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ANALYZING CONTAGION FROM THE U.S. SUBPRIME MORTGAGE-BACKED SECURITIES MARKET

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Abstract

This paper analyzes contagion from the U.S. subprime mortgage-backed securities market, represented by the ABX.HE indices, to several fixed income, equity and volatility markets in line with seminal literature on the subject. We analyze 'spliced' data set constructed in line with the literature, along with two traded ABX.HE indexes. A VAR framework is employed, firstly to extend existing analysis to include 2009, and then to analyze two traded indexes. In order to test the sensitivity of these results ABX returns are then included as an eighth endogenous variable in the VAR. Principal component analysis is employed to reduce the dimensionality of the data. The main principal component obtained is then included as an exogenous variable in the VAR framework and the sensitivity of these results is tested by including this principal component as an eighth endogenous variable. The results indicate evidence of contagion from the ABX indexes during the crisis of 2007-2009 but the source and intensity of this contagion varies across indexes. This highlights the differences across the three ABX data sets analyzed and suggests that splicing the ABX index may impact the results obtained. It also provides evidence that the traded ABX indexes are heterogeneous assets with varying sensitivities to risk factors during the crisis.

Keywords: Subprime Crisis, ABX Indexes, Principal Component Analysis, Contagion

JEL Classifications: G01, G10, G12, G21

1. Introduction

In 2007, the United States' financial system suffered its worst crisis in almost a century, a crisis that originated in the relatively new and small subprime mortgage-backed securities market. Triggered by a declining real estate market and the threat of vast defaults by borrowers, particularly in the subprime sector, the crisis soon evolved from a real estate problem to a much broader global credit crisis (Brunnermeier, 2009). By September 2008, liquidity had all but come to a halt in already unstable financial markets and events such as the fall of Wall Street giant Lehman Brothers and the acquisition and nationalization of insurance giant AIG added to institutions' growing reluctance to lend to one another (Bordo, 2008).

The U.S. government was forced to intervene in an effort to stem to spread of the crisis even further, implementing strategies such as the Emergency Economic Stabilization Act of 2008, which authorized the Treasury to spend up to \$700 billion purchasing troubled assets,

and supplying banks with capital, leading the Act to be dubbed the '\$700 billion bailout plan' by the media (Nothwehr, 2008).

Contagion during such a catastrophic crisis is clearly of importance to investors and financial institutions and so this paper tests for its presence from the U.S. subprime mortgage-backed securities market, represented by the ABX.HE indexes¹, to several fixed income, equity and volatility markets following the VAR framework outlined by Longstaff (2010). The spliced ABX index constructed by Longstaff (2010) is employed, along with two traded ABX indexes in order to ascertain if splicing the data could impact the outcome of the analysis. The results suggest that splicing the data in such a way could produce an incomplete picture of what was happening in this market during the crisis period. Analysis of two traded ABX indexes highlights the differences between them, suggesting that they are heterogeneous assets with different risk profiles that were affected differently once the crisis hit.

The remainder of the paper is organized as follows. Section 2 briefly outlines some related literature and describes the analysis performed by Longstaff (2010). Section 3 then describes the data employed and Section 4 presents some preliminary analysis results. Section 5 extends the analysis presented in Longstaff (2010) to include a 'post-crisis' period of 2009 and Section 6 presents the VAR analysis performed on two traded ABX indexes. The sensitivity of the results presented by Longstaff (2010) is tested in Section 7 by including ABX as an eight endogenous variable in the VAR. Section 8 then presents the results of principal component analysis performed on the three ABX data sets and Section 9 includes the main principal component obtained in further VAR analysis. A final section then concludes.

