Vintage and Credit Rating: What matters in the ABX data during the credit crunch?*

Mardi Dungey[+&] Jerry Dwyer[#] and Tom Flavin[*]
[+]CFAP, University of Cambridge and University of Tasmania
[#]Federal Reserve Bank of Atlanta and University of Carlos III, Madrid
[*] National University of Ireland, Maynooth

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Abstract

The mortgage backed securities market has dramatically declined during the credit crunch of 2007-2008. To understand the factors driving its demise we utilise a latent factor model representing common effects, asset rating effects, vintage of issuance effects and liquidity effects - extending the recent representation of CDO pricing in Longstaff and Rajan (2008). Common and liquidity effects are shown to have an increasing influence on the performance of the ABX-HE indices, with the role of vintage factors changing dramatically over the sample period of January 2006 to May 2008. Consistent with other evidence, risk from systemic factors has transferred risk to more highly rated tranches of these structured finance products.

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*Author contact details: Dungey: mardi.dungey@utas.edu.au, Dwyer: Dwyer: gerald.p.dwyer@atl.frb.org, Flavin: Thomas.Flavin@nuim.ie.

1 Introduction

For the past year, the world has been gripped by the most widespread and destructive financial crisis since the stock market crash of 1929 and the subsequent Great Depression. The banking sector across the globe has suffered huge losses and is currently undergoing a period of serious retrenchment and re-structure. The turbulence and ensuing lack of confidence has spread to other asset markets as well as to the real economy. Many of the world economic powers are now officially in recession. The aim of this paper is to shed light on how the crisis began in the market for US sub-prime housing derivatives and transmitted across the globe. The subsequent financial turmoil has led to major questions about the riskiness of many structured financial products. The perceptions of many market participants of what a AAA-rated tranche was and how it compared to a AAA-rated corporate bond proved to be far wide of the mark when the housing market experienced a downturn. Here we look at the risk factors inherent in tranches of CDOs comprised of sub-prime mortgages.

The paper extends the empirical model of Longstaff and Rajan (2008). They show how a CDO pricing model can be represented by three latent factors related to common shocks, asset quality (rating) and idiosyncratic effects. Their work is applied to pricing tranches of the CDX index, which is compiled from the credit derivatives of 125 single name entities. Our focus is not on corporate credit but rather on credit derivatives from the sub-prime real estate sector. The factor pricing model is extended to incorporate the role of the vintage of asset issuance, as these type of CDOs are distinct in their vintage of issuance as well as other dimensions. In particular, these features make the direct splicing of different issuances, as in Longstaff and Rajan, difficult, particularly during periods of turmoil. In addition we include a specific role for a measure of market liquidity. The model is applied to return data on three different asset tranches (AAA, A and BBB) of mortgage backed securities using the MarkiT ABX-HE indices for three vintages of issuance over the period January 2006 to May 2008. The results show the important and distinct roles played by each of the different factors over the sample period in the performance of these indices, and highlights both the increasing role of common and liquidity factors, and the declining importance of the vintage of issuance.

The paper proceeds as follows. Section 2 examines the operations of the financial institutions involved and attempt to explain the evolution of the 'Credit crunch'. In Section 3 we turn to a description of the ABX-HE dataset and then describe how we extract the measure of market liquidity in Section 4.The modelling framework is described in Section 5 and the results from the application in Section 3. Finally, Section 7 concludes.

2 Background

As real estate prices soared in the midst of favorable economic conditions, the market for sub-prime mortgages became attractive for banks and mortgage providers who were chasing higher returns in a low interest rate environment. Home ownership in the US grew from 64% in 2004, where it had been for almost two decades to 69% in 2007. Banks were increasingly employing the 'Originate and Distribute' model to issue mortgages and consequently transfer the credit risk to investors across the globe. Spreading the risk among investors was viewed as a positive development as the benefits of diversification was assumed to provide insurance for all market participants. In hindsight, the degree of diversification seems to have been exaggerated due to the similarity of structured products and the cross-holdings of these assets by large financial institutions. Some of these securitized products had become so complex, that much of the cross-holdings may have arisen accidentally. Kiyotaki and Moore (2002) show increasing correlations may arise through interlinkages which are not at first apparent to the market due to their complexity.

However, a key question remains and that is 'why did a crisis that originated in a relatively small segment of the US financial system result in the most severe financial crisis since 1929?'. Global equity and government bond markets are approximately 100 times larger than the sub-prime mortgage market. However, the crisis wasn't contained in the housing market or within the US, but rather it has spread across both asset classes and national borders. Potential contributing factors to this transmission are the interdependence of the global banking structure and / or the highly leveraged approach to financing credit that had become prevalent and accessible through the use of structured finance products.

Banks who extended sub-prime mortgages often raised the funds through issuing short-term debt, usually through a Special Purpose Vehicle (SPV). This resulted in an inherent maturity mismatch and an increasing degree of leverage underpinning the mortgage markets. The collapse of the Asset-backed Securities (ABS) markets for commercial paper and mortgage related products resulted in a related liquidity crisis that caused the transmission of the crisis from institutions who were directly exposed to the US sub-prime market to those who were not, but relied on short-term financing to fund their operations. This transmission has provided evidence of a higher level of correlation within the global banking sector than could reasonably have been anticipated.

2.1 Why do banks create SPV's / conduits?

There are two main motivations for banks to create an SPV or other conduit to package and tranche pools of assets, which then allows for the distribution of credit risk. Firstly, there is a *ratings-based arbitrage* incentive, where a financial institution with a credit rating below AAA has an incentive to sell the assets to an SPV. The SPV raises the funds to purchase these assets by issuing short-term Asset-backed Commercial Paper (ABCP). The debt raised by the SPV is collateralized against the asset pool and the parent financial institution issues a 'contingent liquidity line' to the SPV. This liquidity line is intended to act as a safety net in the case that the SPV experiences short-term liquidity problems. With the collateral and the contingent liquidity line in place, the vast majority of SPV's were able to issue AAA-rated ABCP to fund the purchase of the asset pool. This process allowed the parent financial institution to raise funds more cheaply via sales to an SPV rather than directly raising the funds on the open market. This process directly contributed to the degree of leverage in credit markets. Using funds generated from the sale of ABCP, the parent company could extend credit to the value of the original sale and repeat the process. Therefore the amount of credit extended, based on borrowed funds borrowed from another segment of the market, expanded quickly.

Secondly, there was an incentive for banks to move assets 'off balance-sheet'. Following the introduction of the Basel I regulatory framework, capital requirements were no longer based on deposits but rather on the asset side of the balance sheet. In effect, banks that held more loans/assets needed to hold more cash. By selling the assets to a SPV, which was not subject to the Basel requirements, banks could avoid tying up capital in cash and increase their mortgage book even further (using cash generated by sale of assets to the SPV).

2.2 The Role of a SPV

The SPV acquires assets from another institution, often a closely related (parent) company The acquisition is financed by issuing AAA-rated ABCP. A Collateralized Debt Obligation is then created from the asset pool, by dividing it into tranches with different levels of seniority. SPV managers work with the rating agencies to secure the required division. There is some (anecdotal) evidence to suggest that because there are a limited number of rating agencies and the issuers of the CDOs wanted as much 'credit enhancement' as possible, that the resulting CDOs were often very similar across issuers. Cash inflows from the assets underlying the CDO are used to make payments to the holders of each tranche in decreasing order of seniority, i.e. the holders of the AAA tranche receive the first payment, followed by the next most senior tranche and so on.

The prevalence of CDOs and ABS in general increased rapidly during the last decade, particularly during the period 2004-06. DeMarzo (2005) provides a rationale for the issuance of pooled and tranched securities by informed sellers. The seller enjoys an informational advantage regarding the quality of the asset and it is shown that pooling alone may reduce value but the combination of pooling and tranching is value enhancing due to the diversification of risk (though recent events would suggest that mortgage-backed pools of assets failed to deliver expected diversification benefits). Furthermore, this effect increases with the size of the underlying pool of assets. It is argued that it is the friction caused by asymmetric information that is most consistent with the emergence and success of the CDO market. As these vehicles generated profits, there was an increased demand for assets that could be included in the pool of underlying assets - a feature most clearly observed in the associated growth in the market for sub-prime mortgages. Given the success in securitizing mortgages and transferring the associated credit risk, (some) banks almost certainly became less stringent in assessing the suitability of mortgage applicants, resulting in so-called 'liar loans' or NINJA (No Income, No Job or Assets) loans. Sub-prime mortgages were a particularly attractive asset class due to the potential degree of 'credit enhancement' available. Loan applicants could be attracted to the real estate market by offerings of products with an initial period of below market rate adjustable rate mortgages (ARM) When the initial period expired the mortgage rate reverted to rates where many home owners were not able to meet their repayments and defaulted.

