.199]^	[27.666]^	[29.260]^	[34.147]^	[38.543]^	[44.317]^	[1.910]*
(24)	(25)	(25)	(25)	(25)	(25)	(25)	(25)	(25)	(25)	

This table presents the monthly holding period returns for the period January 2000 to December 2010 for bond decile portfolios sorted by liquidity as determined by the Chen *et al*. (2007) methodology. All returns are reported as monthly equivalents. Panel A reports decile portfolio returns using a one-month formation period to calculate the liquidity estimate. Panel B presents decile portfolio returns using a six-month formation period to calculate the liquidity estimate. Panel C reports decile bond portfolio returns using a twelve-month formation period to calculate the liquidity estimate. The bond portfolio with the lowest levels of liquidity is the L decile and the bond portfolio with the highest levels of liquidity is the H decile. L-H is the difference between the lowest and highest decile portfolio returns. *t*-statistics are presented in brackets. The average number of bonds in each decile portfolio is reported in parentheses. *, ** and ^ denote statistical significance at the 10%, 5% and 1% levels, respectively.

Table 7
Average credit rating by liquidity sorted deciles

Rating	L (%)	D2 (%)	D3 (%)	D4 (%)	D5 (%)	D6 (%)	D7 (%)	D8 (%)	D9 (%)	H (%)
Aaa	33.33	32.92	31.43	31.06	29.73	28.97	29.89	31.40	29.02	29.66
Aa	24.87	25.19	28.10	29.29	27.03	27.34	29.20	30.19	28.12	29.21
A	25.13	25.94	25.00	25.00	25.68	28.27	25.98	24.64	27.21	26.97
Baa	16.14	15.71	15.48	15.48	17.57	15.42	14.94	13.77	15.65	14.16
Ba	0.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B	0.26	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

This table reports the Moody's credit ratings in each liquidity decile. The liquidity sorted decile portfolios are calculated using the Chen *et al*. (2007) methodology with a twelve-month formation period. The bonds with the highest liquidity costs are in the low liquidity (L) decile, and the bonds with the lowest liquidity costs are in the high liquidity (H) decile.

liquidity premium estimate using 1-, 6- and 12-month formation periods. This methodological extension provides a more robust assessment of the liquidity factor in the data sample.

Table 6 shows that all low liquidity portfolio (L) returns exhibit higher means than their highest liquidity portfolio (H) counterparts. Panel A shows this liquidity effect is most pronounced in the 1-month formation and holding period, but it is insignificant. Nevertheless, for all formation periods, there are statistically significant differences between the returns of the low and high liquidity deciles for both 6- and 12-month holding periods. This market-wide liquidity premium is most pronounced in the 1- and 6-month formation periods with the difference in decile returns statistically significant at the 5 percent level for the 6- and 12-month holding periods. For the 12-month formation period, the difference between the low liquidity and high liquidity deciles for the 6- and 12-month holding periods is significant at the 10 percent level. In summary, the final column in Table 6 shows that the market-wide liquidity premium can be estimated at between 0.09 percent and 0.15 percent per month.

As a final robustness test, Table 7 reports the average percentage of bonds classified by their Moody's credit rating for each liquidity decile portfolio (based on a 12-month formation period). This finding reveals that the composition of all decile portfolios shows bonds with similar credit ratings. This evidence suggests that there are no or minimal credit rating effects distorting the return and risk of the liquidity sorted decile portfolios.

5.3 Risk factors in bond returns

To evaluate term, default and liquidity proxies as potential risk factors, we start by estimating regressions on bond portfolios formed by credit ratings. We construct market value-weighted bond portfolios sorted by their Moody's

Table 8
Regressions on bond portfolios sorted by credit rating

	Intercept	*Term*	*Default*	*Liquidity*	Adj-R^2	Term to maturity	Duration (years)	Mean no. of bonds in portfolio
Panel A: Regression coefficients								
Aaa	0.000	0.439	0.574	0.172	0.891	5.10	4.15	100.42
Aa	0.000	0.260	0.344	0.370	0.677	3.57	3.03	64.36
A	0.001	0.247	0.495	0.832	0.645	3.15	2.74	55.15
Baa	0.001	0.228	0.450	0.602	0.505	3.02	2.64	14.98
Panel B: Standard errors								
Aaa	0.000	0.013	0.085	0.050				
Aa	0.000	0.030	0.106	0.074				
A	0.001	0.034	0.121	0.139				
Baa	0.001	0.038	0.145	0.161				
Panel C: t-statistics								
Aaa	0.661	34.535^	6.760^	3.437^				
Aa	1.012	8.570^	3.233^	4.989^				
A	1.855	7.301^	4.099^	5.994^				
Baa	1.405	6.013^	3.112^	3.727^				
Panel D: GRS-statistic p-value								
	0.308							