2. Related Literature

The topic of contagion in financial markets has been analyzed extensively in the past few decades and so a great deal of literature examining the subject exists. There is also a growing body of work analyzing contagion during the subprime crisis such as Hess and Holzhausen (2008), Abbassi and Schnabel (2009), Hwang *et al.* (2010) and Cheung *et al.* (2010). Emin (2016), for example, finds that the subprime crisis has caused emerging European stock markets to become more integrated with the world market. However, literature utilizing the ABX indexes to test for the presence of contagion during the crisis of 2007-2009 is not as extensive. Using the ABX indexes to represent the U.S. credit default market, Guo *et al.* (2011) test for cross-market contagions among this market, a U.S. stock market, real estate market, and energy market during the 2007 crisis using a Markov switching vector autoregression (MS-VAR) framework. They find that stock market and oil shocks are driving forces behind credit default and stock market variations. Longstaff (2010) utilizes the ABX indexes to represent the U.S. subprime mortgage-backed securities market and tests for contagion from this proxy to several fixed income, equity and volatility markets using a VAR framework. This paper extends Longstaff (2010), tests the sensitivity of those results and applies the framework to two traded ABX indexes. I therefore adopt a working definition of contagion in line with Longstaff (2010, p. 3) as 'an episode in which there is a significant increase in cross-market linkages after a shock occurs in one market'. Longstaff (2010) highlights that the literature examining contagion broadly classifies three potential devices through which contagion may be transmitted to financial markets. The first mechanism is termed the 'correlated information channel'. In this channel contagion occurs through the transmission of information by means of price discovery and should cause instantaneous price effects following a crisis. The second channel presented is known as the 'liquidity channel'. This implies that a crisis be related to credit shortages and increased trading in other financial markets. The third outlet is labelled the 'risk-premium channel' through which shocks to an affected security may have predictive ability for subsequent returns of other securities. Using a VAR framework, Longstaff (2010) finds strong evidence of contagion in the financial markets examined over the crisis period. It is also found that this contagion was mainly transmitted through liquidity and risk-premium channels, rejecting the correlated information channel. Significant price discovery supports this hypothesis.

¹ From herein referred to as the 'ABX index' or simply the 'ABX'.

3. Data

This paper treats Longstaff (2010) as the benchmark for testing for contagion from the ABX indexes and so employs the spliced ABX index and VAR variables utilized by that work. Data from two actual traded ABX indexes, the ABX 06-1 index and the ABX 06-2 index, are then analyzed in order to ascertain if splicing the data could influence the results.

3.1. ABX Indexes

The exceptional growth of the subprime mortgage-backed securities sector during the early 2000s led to the creation of the ABX.HE indexes, a standardized index that provided credibility, transparency and liquidity to this relatively new and innovative structured finance market. Produced by the Markit Group, trading on the ABX was launched on 19th January 2006 to enthusiastic investors. Indeed, volume on the first trading day was reported to be approximately \$5 billion, although this decreased in subsequent trading days (Whetten, 2006). The name ABX.HE stands for 'Asset-Backed Securities Index-Home Equity' and it represents a standardized basket of home equity asset-backed reference obligations, basically a basket of synthetic CDOs underlying subprime mortgages. The indexes track twenty equally weighted, static U.S. portfolios of credit default swaps backed by subprime mortgages. Each sub index covers specifically rated reference obligations (AAA, AA, A, BBB, and BBB-). AAA rated ABX securities thus reference a specific AAA-rated class from each of the twenty reference residential mortgage-backed security (RMBS) pools, while AA rated ABX securities reference AA-rated class from the pool and so on down to BBB-. However, considering that there are actually approximately fifteen tranches in each mortgage-backed security and the indexes only take into account five of these (AAA, AA, A, BBB, BBB-) the ABX cannot be seen as a perfect representation of the market. Nonetheless it is the closest proxy available (Finger, 2007).

Each index is based on twenty subprime mortgage backed securities, with the same credit rating, issued over the previous six-month period and indexes are renewed or 'rolled' every six months. In order to be included in the index each RMBS must meet stringent requirements, such as deal size must be at least \$500 million, the weighted average FICO score of the creditors backing the securities issued in the RMBS transaction may not be greater than 660 and at least four of the required tranches must be registered pursuant to the U.S. Securities Act of 1933.

Only four indexes were issued, with the fifth subject to several postponements and unlikely to go ahead. It is important to note that the tranches within the ABX do not differentiate borrowers according to how risky they are. Instead, they simply distinguish the order in which investors bear losses and receive payments. The misconception that an AAA rated ABX asset was equal to that of a corporate bond led to many mandate-driven bodies, such as pension funds and universities, to heavily invest in these securities. As the crisis of 2007 unfolded, it became clear that the ABX had been grossly mispriced. Fender and Scheicher (2008) propose one way to calculate ABX prices as:

$$p = 100 + c \sum z_i s_i t_i f_i - (1 - \delta) \sum z_i (s_i - 1 - s_i) f_i \quad (1)$$

in which p = index price, c = coupon payment, z = risk-free discount factor, s = probability of no default, t = time period, δ = recovery rate (i.e. the price of the bond immediately after default as a percentage of its face value) and f = bond factor measuring prepayments on ABX bonds. This may be written in simplified terms as:

$$Price = 100 + PV(Coupons) - PV(Writedowns) \quad (2)$$

One hundred is the par value of the index. The present value of the coupons is fixed as a percentage of notional over the life of the index on initiation of a new vintage. It is paid by the protection buyer to the protection seller for insurance should a credit event occur. The present