2.3 Buyers of Tranches

The buyers of asset backed securities were seeking a number of different asset characteristics. Consider a simple structure for an ABS with only three tranches, i.e. Senior (AAA), Mezzanine (A) and Equity (BBB-). The senior tranche is by far and away the largest part of the structured product, often contributing between 70% - 80% of the asset pool.[1] On a practical level, the issuer needs such a large proportion to be rated AAA as this tranche is really the only liquid asset when put on sale. Other large financial institutions, insurance companies and pension funds, who are given a 'ratings-based mandate' can buy only these AAA rated assets. This restriction may be legally imposed or may just be company policy. Indeed, the demand for AAA-tranched securities may have

[1] Hu (2007) reports that for CDOs issued in 2006, Aaa-rated assets accounted for 85% of dollar value and 36% of the number of tranches, while the figures for Baa and lower rated assets were 3.7% and 24% respectively.

stemmed from such investors as there is a relative shortage of AAA-corporates.[2] Investors who (mis-)perceived that AAA-rated tranches were same as AAA-rated corporates were attracted to the CDO market as senior tranches typically offered a return of 2-3% more than AAA-rated corporate bonds. However, this meant a large under-estimation of the inherent risk on the part of the investor as will be discussed below.

At the other end of the spectrum, the equity tranche (3-5% of the pool) is most often held by the issuer themselves. Partly, this was meant to inspire confidence by implicitly telling others that if the issuer is prepared to hold the most risky tranche, then investors should be willing to hold more senior tranches. Leland and Pyle (1977) describe this type of behavior in a setting where an entrepreneur signals asset quality by their willingness to hold an equity stake. In the case of (sub-prime) mortgage backed securities, there was another implicit bet in holding the equity tranche and that was that property prices would continue to increase. As long as house prices maintained an upward trend, then a default on a mortgage meant that, while the equity tranche cashflows were reduced, the mortgage issuer took possession of an appreciating asset which could be sold on. An interesting exchange between a financial firm and a rating agency is reported in Coval, Jurek and Stafford (2008) where the rating agency admit that their model has an implicitly built-in assumption that house prices will gradually increase by about 2% per annum. When pushed as to what might happen in the event of house prices becoming flat or experiencing a modest decrease, the rating agency acknowledges that the model would most likely fail.

In between, the Senior and Equity tranches is the Mezzanine tranche (15-20%) which is often difficult to sell. There is no large natural buyer in the market for this tranche. This is where the real 'financial alchemy' is seen - the mezzanine tranche of a number of CDOs are pooled together to form another structured product - a CDO-squared. This new pool is again tranched and rated, with up to 80% of this receiving a AAA rating. This also leads to larger

[2] For example, Benmelech and Dlugosz (2008) report that as of 2007 few sovereigns and only five nonfinancial corporations have AAA ratings .

than anticipated correlation in the downturn as many CDOs are represented in the CDO-squared. Coval, Jurek and stafford (2008) state that CDO-squareds are particularly prevalent in mortgage-backed CDO markets.

2.4 Valuation / Pricing of CDOs

The valuation of the CDO tranches has been revealed as particularly hazardous. With hindsight, the risk of these products was greatly under-estimated by the financial community. For valuation models, there are three key inputs - asset default correlations, recovery rates and prepayment risk. Prepayment risk for pools of mortgages can be quite large as it gives rise to the type of 're-investment' risk attached to bond coupons. Typically, prepayments are greatest when interest rates are falling, meaning that re-investing usually yields lower return. However, even if this is a difficulty for CDO valuation in general, it was not a big factor in the recent crisis. Much more important was the estimation of asset default correlations and recovery rates. Most often default correlations were based on historical data. Because of the relative short data span available on sub-prime mortgages, these were most likely to be understated, being predominantly based on a period of increasing house prices and benign economic conditions. Furthermore, banks who operated in specific regions were exposed to geographical factors as certain areas suffered quicker and deeper depreciations of real estate prices than others. Structured products of banks based in these regions had much higher risk exposures than the average CDO. The same factors also affected optimistic estimates of recovery rates based on a period of rising house prices. Consequently, the risk priced in the different CDO tranches was under-estimated (see Coval, Jurek and Stafford, 2008; and Brennan, Hein and Poon, 2008) and the realization of this, as the crisis deepened, amplified the downward pressure on tranche prices.

2.5 What went wrong?

The issuers of mortgages and CDOs had made an implicit bet on the housing market continuing to increase. Therefore the slowdown in real estate prices and the consequent downturn experienced since 2006 led to uncertainty in the value of the structured products as the default correlations and recovery rates utilized in the valuation process proved unreliable and both moved in an unfavorable direction. The higher default correlations led to increasing systematic risk whose effects began to transmit far deeper into the CDO structure than the buffer provided by the equity tranche. By August 2007, markets had witnessed the demise of New Century Financial in the US and two German banks who had large exposure to the US sub-prime market. Hedge funds attached to Bear Stearns had also admitted to having difficulty in realizing the value of structured financial products. This uncertainty in the value of CDO and other derivative products became manifest when BNP Paribas suspended redemption of funds for a number of weeks as it could not satisfactorily value assets in the funds.

This inherent uncertainty in asset value and credit quality led to a decrease in tranche prices. Concurrently, the rating agencies had to revise and downgrade many of the mortgage-backed securities. Craig, Smith and Ng (2008) report that 90% of the CDO tranches underwritten by Merrill Lynch were downgraded from AAA-rated to 'junk'. Writing in July 2007, Hu notes an increasing number of downgrades and reviews in the CDO market and particularly where the underlying pool is exposed to sub-prime mortgages. These downgrades compounded the problems in the market as many large players in this market who have a ratings-based mandate were compelled to sell off these assets in extremely thin markets. This further compounded the downward spiral in tranche prices.

With the value of the underlying asset pools under pressure, the problems of the SPV were deepened by lack of appetite on the part of investors for asset-backed commercial paper (ABCP) issued to fund positions. Therefore, many SPV's were forced to call on the contingent liquidity lines provided by the larger banks which put pressure on the liquid assets of the parent company. Some banks decided to take these asset back onto their own balance sheet in order to avoid the reputation effects that would have been incurred if the SPV had been unable to fund their operations. This action, of course, required the banks to increase their cash holdings in accordance with the Basel regulations at a time when liquidity was becoming increasingly tight. Banks' liquidity was further squeezed as they faced increasing levels of so-called warehousing risk. This arose when loans that were originated with a view to subsequent distribution had to be kept on balance sheet due to a lack of demand on behalf of the distributor. As these loans were drawn down, the originator had no option but to retain them on balance sheet and increase the capital requirement. This led to a liquidity crisis that effected many of the largest players in financial markets and extended the crisis to those without direct exposure to the US sub-prime market.

The most vulnerable institutions to this extension of the crisis, were those which operated on the basis of a maturity mismatch, i.e. borrowing short-term and extending long-term loans. Northern Rock in the UK was a classic example. The lack of liquidity in short-term markets meant that funding maturities became increasingly shorter and spreads became wider. The ABCP market all but disappeared. The values of firms gripped by lack of liquidity were quickly eroded, causing equity prices to fall. Thus, with falling equity prices and widening corporate spreads, the crisis had made its way to all sectors of the financial system.

2.6 Transfer of risk between tranches

Coval, Jubek and Stafford (2008) analyze the risk inherent in the securitization process and in particular how risk is transferred between tranches in the event of increasing systemic risk. They argue that a "neglected feature of the securitization process is that it substitutes risks that are largely diversifiable for risks that are highly systematic". Unlike the corporate bond market, where an individual idiosyncratic corporate default does not necessarily have consequences for other firms, in a CDO the default of any of the underlying assets increases the risk of all investors.