This table presents the results for Aaa, Aa and A rated bond returns from January 2000 to December 2010. The Baa portfolio regression is for the period February 2005 to December 2010. The regression is as follows:

$$R_{i,j} - R_{f,t} = \alpha_i + \beta_1 Term_{i,t} + \beta_2 Default_{i,t} + \beta_3 Liquidity_{i,t} + \varepsilon_{i,t}$$

where $R_{i,t}$ is the return of the portfolio of bonds formed on credit rating at time t, $R_{f,t}$ is the risk-free rate, $Term_{i,t}$ is the difference between the monthly value-weighted returns of Australian government bonds with a maturity greater than ten years and the 90-day bank accepted bill, $Default_{i,t}$ is the difference in monthly returns of a value-weighted portfolio of all corporate bonds with a maturity greater than five years and a value-weighted portfolio of Australian government bonds with a maturity greater than five years, $Liquidity_{i,t}$ is the value-weighted systematic liquidity risk premium calculated earlier in this paper orthogonalised to the term and default factors. The final two columns report the average term to maturity and Macaulay duration of the respective bond portfolios. Panels B and C report Newey and West (1987) heteroscedasticity and autocorrelation corrected (HAC) standard errors (and t-statistics) with four (4) lags. Panel D reports the p-value for the Gibbons *et al.* (1989) (GRS) test of portfolio efficiency. *, ** and ^ denote statistical significance at the 10%, 5% and 1% levels, respectively.

credit rating from Aaa to Baa.[13] We estimate regressions with a February 2005 start date on Baa rated bonds due to their limited sample, while all other bond portfolios are analysed over the full period from January 2000 to December 2010. Table 8 presents the regression estimates from the three-factor asset pricing model of Equation (10).

Table 8 shows that the term, default and liquidity betas are all positive and significant over our observation period. The estimated betas imply that increases in these independent variables are associated with increases in bond returns across all portfolios sorted by credit rating. We evaluate the constants in these regressions by estimating the Gibbons *et al*. (1989) GRS test that all intercepts are jointly equal to zero, which results in an insignificant *F*-statistic. This finding suggests that the three-factor asset pricing model adequately captures all relevant risk premia in bond returns.

A closer examination of Panel A in Table 8 shows that the largest and smallest term betas are related to the AAA, with the longest durations, and Baa, with the shortest duration, bond portfolios. We report positive and significant default betas; however, they do not consistently increase with lower credit ratings. The non-monotonic increase in the default beta is similar to the results in Lin *et al*. (2011). This finding is a function of the shorter durations associated with the lower credit rating portfolios, which mask the expected monotonic increase in the default beta. We examine this issue more closely in the proceeding analysis where we perform a double sort of these portfolios based on credit rating and duration. Furthermore, the Baa portfolio represents only 5.97 percent of the data sample therefore limiting any wider inferences given this small category of securities.

The results presented in Table 8 exhibit liquidity betas that generally increase as credit ratings decrease. This finding is consistent with Lin *et al*. (2011), which shows that low-quality bonds are generally more sensitive to fluctuations in the liquidity factor. Finally, Table 8 reports higher adjusted-R^2s for the AAA portfolio, which decrease with lower quality bond portfolios. This is also consistent with Lin *et al*. (2011). Overall, the central finding in Table 8 suggests that the three independent variables of term, default and liquidity matter in explaining the variation of Australian bond returns when they are grouped into portfolios sorted by credit ratings.

As a final robustness test, we further subdivide each credit rating category into four portfolios sorted by Macaulay duration. We estimate the three-factor asset pricing model in Equation (10) on these 16 bond portfolio returns, and the results are reported in Table 9. The estimates from the regression analysis confirm that the term, default and liquidity factors are positive and significant for a large proportion of these bond portfolios (with 13 of the 16 bond

[13] It is important to note that the lack of sufficient data for Ba and B rated securities means that lower rated bonds are excluded from the analysis.