value of write-downs or losses is variable and is paid from the protection seller to the buyer in the case of a credit event. Equations (1) and (2) highlight that it is vital that the value of the coupons is high enough to cover potential losses. However, as it transpired, they were not and when defaults began accumulating write-downs rapidly increased. Protection sellers simply could not afford to cover the losses. Trading in the ABX came to almost a complete halt following the subprime crisis of mid-2007. It did resume following the shock as investors tentatively re-entered the market but it is highly unlikely that trading volumes will ever reach the highs experienced in the months leading up to the crisis. ABX data have been obtained from the Markit Group and weekly (Wednesday to Wednesday) returns are used in the analysis for the period spanning 2006-2009.²

3.2. Longstaff (2010) Spliced ABX Index

Longstaff (2010) constructs an on-the-run ABX index by splicing the series together at the date that each new vintage³ is issued. The series is therefore spliced together on July 19th 2006, January 19th 2007 and July 19th 2007. As each new series began trading at par it is necessary to re-base the series at each splicing date. Weekly (Wednesday-to-Wednesday) returns are used and the data analyzed in Longstaff (2010) span from January 19th 2006 to December 31st 2008. The sample is divided into three separate one-year periods, the 2006 'pre-crisis' period, the 2007 'subprime crisis' period and the 2008 'global-crisis' period, in order to test for contagion when moving from a tranquil pre-crisis period to a volatile crisis period. As data have been obtained for 2009, this study includes this year as a 'post-crisis' period.

Figure 1 plots the time series of ABX index returns for each index under analysis over the full sample period. Figure 1 illustrates that during the 2006 'normal' period, all five ratings tranches were trading at or near par in each index analyzed. From 2007 onwards, however, returns in all three indexes become increasingly volatile as the crisis hit. This volatility continues throughout 2008 and 2009, although does diminish somewhat. However, returns do not revert to the stable values experienced during 2006, suggesting that this market was still subject to volatility during the 'post-crisis' period.

² It should be noted that, because the ABX 06-2 index began trading in July 2006, the data set is unbalanced.

³ ABX 'index' and ABX 'vintage' are used interchangeably throughout this paper.

Spliced ABX Index Returns 2006-2009

ABX 06-1 Index Returns 2006-2009

ABX 06-2 Index Returns 2006-2009

Figure 1. ABX Weekly Returns

3.3. VAR Variables

Longstaff (2010) uses weekly returns of the five assets comprising the spliced ABX index, as described above, to proxy for returns in the troubled subprime mortgage-backed CDO market. We test for contagion from this market to several equity, volatility and fixed-income markets using a VAR framework. Weekly changes in the constant maturity 1- and 10-year Treasury yields are included to capture changes in the Treasury bond market while changes in corporate bond spreads are measured by subtracting the 10-year Treasury yield from the Moodys Aaa and Baa corporate yield indexes. Treasury yield and corporate yield data have been obtained from the Federal Reserve Board. Weekly returns for the S&P 500 and the S&P 500 subindex of financial firms capture changes in the U.S. stock market while the VIX volatility index provides a measure of market volatility. Data for these three VAR variables have been obtained from the Bloomberg system.

Figure 2. VAR Variables

Figure 2 plots the time series of these VAR variables over the entire sample period. While the corporate spreads and VIX are quite volatile throughout, the S&P 500 and S&P 500

sub-index of financial firms appear to become most volatile around mid-2008, which would coincide with the onset of the global credit crunch and increased volatility in stock markets. Changes in the two Treasury yields become increasingly volatile from 2007 onwards, with the shorter maturity 1-year bill experiencing most volatility in 2008. In fact, during that year the 1-year constant maturity Treasury rate fell from 2.71% in January to 0.49% in December, (Federal Reserve Board, n.d.). The 10-year bond continues to be quite volatile during the 'post-crisis' period of 2009. This longer maturity bonds' rate ranges from a high of 5.25% to 2.20% over the sample period, with the lowest values experienced from the end of 2008 through early 2009. These movements are illustrated graphically in Figure 3, which plots the two Treasury Bill rates over the sample period.

Figure 3. Treasury Bill Rates

As McAndrews *et al.* (2008) state, these Treasury securities contain liquidity premium, with the 10-year bond usually containing larger liquidity than other Treasury bonds. It is possible then that weekly changes in this longer maturity bond experience a greater degree of volatility relative to the one-year Treasury Bill during the 2008-2009 period because of the effects of the liquidity freeze in mid- to late-2008. Longstaff (2010) finds strong evidence of contagion emanating from the spliced ABX index during the 2007 'subprime-crisis' period, along with significant price discovery, thus rejecting the 'correlated information' channel of contagion and supporting the 'risk-premium' channel. Further VAR analysis employing 'liquidity' measures then supports the 'liquidity' channel of contagion during the subprime crisis of 2007. Evidence of contagion then dissipates during the 2008 'post-crisis' period.