Coval, Jubek and Stafford (2008) obtain some interesting insights using simulation exercises based on the response of a *typical* CDO to changes in the investment environment. Firstly, they investigate the case where the estimated default correlation of assets within the collateralized pool is larger than anticipated. As default correlation increases (consistent with an increase in non-diversifiable risk), there is a transfer of risk from junior to senior tranches, with the effects on the CDO-squareds being hugely amplified. This is due to the fact that these comprise mainly of mezzanine tranches from the 'first-generation' securitization. Secondly, they investigate the response of tranches to underestimating the probability of default of the assets underlying the pool. They expected payoffs behave as we might expect, largest for the equity tranche and slowly eroding the value of payments to the most senior claims. Interestingly, the effects for the CDO-squareds are much greater. For modest increases in the probability of default, the junior and mezzanine tranches disappear and there are significant losses to the senior tranches.

The first simulation exercise would seem particularly apposite to the investigation of this paper where the probability of default for the sub-prime mortgages underlying ABX-HE index tranches is increasing. The increase in systematic risk should have the most pronounced effect on the AAA-rated assets (at least in a relative sense), thereby yielding the largest increase in risk in the tranche that was previously regarded as being the safest).

3 Data

The price declines in asset backed securities during the credit crunch of 2007-2008 have been dramatic. These declines are partly associated with declines in the value of the underlying assets, but also seem to represent a significant reassessment of the risk profiles of such assets. This paper provides a measure of the extent of the reassessment of these risk perceptions. The paper examines relatively new indices of prices for Credit Default Swaps (CDS) written on Mortgage-backed securities. These indices, entitled ABX.HE, are produced by MarkiT and were first introduced in January 2006. Financial market participants use ABX.HE indexes to track the subprime-mortgage market.

Each index is based on twenty mortgage-backed securities, with the same credit rating, issued over the previous six month period, e.g. the ABX.HE 06-1 index is constructed from deals underwritten in the second half of 2005. The issuers comprise the largest players in the market.[3] There are strict requirements that must be met by the issuers to qualify for inclusion in the construction of the index. For example, each deal must be for at least $500 million and each tranche must have an average life of between four and six years, except for the AAA tranche, which must have a weighted average life greater than five years. Furthermore, no loan originator can have more that four deals included, thus ensuring each index is diversified across issuers.

Typically, these indices are 'rolled' every six months with indices commencing in January 2006, June 2006, January 2007 and June 2007 currently being traded. Due to conditions in the credit markets in early 2008, there was no new roll as there was an insufficient number of deals meeting the eligibility requirements for inclusion. Just like new rolls in the corporate bond markets, these new rolls ensure the index reflects the maximum liquidity. However, these indices are not suitable for splicing to create a continuous data series. Rather each new roll is best viewed as a unique vintage profile with the risk of the reference portfolio of CDS likely to change between rolls. The set of underlying loans for each vintage reflects market conditions in the preceding six months and may thus represent very different risk characteristics. In this respect, the rolls of the ABX.HE data are very different from the corporate bond indices of iTraxx, for example. Table 1 shows the weakening degree of comovement of the assets across vintages. This shows quite different relationships between the rated tranches over time and indicates that these assets are better viewed as unique assets rather than endeavouring to form one continuous security for each tranche.

Each new roll is sub-divided into five different tranches, varying from AAA (best rating) to BBB (lowest rating). Ratings are based on those produced by

[3]Licensed Dealers in the ABX.HE indices include the following: ABN AMRO; Bank of America; Barclays Capital; Bear Stearns; BNP Paribas; Calyon; Citigroup; Credit Suisse; Deutsche Bank; Goldman Sachs; JPMorgan; Lehman Brothers; Merrill Lynch; Morgan Stanley; RBS Greenwich; UBS; and Wachovia.

Table 1:
Correlation coefficients between assets of different credit ratings within Vintages.

	Vintage 06-1	Vintage 06-2	Vintage 07-1	Vintage 07-2
Corr(AAA,A)	0.745	0.676	0.577	0.614
Corr(AAA,BBB)	0.556	0.443	0.484	0.367
Corr(A,BBB)	0.715	0.609	0.654	0.486

Table 2:
Summary statistics for assets by Vintage.

	Std Dev	Min	Max	Skewness	Kurtosis	Nobs
Vintage 06-1						
AAA	0.411	-4.070	2.840	-1.922	29.65	569
A	1.971	-13.131	10.627	-0.485	10.95	569
BBB	2.047	-11.981	11.564	-1.215	9.76	569
Vintage 06-2						
AAA	0.893	-5.679	5.579	-0.570	13.567	444
A	2.758	-16.813	10.930	-1.060	6.881	444
BBB	2.320	-10.653	8.165	-0.967	3.753	444
Vintage 07-1						
AAA	1.400	-6.537	6.550	-0.147	6.683	318
A	2.919	-10.802	9.999	-0.259	1.944	318
BBB	2.700	-17.263	9.530	-1.314	6.030	318
Vintage 07-2						
AAA	1.831	-10.059	7.044	-0.543	6.648	192
A	3.609	-13.156	10.100	-0.302	1.235	192
BBB	3.394	-14.762	9.916	-0.750	2.444	192

both Moody's and S&P, with the lower of the two ratings taken when different. Initially, each index is set equal to 100 with a subsequent decrease (increase) signalling that credit spreads have widened (tightened).

This paper considers assets from three of the vintages (we omit the vintage issued in June 2006) across three credit ratings. The credit ratings, AAA, A and BBB, are chosen to encompass the entire spectrum. We work with daily returns of each series, where returns are computed as the difference in log prices. Our sample covers the period from January 19, 2006 to May 30, 2008. Figure 1 plots the data. Note that our data set is unbalanced. Although all vintages exist at the end of the sample period, their issues arrive progressively through the sample period, which is the feature captured by the use of the dummy variables in the model framework. Table 2 presents some summary statistics. Within each vintage, the standard deviation of return is inversely related to the credit rating of the asset. Across vintages, the standard deviation increases with the most recent vintage displaying the highest risk. Consistent with most asset return data, the distributions are negatively skewed with the absolute value of the minimum return greater than its corresponding maximum. It is noteworthy that within vintages, AAA rated tranches exhibit the highest levels of excess kurtosis but kurtosis declines across vintages. This may suggest that AAA securities experienced the most serious revision over the sample.

To estimate an 'exogenous' liquidity premium, we turn to the market for single name assets and associated derivatives. In particular, we use daily data on CDS index premia and yield spreads on corporate bonds over the 3-month US Treasury bill rate. Specifically the CDS index data is obtained from the CDX database provided by the MarkiT Group Ltd. We use the CDX.NA.IG GEN and CDX.NA.IG GEN 5Yr indices, which are equally weighted credit spreads from 125 (from 5 sub-sectors) North American investment grade companies. Corporate bond yields are the effective yields on AAA, A and BBB rated corporate bond indices compiled by Merrill Lynch. This data begins in October 2003 and runs until the end of May 2008.

4 The Liquidity Premium

Liquidity risk has played a major role in the propagation of the recent credit crunch and in particular, with the partial freezing of some asset and derivative markets. The aim of this analysis is to provide a measure of liquidity risk and assess its impact on the sub-prime mortgage backed CDO market, which has been severely impaired by recent events in credit markets. This measure will provide an observable risk factor in our empirical framework, which in combination with other unobservable factors allows us to examine the evolution of risk factors and perceptions in the markets under analysis.

Since the risk of default on corporate bonds and the risk of credit default swaps are inextricably linked to the performance of the issuer[4], default risk can be measured by identifying a factor that is common to both instruments. Common influences may include macroeconomic factors that affect the firm default probability and recovery rates, see Blanco, Brennan and Marsh, 2005. They argue that the price of CDS and credit spreads for each reference entity should be the same, and provide empirical evidence of this relationship holding in the long run. The asset-specific factors associated with both instruments also provide relevant information. In particular, the idiosyncratic factor associated with credit default swaps will be free of default risk and will therefore be mainly related to liquidity risk. Of course, it can be argued that there is also some commonality in liquidity risk, so a better characterization of the CDS idiosyncratic factor is that it measures the CDS liquidity premium.