Table 9
Regressions on bond portfolios subdivided by credit rating and duration

Credit Rating	Aaa	Aaa	Aaa	Aaa	Aa	Aa	Aa	Aa	A	A	A	A	Baa	Baa	Baa	Baa
Duration (yr)	0 to 1	1 to 3	3 to 5	>5	0 to 1	1 to 3	3 to 5	>5	0 to 1	1 to 3	3 to 5	>5	0 to 1	1 to 3	3 to 5	>5
Panel A: Coefficient																
Intercept	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.001	0.001	0.001	0.002	0.000	0.001	0.002	0.001
Term	0.051	0.217	0.450	0.798	0.032	0.201	0.404	0.621	0.024	0.180	0.384	0.666	0.025	0.195	0.403	0.605
Default	0.056	0.339	0.130	0.959	0.181	0.291	0.597	0.501	0.087	0.357	0.634	0.859	0.252	0.261	0.681	0.317
Liquidity	0.000	0.058	0.109	0.187	0.063	0.233	0.602	2.005	0.259	0.705	1.493	1.518	-0.009	0.816	0.571	1.220
Panel B: Standard error																
Intercept	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.003
Term	0.012	0.021	0.259	0.013	0.018	0.282	0.045	0.056	0.014	0.036	0.044	0.073	0.287	0.053	0.055	0.087
Default	0.019	0.076	0.646	0.079	0.086	0.123	0.221	0.344	0.064	0.157	0.238	0.460	0.140	0.156	0.251	0.409
Liquidity	0.027	0.061	0.186	0.067	0.044	0.060	0.190	0.399	0.053	0.135	0.258	0.554	0.147	0.285	0.207	0.775
Panel C: *t*-statistic																
Intercept	0.393	0.927	0.685	0.140	0.763	1.399	0.780	0.054	2.194**	2.150**	1.636	1.627	0.276	1.339	2.157**	0.412
Term	4.196^	10.106^	17.414^	59.393^	1.751*	7.129^	8.946^	11.070^	1.713*	4.957^	8.638^	9.176^	0.870	3.690^	7.408^	6.957^
Default	3.016^	4.451^	4.990^	12.171^	2.100^	2.375**	2.698^	1.457	1.349	2.272**	2.664^	1.868*	1.796*	1.673*	2.717^	0.775
Liquidity	–0.014	0.952	1.700*	2.800^	1.447	3.854^	3.170^	5.029^	4.866^	5.218^	5.790^	2.741^	–0.613	2.861^	2.757^	1.574

(continued)

Table 9 (continued)

Credit Rating	Aaa	Aaa	Aaa	Aaa	Aa	Aa	Aa	Aa	A	A	A	A	Baa	Baa	Baa	Baa
Panel D: Portfolio statistics																
Adj-R^2	0.281	0.589	0.797	0.981	0.180	0.523	0.714	0.782	0.241	0.493	0.695	0.627	0.007	0.439	0.544	0.305
Mean	0.46%	0.50%	0.49%	0.47%	0.47%	0.51%	0.48%	0.38%	0.51%	0.55%	0.53%	0.65%	0.49%	0.48%	0.72%	0.47%
Std. Dev.	0.21%	0.56%	1.00%	1.60%	0.23%	0.56%	0.98%	1.72%	0.25%	0.66%	1.18%	1.87%	0.73%	0.86%	1.09%	2.35%
Median	0.44%	0.44%	0.45%	0.55%	0.46%	0.48%	0.47%	0.52%	0.50%	0.52%	0.58%	0.57%	0.53%	0.52%	0.62%	0.69%
Maturity (yr)	0.52	2.06	3.98	7.99	0.53	2.09	3.89	7.18	0.53	2.03	3.92	6.99	0.52	2.00	3.93	6.26
Duration (yr)	0.44	1.93	3.52	6.23	0.47	1.95	3.43	5.70	0.47	1.90	3.46	5.57	0.48	1.87	3.45	5.10
Mean No. of Bonds	9.65	31.69	28.79	30.28	9.40	30.84	18.89	5.24	8.95	26.25	14.67	5.27	2.57	7.01	4.20	1.19
GRS *p*-value	0.291															