4. Preliminary Analysis

Table 1 reports summary statistics for weekly returns for each of the three ABX indexes under analysis over the entire sample period.

Table 1. Summary statistics for ABX indexes weekly returns

Data Set	Rating	Mean	Std. dev	Skewness	Kurtosis	Min	Max
Spliced ABX Index	AAA	-0.432	4.749	-0.072	2.709	-16.573	14.839
	AA	-1.338	5.852	-1.453	7.266	-29.754	21.416
	A	-1.410	5.799	-1.420	5.811	-28.786	18.773
	BBB	-1.604	4.764	-1.116	3.825	-21.429	13.595
	BBB-	-1.572	4.950	-1.107	4.468	-26.617	12.941
ABX 06-1 Index	AAA	-0.068	2.599	-0.555	9.487	-14.933	12.209
	AA	-0.386	5.571	0.720	11.475	-26.347	35.223
	A	-0.889	6.058	0.027	3.920	-19.908	24.216
	BBB	-1.323	5.762	-1.535	8.032	-32.947	21.367
	BBB-	-1.349	5.143	-1.978	7.814	-27.130	16.264
ABX 06-2 Index	AAA	-0.316	4.908	-0.495	3.794	-21.611	15.598
	AA	-1.209	6.255	-0.043	3.183	-22.713	22.821
	A	-1.447	6.400	-1.219	4.415	-30.747	14.484
	BBB	-1.442	6.398	-0.079	3.318	-23.259	25.172
	BBB-	-1.475	5.922	0.174	3.1364	-19.075	23.809

Mean returns are negative in all ratings tranches, and are monotonically related to credit rating in all but the ABX 06-2 index. Of the traded indexes, the ABX 06-2 index experiences lower mean returns in each ratings tranche than the earlier issued ABX 06-1 index, suggesting that this later issuance may have been hit harder by the crisis than the first vintage. Standard deviations are high in all cases, indicating the high volatility of returns. They do not appear to be inversely related to credit rating as, based on these, the AA rated asset is most volatile in the spliced ABX index, while the BBB rated asset is most volatile in the ABX 06-1 vintage index and the A rated asset is most volatile in the ABX 06-2 vintage. The ABX 06-2 vintage tranches display relatively higher standard deviations than the earlier issued ABX 06-1 vintage, suggesting that this more recent issuance was more volatile. This could be due to the fact that this vintage was based on subprime mortgages issued in the first half of 2006 and so would have been of worse quality than those included in the ABX 06-1 vintage index. This is also reflected in the wider gap between minimum and maximum values in the ABX 06-2 vintage index than in the ABX 06-1 vintage index. It is also noteworthy that in almost all three indexes analyzed, the absolute value of minimum return exceeds that of the associated maximum return. Unsurprisingly, all returns are negatively skewed and it is clear that normality is rejected in all cases. The ABX 06-1 vintage experiences higher levels of excess kurtosis in all ratings tranches than the other two indexes analyzed. This highlights the differences between vintages and also, differences between the traded ABX indexes and the spliced ABX index.

Table 2. Summary statistics for VAR variables

Variable	Mean	Std. dev	Skewness	Kurtosis	Min	Max
S&P 500	-0.015	2.847	-0.855	5.374	-15.169	10.118
S&P 500 Subindex	-0.153	5.504	0.039	4.234	-23.208	22.192
1-Year T-bill	-1.980	13.412	-1.058	5.869	-67.000	50.000
10-Year T-bill	-0.377	15.307	-0.023	1.214	-49.000	52.000
VIX	0.935	12.447	1.104	2.783	-29.415	51.176
Aaa Spread	1.016	11.929	0.905	2.637	-22.951	59.574
Baa Spread	0.378	5.864	0.673	2.491	-14.541	26.216

Table 2 provides summary statistics for weekly changes in each of the VAR variables over the entire sample period. Unsurprisingly, we observe negative means for the stock market and Treasury bond market measures and positive means for weekly changes in the VIX and the two corporate spreads. Standard deviations are high for each financial market variable, but it is weekly changes in the two Treasury Bill Rates that experience the highest standard deviations. As stated above, these Treasury notes are known to contain liquidity (McAndrews *et al.* 2008) and so experienced high levels of volatility during the subprime and liquidity crisis periods.