We estimate the CDS liquidity premium from a trivariate latent factor model comprising of credit default swap premia, the yield spread of AAA-rated, and A-rated, corporate bonds over the 3-month US Treasury bill rate.

$$y_{i,t} = \lambda_i w_t + \phi_i f_{i,t}; i = CDS, BTS_{AAA}, BTS_A \tag{1}$$

where w_t represents a common factor, and $f_{i,t}$ is the idiosyncratic factor as-

[4] Usually the reference obligation in a CDS is an unsubordinated corporate or government bond.

sociated with asset i. λ_i and ϕ_i are the asset-specific factor loadings. Under the assumption that the factors are distributed $N(0,1)$, the parameters can be estimated by GMM by recognizing that

$$Var(y_{i,t}) = \lambda_i^2 + \phi_i^2 \tag{2}$$

and

$$Cov(y_i, y_j) = \lambda_i \lambda_j. \tag{3}$$

Identification is achieved with the minimum of three assets, as considered here. The model can be extended to account for both persistence and GARCH features of the data, but that was found to be unnecessary in this application: see Dungey and Martin (2007).

The CDS liquidity premium is the corresponding idiosyncratic factor, which is given by

$$\phi_{CDS} f_{CDS,t} = CDS_t - \lambda_{CDS} w_t. \tag{4}$$

The next section proceeds to build a modelling framework for the ABX data, building up to a model which incorporates both the features of the ABX data and the specific influence of the liquidity premium.

5 Modelling framework for ABX data

In recent work, Longstaff and Rajan (2008), illustrate how a pricing model for collateralized debt obligations (CDOs) can be ultimately represented as a three factor model, with the factors representing the credit rating of the asset, a global factor and idiosyncratic component. The underlying pool of assets are based on the credit derivatives of 125 individual firms. Using data for the period October 2003 to October 2005 they estimate the default probabilities for different tranches of the CDOs. In an application to the more recent period, Bhansali, Gringrich and Longstaff (2008) show the substantial increase in systemic risk occurring in the 2007-2008 period.

The approach to the data taken in these two papers treats the data from the CDOs as a continuous stream from an homogenous asset. In particular, asset backed securities of this type are issued at regular time intervals, with the intent that there would be a continued market for rolling over positions from one contract to others, as well as a continued secondary market for older vintages of issue - in this way resembling the on-the-run and off-the-run bond markets, as opposed to the expiration of a futures contract. Longstaff and Rajan (2008) deal with the need for a continuous stream of data to represent prices or returns in this market by simply splicing the data together at a point in time - in their paper they point this out, and indeed it seems to make little difference in the non-crisis period they cover.

However, one of the defining features of the asset backed securities markets during the past two years has been a perception that the underlying assets are declining in quality. As evidence of this Figure 3 presents the prices for the AAA tranche of four ABX indices issued in January and June of 2006 and 2007. It is clear in the chart that the behavior of the price declines in these assets as the 2007-2008 credit crunch unfolds differs for each tranche, and it has not been possible to form a single splicing point that consistently links two of the vintages together.

In this paper, we extend the type of analysis undertaken on asset backed securities to exploit the information on the credit rating of the asset, the global and idiosyncratic characteristics as in Longstaff and Rajan (2008) and also incorporate the information pertaining to the vintage of the issuance. The global, rating and vintage factors are expected to be more important in dealing with mortgage-backed securities, as these are more susceptible to economic conditions, than single name credit derivatives. Specifically, drawing on the methodology developed in Dungey, Martin and Pagan (2000) and Dungey and Martin (2007) we propose a latent factor model where, $y_{i,j,t}$ represents the return in an asset backed security of vintage i (where the vintage represents the date of issue of that security) where that asset carries rating j. The return is modelled as a linear combination of a vintage factor representing the vintage to which it belongs, $v_{i,t}$, and a ratings factor, $k_{j,t}$, as well as a response to shocks common to all assets in the dataset, given by fw_t and idiosyncratic shocks, $f_{i,j,t}$. The basic factor model can be expressed as:

$$y_{i,j,t} = \alpha_0 + \beta_{i,j} fw_t + \theta_{i,j} v_{i,t} + \varphi_{i,j} k_{j,t} + \phi_{i,j} f_{i,j,t}. \tag{5}$$

This linear model is similar in construct to that resulting from the theoretical set up in Longstaff and Rajan (2008).[5] We also augment this model to specifically incorporate the role of the liquidity premium. The inclusion of this measure of liquidity risk allows us to separate its effects from the pure effects due to the evolution of the common, vintage and rating risk factors associated with tranches of pooled sub-prime mortgage-backed securities. The full model has the form

$$y_{i,j,t} = \alpha_0 + \beta_{i,j} fw_t + \theta_{i,j} v_{i,t} + \varphi_{i,j} k_{j,t} + \phi_{i,j} f_{i,j,t} + \delta_{i,j} liq_t \tag{6}$$

To capture the characteristics of the data the factors may display some autoregressive characteristics, here we propose that the common, ratings and vintage factors display AR(1) characteristics, but in line with evidence from previous research on factor models do not impose this structure on the idiosyncratic shocks, see for example Dungey et al (2005). Thus the full specification of the model has the following additional features:

$$\begin{aligned} fw_t &= \rho_w fw_{t-1} + \eta_{w,t} && (7)\\ v_{i,t} &= \rho_{v,i} v_{i,t-1} + \eta_{v,i,t} && (8)\\ k_{j,t} &= \rho_{k,j} k_{j,t-1} + \eta_{k,j,t} && (9)\\ f_{i,j,t} &= \eta_{i,j,t} && (10)\\ \eta_{m,n,t} &\sim N(0,1) \text{ for all } m,n && (11) \end{aligned}$$

A further refinement in order to capture the characteristics of this data can be to instead allow for $\eta_{i,j,t} \sim N(0, h_{i,j})$ for all i,j where $h_{i,j}$ describes a GARCH(p,q)

[5]Note that although Longstaff and Rajan (2008) test their three factor model against reduction to a two or one factor model, they do not consider expansion to further factors.

process such as the GARCH(1,1) given by $h_{s,i,t} = 1 - \alpha_{i,j} - \beta_{i,j} + \alpha_{i,j}\eta^2_{i,j,t-1} + \beta_{i,j}h_{i,j,t-1}$, see Dungey and Martin (2007).

It is convenient to rewrite this model in its state-space form as

$$Y_t = Z\alpha_t + \Theta X_t + S\varepsilon_t \tag{12}$$

$$\alpha_{t+1} = \Upsilon\alpha_t + Ru_t \tag{13}$$

where Y_t is the vector of the returns in each asset, $E[\varepsilon_t] = 0, E[\varepsilon_t\varepsilon_t'] = H, E[u_t] = 0, E[u_t u_t'] = Q$, and the vector X_t contains the measure of liquidity liq_t.The evolving latent factors are contained in the vector α_t and the idiosyncratic factors, $f_{i,j,t}$ are contained in the vector ε_t.That the Kalman filter has the same form as the factor model can be seen by the definitions of each of the matrices for the 3 vintages and 3 asset ratings case:

$$Z = \begin{bmatrix} \beta_{1,AAA} & \theta_{1,AAA} & 0 & 0 & \varphi_{1,AAA} & 0 & 0 \\ \beta_{1,A} & \theta_{1,A} & 0 & 0 & 0 & \varphi_{1,A} & 0 \\ \beta_{1,BBB} & \theta_{1,BBB} & 0 & 0 & 0 & 0 & \varphi_{1,BBB} \\ \beta_{2,AAA} & 0 & \theta_{2,AAA} & 0 & \varphi_{2,AAA} & 0 & 0 \\ \beta_{2,A} & 0 & \theta_{2,A} & 0 & 0 & \varphi_{2,A} & 0 \\ \beta_{2,BBB} & 0 & \theta_{2,BBB} & 0 & 0 & 0 & \varphi_{2,BBB} \\ \beta_{3,AAA} & 0 & 0 & \theta_{3,AAA} & \varphi_{3,AAA} & 0 & 0 \\ \beta_{3,A} & 0 & 0 & \theta_{3,A} & 0 & \varphi_{3,A} & 0 \\ \beta_{3,BBB} & 0 & 0 & \theta_{3,BBB} & 0 & 0 & \varphi_{3,BBB} \end{bmatrix} \tag{14}$$

$$\alpha_t = \begin{bmatrix} fw_t \\ v_{1,t} \\ v_{2,t} \\ v_{3,t} \\ k_{AAA,t} \\ k_{A,t} \\ k_{BBB,t} \end{bmatrix} \quad \Theta = \begin{bmatrix} \delta_{1,AAA} \\ \delta_{1,A} \\ \delta_{1,BBB} \\ \delta_{2,AAA} \\ \delta_{2,A} \\ \delta_{2,BBB} \\ \delta_{3,AAA} \\ \delta_{3,A} \\ \delta_{3,BBB} \end{bmatrix}, \tag{15}$$