This table reports the following regression for the period January 2000 to December 2010 (again, the Baa portfolio regression is for the period February 2005 to December 2010): $R_{i,t}$ - $R_{f,t}$ = $\alpha_i + \beta_1 Term_{i,t} + \beta_2 Default_{i,t} + \beta_3 Liquidity_{i,t} + \varepsilon_{i,t}$ where $R_{i,t}$ is the return of the portfolio of bonds formed on credit rating at time t, $R_{f,t}$ is the risk-free rate, $Term_{i,t}$ is the difference between the monthly value-weighted returns of Australian government bonds with a maturity greater than ten years and the 90 day bank accepted bill. $Default_{i,t}$ is the difference in monthly returns of a value-weighted portfolio of all corporate bonds a maturity greater than ten years and a value-weighted portfolio of Australian government bonds with a maturity greater than ten years. $Liquidity_{i,t}$ is the value-weighted systematic liquidity risk premium calculated earlier in this paper orthogonalised to the term and default factors. Panel A reports the regression coefficients for each regression. Panels B and C report Newey and West (1987) standard errors and t-statistics. Panel D presents the portfolio monthly mean, median, standard deviation, term to maturity (in years) and Macaulay duration (in years). Panel D reports the p-value for the Gibbons *et al.* (1989) (GRS) test of portfolio efficiency. *, ** and ˆ denote statistical significance at the 10%, 5% and 1% levels, respectively.

portfolios reporting insignificant intercepts).[14] The Gibbons *et al*.'s (1989) GRS test statistic is also insignificant. While the analysis provides a new level of empirical evidence, the statistical inferences from Table 9 are limited. This limitation is a result of the smaller number of bonds sampled in the lower credit portfolios compared to those in the higher credit rating portfolios. For instance, the AAA portfolio with a duration greater than five years reports an average of 30 bonds in the portfolio throughout the sample period. In contrast, the Baa portfolio with a duration greater than five years report an average of a single bond only in the portfolio over the same period.

The details in Table 9 show that 15 of 16 portfolios exhibit significant term betas. Unsurprisingly, the bond portfolios with the longest Macaulay durations exhibit the largest term betas, reflecting their sensitivity to the term structure of interest rates. Moreover, 13 of 16 portfolios report significant default betas. Of the 16 portfolios, 11 show significant liquidity betas. These results support the notion that liquidity betas are negatively correlated with credit ratings, which again is consistent with Lin *et al*. (2011).

Finally, the Aaa rated portfolios exhibit the highest adjusted-R^2s in each duration category, and the coefficient of determination usually decreases with lower credit ratings. This finding suggests that the three independent variables of term, default and liquidity are efficient at explaining the variation of AAA bond returns. Lower credit-rated bond returns tend to fluctuate more due to non-risk based factors not captured in this study. As with previous international findings, we report that all bond portfolios in the 0- to 1-year duration category exhibit the lowest adjusted-R^2s across all credit rating categories. This suggests that bonds trading at the short end of the yield curve are exposed to idiosyncratic or non-risk based pricing factors not captured by the term, default and liquidity factors.

6. Conclusion

The robustness of risk factors in capturing the cross-section of bond returns is important to both practitioners and academics. Using the literature in the US setting, we explore the Australian bond market to provide further insights into the debate. We report new evidence on bond liquidity and use this information variable to estimate a market-wide liquidity risk premium in Australia. We use

[14] The findings demonstrate that the term, default and liquidity factors are efficient at explaining the variation of bond portfolio returns sorted by credit ratings and duration. To determine whether term, default and liquidity are priced risk factors, we must perform a two-step process of (i) estimating factor loadings on the test portfolios (as in Table 9) and then (ii) performing a cross-sectional analysis of whether our current factor loadings are related to the cross-section of returns. Table 8 reports four test portfolios only (i.e. Aaa, Aa, A and Baa); therefore, the second stage of the cross-sectional analysis is not viable. Refer to Core *et al*. (2008) for an overview of the various methods of estimating a priced risk factor in a cross-sectional setting.

term, default and liquidity proxies as independent risk factors to explain the common variation of Australian bond returns.

Our findings largely corroborate the risk factors faced by US bond investors. The estimation of an Australian bond liquidity factor has allowed the time variation of this risk factor to be captured. We document that a three-factor model approach to bond asset pricing seems robust regardless of whether bonds are sorted into credit rating or duration portfolios. The pervasiveness of these three factors identified in both the US and Australia has important implications for practice. Our findings suggest that an empirical asset pricing model with the term, default and liquidity factors can be efficiently used for practical applications such as calculating the cost of debt, evaluating performance of active bond fund managers and hedging the underlying risks in bond portfolios.

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