Υ is a 7×7 diagonal matrix of the autoregressive parameters, $\rho = [\rho_w\ \rho_{v,i}\ \rho_{k,j}]$ for all i, j, S_t is a 9×9 matrix with the parameters $\phi_{i,j}$ on the main diagonal, and R is the appropriately sized identity matrix, representing our assumption that the variance of the factors is standardized to one. The parameters can then be estimated using the standard Kalman filter procedure, with starting values based on those obtained from the factor model. The standard Kalman filter prediction equations are given by

$$a_{t+1} = \Upsilon a_{t|t} \tag{16}$$

$$P_{t|t+1} = \Upsilon P_{t|t}\Upsilon' + SQS' \tag{17}$$

where $P_{t|t+1}$ is the prediction vector. The updating equations are given by

$$a_{t|t} = a_t + P_t Z' F_t^{-1} v_t \tag{18}$$

$$P_{t|t} = P_t - P_t Z' F_t^{-1} Z P_t' \tag{19}$$

where

$$v_t = Y_t - Z\alpha_t - \theta X_t \tag{20}$$

$$F_t = Z P_t Z' + Z. \tag{21}$$

A further complication is accommodated. The first is the is the unbalanced nature of our data, i.e. the data for different vintages does not exist for the entire sample period. To accommodate this we construct two matrices of dummies as follows

$$D_t = \begin{bmatrix} 1 & 0 & 0 & 0 & 1 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 1 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & d_{1t} & 0 & 0 & d_{1t} & 0 & 0 \\ 0 & d_{1t} & 0 & 0 & 0 & d_{1t} & 0 \\ 0 & d_{1t} & 0 & 0 & 0 & 0 & d_{1t} \\ 0 & 0 & d_{2t} & 0 & d_{2t} & 0 & 0 \\ 0 & 0 & d_{2t} & 0 & 0 & d_{2t} & 0 \\ 0 & 0 & d_{2t} & 0 & 0 & 0 & d_{2t} \end{bmatrix} \quad D2_t = \begin{bmatrix} 1 \\ 1 \\ 1 \\ d_{1t} \\ d_{1t} \\ d_{1t} \\ d_{2t} \\ d_{2t} \\ d_{2t} \end{bmatrix} \tag{22}$$

where d_{1t} takes the value 1 from the time of vintage 2 onwards and 0 else, and d_{2t} takes the value of 1 from the time of vintage 3 onwards and 0 else. The Kalman filter equations are then modified by replacing Z with $Z \circ D_t$ and Θ with $\Theta \circ D2_t$ wherever they appear in the filter, where the operation $\circ$ refers to element by element multiplication.

6 Empirical Results

We begin by extracting the 'exogenous' liquidity premium from the markets for corporate bonds and associated credit defaults swaps. We estimate the factor model given by equation (4) and recover the estimates. There is strong evidence that is w_t directly proportional to the A-rated yield spread (BTS_A), so the common factor is represented by the BTS_A itself. Therefore the liquidity premium associated with the CDS index is computed as

$$\hat{\phi}_{CDS} f_{CDS,t} = CDS_t - \hat{\lambda}_{CDS} BTS_{A,t}. \tag{23}$$

Figure 2 depicts the premium. As expected, it shows most movement in the latter half of the sample as worries about liquidity gripped global credit markets. The first initial jump occurs around July 2007, but this decays quite quickly and returns to 'normal' levels by September. However, from then on, we observe a rapid increase over the remainder of 2007 and early 2008 as markets reacted to the adverse news affecting the credit quality of certain instruments and institutions. It reaches a peak in March 2008, with the Fed bailout of Bear Stearns. Subsequently, the premium falls quite substantially to pre-July 2007 levels.

The model from equations (12) to (15), incorporating the dummies given in (22), is estimated on the standardized residuals of univariate GARCH(1,1) models for each of the ABX series returns. Starting values for the Kalman filter are obtained from indirect estimation of the system given in equations (5) to (11) using the variances and covariances between assets of different vintages and ratings to form the auxiliary model.[6] To build the model we first impose that

[6] Specifically note that we can form the following variance conditions:

$$var(y_{i,j}) = \frac{\beta_{i,j}^2}{1-\rho_w^2} + \theta_{i,j}^2 + \varphi_{i,j}^2 + \phi_{i,j}^2, \tag{24}$$

and the contribution of any individual factor to volatility in a particular asset can be expressed as a proportion of the total volatility. These variance conditions provide one aspect of the auxiliary model in the indirect estimation. Others are provided by other elements of the complicated covariances available between the asset markets, including covariance terms between assets of the same vintage but different credit rating (denoted A and B);

$$var(y_{i,A}, y_{i,B}) = \frac{\beta_{i,A}\beta_{i,B}}{(1-\rho_w^2)^2} + \theta_{i,A}\theta_{i,B},$$

across assets of the same credit rating but different vintage,

$$var(y_{1,j}, y_{2,j}) = \frac{\beta_{1,j}\beta_{2,j}}{(1-\rho_w^2)^2} + \varphi_{1,j}\varphi_{2,j},$$

Table 3:
Coefficient estimates for the state space form of the factor model given in equations (12) to(15) and including (22) with $p_{i,j,t} = \rho_w = 0.9$ for all i, j.(Standard errors to be computed and included).

	estimate		estimate
$\beta_{1,AAA}$	0.418	$\varphi_{1,AAA}$	0.476
$\beta_{1,A}$	0.243	$\varphi_{1,A}$	-0.172
$\beta_{1,BBB}$	0.425	$\varphi_{1,BBB}$	-0.000
$\beta_{2,AAA}$	0.883	$\varphi_{2,AAA}$	0.014
$\beta_{2,A}$	0.543	$\varphi_{2,A}$	-0.723
$\beta_{2,BBB}$	0.754	$\varphi_{2,BBB}$	0.000
$\beta_{3,AAA}$	0.251	$\varphi_{3,AAA}$	-0.005
$\beta_{3,A}$	0.335	$\varphi_{3,A}$	-0.200
$\beta_{3,BBB}$	0.267	$\varphi_{3,BBB}$	0.000
$\theta_{1,AAA}$	-0.696	$\delta_{1,AAA}$	-0.227
$\theta_{1,A}$	-0.277	$\delta_{1,A}$	-1.047
$\theta_{1,BBB}$	-0.846	$\delta_{1,BBB}$	-0.216
$\theta_{2,AAA}$	-0.501	$\delta_{2,AAA}$	0.036
$\theta_{2,A}$	0.225	$\delta_{2,A}$	0.113
$\theta_{2,BBB}$	-0.398	$\delta_{2,BBB}$	0.380
$\theta_{3,AAA}$	0.000	$\delta_{3,AAA}$	-0.640
$\theta_{3,A}$	-0.000	$\delta_{3,A}$	-0.563
$\theta_{3,BBB}$	0.000	$\delta_{3,BBB}$	0.722

the matrix Υ be diagonal with all elements equal to 0.9 (i.e. there is a common autocorrelation parameter for each of the unobserved factors equal to 0.9). This restriction was not rejected when tested against freely estimated values of Υ and hence the restriction was retained in the final specification. Coefficient estimates for the final system are given in Table 3.

Figures for the influence of the world factor, vintage factor, rating factor and the absolute value of the liquidity factor for each asset are given in Figures

and where the assets are of neither the same credit rating nor the same vintage (for example a vintage 1, A-rated asset and a vintage 2, B-rated asset)

$$var(y_{1,j}, y_{2,j}) = \frac{\beta_{1,A}\beta_{2,B}}{(1-\rho_w^2)^2}.$$

There are corresponding expressions for covariances between differently rated assets and assets in different vintages.

(4) to (6). Analyzing the factors allows us to assess the impact of the world, vintage, rating factors as well as our liquidity premium on the performance of different asset tranches. We examine each of these in turn.

6.1 World factor

For all assets of a given vintage, the influence of the world factor is remarkably similar. The early part of the sample shows that the systemic risk is relatively small and the impact of the world factor on asset returns is low. However, at the time of the onset of the financial turmoil, we see a significant and persistent increase in the systematic factor for all assets. This is consistent with higher non-diversifiable risk for investors emanating from the higher correlation of all assets within the collateralized pool.

As argued by Coval, Jubek and Stafford (2008), the increasing systemic risk results in a transfer of risk from the equity tranche to more senior claims. As this non-diversifiable risk increases, the difference in risk exposure from holding a senior or an equity tranche is reduced and disappears in the extreme position of all asset pairs being perfectly correlated. Given the almost uniform impact of the world factors across assets, this is consistent with very high asset correlations and consequently, much higher than anticipated levels of risk for the more senior tranches. This implies that the pricing of the tranches grossly under-estimated the risk of the individual ratings. The senior claim, which in relative terms, suffers most from the increased systemic risk is thus very much over-priced and the return offered is insufficient to compensate the investor for the inherent risk. This result is consistent with work of Brennan, Hein and Poon (2008) who also point to the mispricing of CDO tranches. The commonality of asset performance (driven by the increased role of the world factor) across ratings demands a re-assessment of the risk inherent in these securitized mortgage-backed products.

6.2 Vintage factors

The importance of the vintage factor decreases over time. In the earliest vintage, the factor enjoys its greatest impact on asset performance and its strongest effect is seen on the BBB tranche. Hence, for mortgage-backed assets issued in this period, the influence of the vintage factor plays a crucial part in forming a distinction between the various tranches. However, its role in determining asset volatility is eroded over the sample. For the second vintage, it has a far lesser role in determining asset volatility and the factor associated with the final time period exerts a negligible influence on the distribution of asset returns. In this respect, the vintage factors appear to be subsumed over time by global events whereby the increasing role of the systematic factor reduces the role of vintage risk. Therefore this risk source is most pronounced in the early vintage which was issued in a relatively calm financial environment and there is a clear differentiation of tranches. As asset performance becomes more uniform, vintages factors become less important.

6.3 Ratings factors

The ratings factors display the importance of the quality of the asset rating. In the first vintage, which is based on deals initiated in the second half of 2005, there is a relatively large contribution to the performance of AAA-rated instruments from its ratings factor, although not as great as the vintage factor. Therefore, in this period of relative calm, being a AAA-rated security helped to distinguish this asset from the others. During later vintages, this influence is less evident (as the world factor becomes dominant). In fact, the largest impact of the ratings factor is felt by the BBB rated instruments, recognizing the risk premium due to these assets during the more turbulent times.

6.4 Liquidity factor

The liquidity factor is important for each asset and its influence increases over time. This is consistent with the role of liquidity shortages in transmitting the credit crisis across asset types, markets and across national borders. For all assets, there are two periods of high liquidity risk associated with the period June to September 2007 and January to March 2008. The former is the period of emergence of the crisis and lead up to problems with Northern Rock, and the latter covers the period of uncertainty prior to the acquisition of Bear Stearns by JP Morgan. In general, for any given vintage, liquidity risk increases with a decline in rating; while for any given rating, the liquidity risk increases across vintages. The liquidity risk arises from the requirement of pension funds and other financial institutions to off-load downgraded assets in extremely thin markets. This is compounded by the reluctance of investors to return to the market for mortgage-backed securities and the higher than expected capital requirements incurred by financial institutions faced with increased warehousing risk and simultaneous balance sheet expansion due to the need to take assets back on balance sheet. The combination of the world factor and liquidity risk inherent in the various tranches accounts for the commonality in the downward price pressure experienced by all assets across ratings and vintages.

6.5 Summary

The combinations of different factors contributing to the performance of each of the 9 assets examined is revealing. In the case of the AAA-rated assets, only in the final vintage (the January 2007 issue) does the liquidity factor outweigh the vintage factor in its relative contribution. In all of the June 2007 issues, regardless of the rating of the asset, the liquidity factor is the dominant factor. And indeed for all A rated assets liquidity is the dominant factor throughout all vintages, potentially reflecting the repackaging of Mezzanine level tranches into CDO-squareds as discussed in Section 2.3. In the BBB rated assets, however, the vintage factor is also the dominant factor in the first vintage. A natural interpretation is that this reflects the generally higher quality of the vintage 1 assets, where the ratings had greater meaning than in later vintages. For AAA rated assets, liquidity dominated the factors influencing all asset performance.

The role of the common factor is also interesting. In the early part of our sample, this is relatively unimportant and suggests relatively low correlation between assets in the underlying pool. However, as this factor increases in volatility and importance, the correlation between assets increases and there is less differentiation across the tranches of the underlying pool. This has a relatively larger impact on the most senior claims as the realization dawns on market participants that the inherent risk in the structured products has been greatly under-estimated and consequently AAA-rated securities have been grossly mispriced. Ultimately, as argued by Coval, Jurek and Stafford (2008), the evolution of this factor is most revealing and bears the largest repercussions for the market for (sub-prime) mortgage-backed CDO instruments. Undoubtedly, any re-emergence of this type of product will only be possible when the true vulnerability of the pool to systematic is properly incorporated into pricing models.

7 Conclusions

This paper focuses on the role of risk factors in explaining the decline in quality and value of sub-prime mortgage-backed CDOs. The dramatic collapse of this market and its seemingly disproportionate impact on other asset markets and forms the background to the current study. We extend the modelling approach of Longstaff and Rajan (2008) by adopting a factor model and using features of the data to identify four unobservable factors. In particular, we uncover a world/common factor that captures the role of systematic risk; a ratings factor that is due to perceptions of asset quality; a vintage factor arising from changing risk profiles of issues of mortgage backed securities over different issuances and an idiosyncratic factor from the data on tranched assets of CDOs. We also estimate the effects of liquidity risk by including an exogenous measure recovered from the markets for single-name corporate bonds and credit default swaps. We employ data on AAA, A and BBB-rated assets across three different vintages of security issuance from the ABX-HE indices over the period from January 2006 to May 2008.

Our results show the relative importance of the factors representing liquidity effects, ratings effects, vintage effects and common market conditions. There is a strong influence of the common factor across the time period. As the systemic risk increases and asset correlation increases, the influence of the other factors is less defined. This is consistent with risk being transferred from lower- to higher-rated tranches, with assets becoming less differentiated. Different asset vintages show differing characteristics, and the vintage factor has a differing and important role to play across assets of different credit rating, strongly supporting the extension of empirical work on asset backed securities to account for differing vintages of issuance. The results also emphasize the importance of liquidity effects, particularly to lower rated asset indices in later vintages. By the last vintage of issuance considered in the sample, January 2007, liquidity effects dominate the performance of all assets, regardless of their credit ranking.

The increasing role of the liquidity premium, combined with increasing systematic risk as the crisis deepened suggests that vulnerability to non-diversifiable risk was not fully appreciated or indeed properly priced in this segment of the CDO market. A re-assessment of these structured products seems inevitable.

References

[1] Benmelech, E., Dlugosz, J., 2008. The alchemy of CDO credit ratings. Manuscript, Harvard University.

[2] Bhansali, V., Gingrich, R., Longstaff, F., 2008. Systemic credit risk: what is the market telling us?, manuscript, UCLA.

[3] Blanco, R., Brennan, S., Marsh, I., 2005. An empirical analysis of the dynamic relation between investment-grade bonds and credit default swaps. Journal of Finance, 60 (5), 2255-2281.

[4] Brennan, M., Hein, Poon, S.H., 2008. ??

[5] Brunnermeier, M.K., 2008. Deciphering the 2007-08 Liquidity and Credit Crunch. Journal of Economic Perspectives, forthcoming.

[6] Coval, J., Jubek, J., Stafford, E., 2008. The Economics of Structured Finance. Working paper 09-060, Harvard Business School.

[7] Craig, S., Smith, R., Ng, S., 2008. Merrill aims to raise billions more: firm dumps mortgage assets as crisis drags on; another big write-down. Wall Street Journal, July 29.

[8] DeMarzo, P., 2005. The pooling and tranching of securities: a model of informed intermediation, Review of Financial Studies, 18, 1-35.

[9] Dungey, M., Martin, V.L., 2007. Unravelling financial market linkages during crises. Journal of Applied Econometrics, 22 (1), 89-119.

[10] Dungey, M., Pagan, A., Martin V., 2000. A Multivariate Latent Factor Decomposition of International Bond Yield Spreads. Journal of Applied Econometrics, 15, 697-715.

[11] Kiyotaki, N., Moore, J., 2002. Balance Sheet Contagion. American Economic Review, 92 (2), 46-50.

[12] Hu, J., 2007. Assessing the credit risk of CDOs backed by structured finance securities: rating analysts' challenges and solutions. Available at SSRN: http://ssrn.com/abstract=1011184

[13] Leland, H., Pyle, D., 1977. Information asymmetries, financial structure and financial intermediaries. Journal of Finance, 32, 371-387.

[14] Longstaff, F. and A. Rajan (2008) "An Empirical Analysis of the Pricing of Collateralized Debt Obligations", Journal of Finance, 63 (2), 529-563.

8 Appendix: Details on Data Series

The data series used in this paper are described below:

LiquidityPremium:

- 3 Month Treasury bill Secondary Market Rate: Board of Governors of Federal Reserve System, Table H.15 Selected Interest Rates, from FRED: Series ID: DTB3
- Merrill Lynch Corporate Bonds, A rated, Effective Yield, from Bloomberg.
- Credit Default Swap Rate index from: CDX.NA.IG GEN, from Bloomberg.

ABX Data:

- ABX-HE-A 06-1: 0.54% Coupon Closing Price, RED ID: 0A08AFAA7
- ABX-HE-A 07-1: 0.64% Coupon Closing Price, RED ID: 0A08AFAC0
- ABX-HE-A 07-2: 3.69% Coupon Closing Price, RED ID: 0A08AFAD8
- ABX-HE-AAA 06-1: 0.18% Coupon Closing Price, RED ID:0A08AHAA1
- ABX-HE-AAA 07-1: 0.09% Coupon Closing Price, RED ID:0A08AHAC6
- ABX-HE-AAA 07-2: 0.76% Coupon Closing Price, RED ID:0A08AHAD4
- ABX-HE-BBB 06-1: 1.54% Coupon Closing Price, RED ID:0A08AIAB6
- ABX-HE-BBB 07-1: 2.24% Coupon Closing Price, RED ID: 0A08AIAC4
- ABX-HE-BBB 07-2: 5.00% Coupon Closing Price, RED ID: 0A08AIAD2

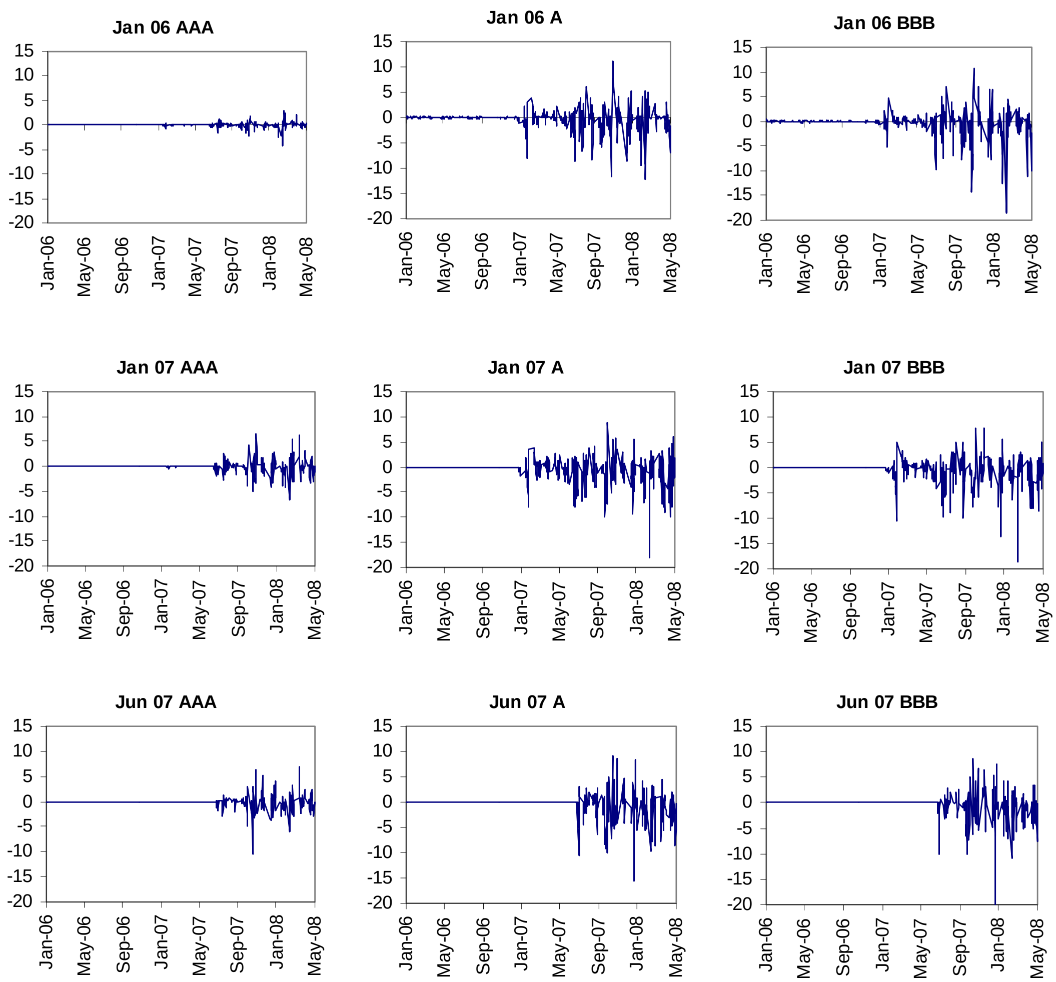

Figure 1: Daily log returns on ABX indices by vintage of issue and rating.

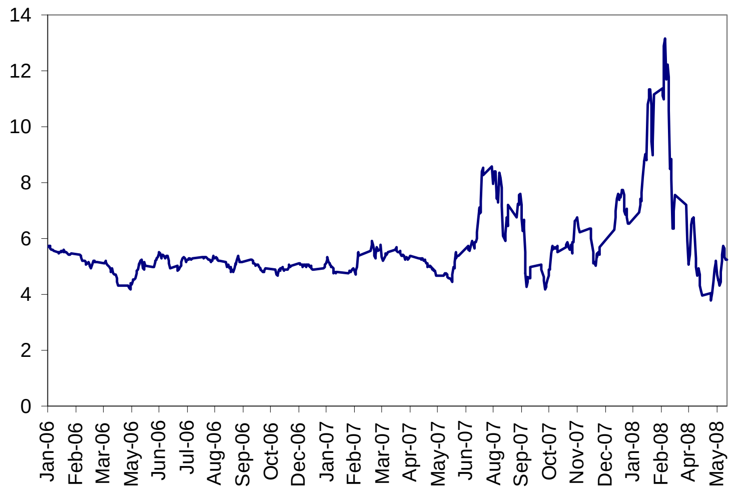

Figure 2: The Estimated Liquidity Premium from equation (23).

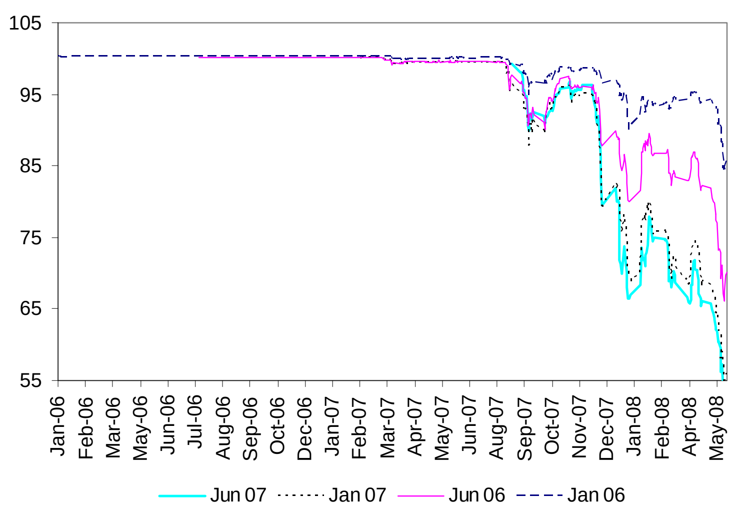

Figure 3: Price index of AAA rated ABX contracts of different vintages.

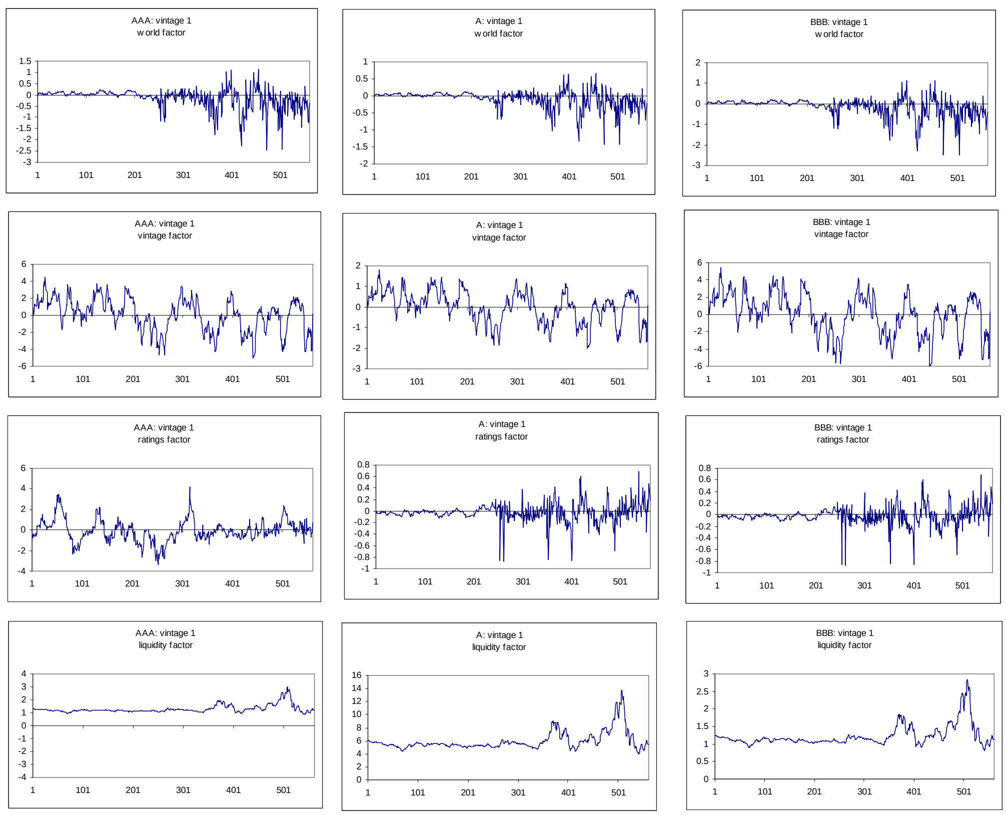

Figure 4: Contributions of common, vintage, ratings and liquidity factors to asset returns in vintage 1 (January 2006).

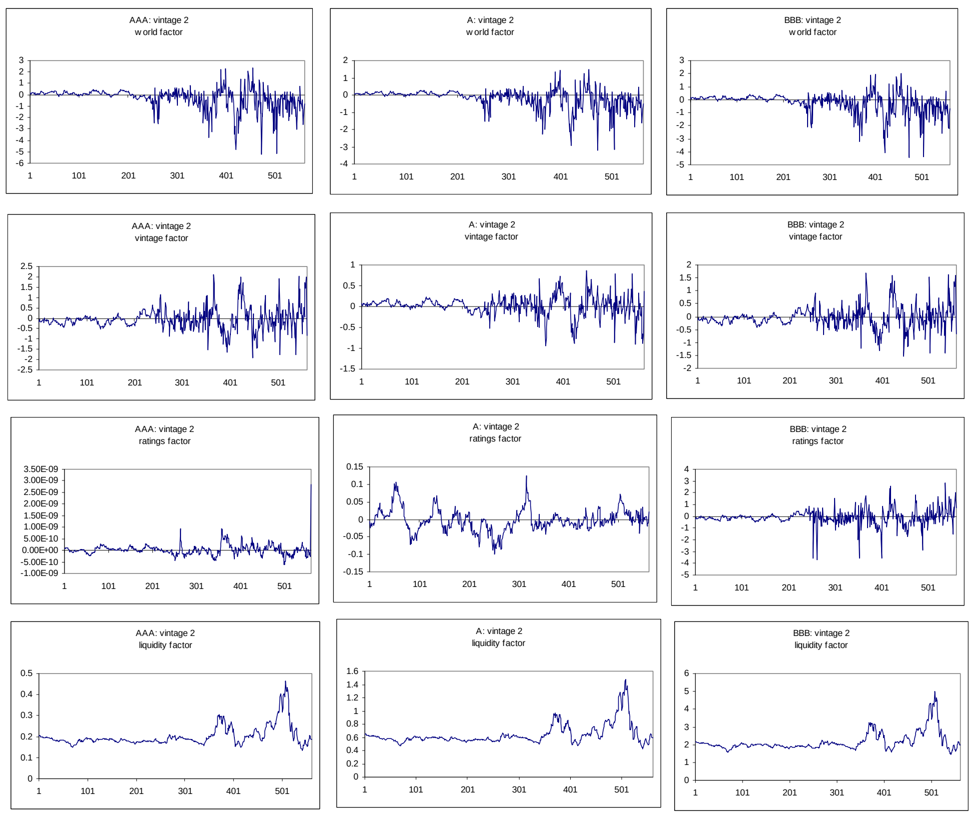

Figure 5: Contributions of common, vintage, ratings and liquidity factors to asset returns in vintage 2 (July 2006).

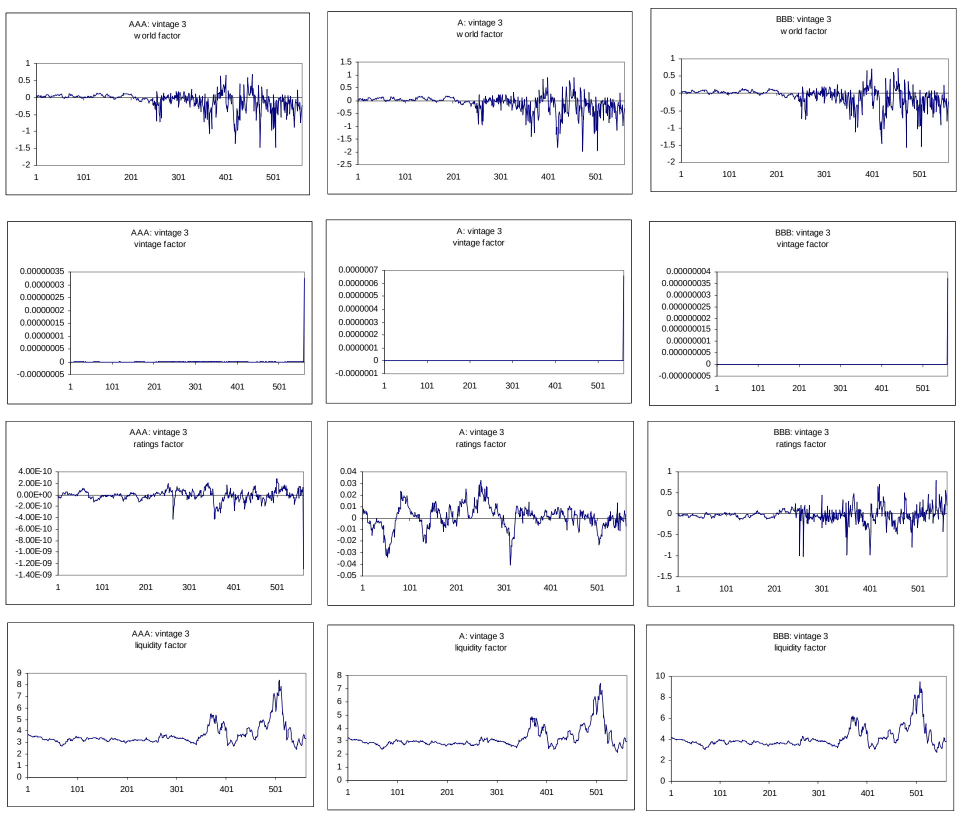

Figure 6: Contributions of common, vintage, ratings and liquidity factors to asset returns in vintage 3 (January 2007).