These Treasury Bills, along with weekly S&P 500 returns are negatively skewed, while all other financial variables experience positive skewness, although the S&P 500 subindex of financial firms is only slightly positively skewed. The S&P 500 experiences the highest level of excess kurtosis, which is unsurprising for stock returns.

Table 3. ABX indexes correlation coefficients

Spliced ABX Index					
Rating	AAA	AA	A	BBB	BBB-
AAA	1.00				
AA	0.63	1.00			
A	0.46	0.78	1.00		
BBB	0.35	0.64	0.69	1.00	
BBB-	0.33	0.59	0.67	0.94	1.00
ABX 06-1 Index					
Rating	AAA	AA	A	BBB	BBB-
AAA	1.00				
AA	0.82	1.00			
A	0.45	0.59	1.00		
BBB	0.37	0.43	0.75	1.00	
BBB-	0.36	0.41	0.64	0.91	1.00
ABX 06-2 Vintage					
Rating	AAA	AA	A	BBB	BBB-
AAA	1.00				
AA	0.62	1.00			
A	0.44	0.76	1.00		
BBB	0.28	0.59	0.74	1.00	
BBB-	0.24	0.52	0.66	0.94	1.00

Table 3 reports raw correlations for the weekly returns of the indicated ABX indexes. These indicate that the two lower rated assets are highly correlated with each other and also experience a relatively high degree of correlation with the middle A rated tranche. This is expected as these three assets were perceived to be the riskiest in the indexes. As is the fact that the two highest rated assets experience a relatively high correlation with each other. Most of the correlation coefficients among the higher rated assets in the ABX 06-2 vintage are considerably lower than those reported for the ABX 06-1 vintage returns. This suggests that this later issuance was subject to lesser degrees of co-movement among these assets, and so the higher rated assets in these two vintages behaved differently. This would indicate that the relationships between the ratings tranches in these vintages varied and so these assets should be treated as heterogeneous by investors. It is noteworthy that the correlation between the lower rated assets actually increases in the ABX 06-2 vintage index relative to the ABX 06-1 vintage index, indicating that it was only the riskiest assets that experienced a higher level of co-movement across the vintages examined.

Table 4 reports correlation coefficients between the five ABX tranches in each of the three indexes and the VAR variables over the entire sample period. We see that the S&P 500 is positively correlated with all five assets in the two traded ABX indexes but experiences much lower correlations with the spliced ABX index, in fact, the AAA rated asset in the spliced ABX index is slightly negatively correlated with the S&P 500 index. This is also true for the S&P 500 sub-index of financial firms, although all three A rated assets in the spliced ABX index experience negative correlations with the spliced ABX index. This suggests that differences exist between the spliced ABX index and those ABX assets actually traded by investors. As expected, the two Treasury Bills are positively correlated with all assets in the three ABX indexes, while the two corporate spreads experience negative correlation with all ABX assets. Also unsurprisingly, changes in the VIX volatility index are negatively correlated with all ABX returns in the two traded indexes, suggesting that increased volatility in financial markets corresponds to lower ABX returns. Correlation coefficients between the VIX and the spliced ABX index are relatively lower, and the AAA asset actually experiences positive correlation with

the VIX. This again suggests that the spliced ABX index is not equivalent to what was traded in the market.

Table 4. VAR variables correlation coefficients

Spliced ABX Index					
Rating	AAA	AA	A	BBB	BBB-
S&P 500	-0.04	0.01	0.02	0.11	0.06
S&P 500 Subindex	-0.07	-0.01	-0.03	0.05	0.03
1-Year T-bill	0.15	0.26	0.24	0.15	0.10
10-Year T-bill	0.31	0.32	0.30	0.19	0.18
VIX	0.05	-0.05	-0.07	-0.17	-0.13
Aaa Spread	-0.23	-0.16	-0.16	-0.08	-0.05
Baa Spread	-0.30	-0.22	-0.21	-0.12	-0.08
ABX 06-1 Index					
	AAA	AA	A	BBB	BBB-
S&P 500	0.36	0.37	0.25	0.24	0.25
S&P 500 Subindex	0.38	0.42	0.27	0.26	0.27
1-Year T-bill	0.12	0.18	0.19	0.25	0.27
10-Year T-bill	0.25	0.19	0.20	0.18	0.20
VIX	-0.22	-0.25	-0.22	-0.20	-0.21
Aaa Spread	-0.18	0.13	-0.12	-0.20	-0.21
Baa Spread	-0.17	-0.15	-0.12	-0.18	-0.20
ABX 06-2 Index					
	AAA	AA	A	BBB	BBB-
Baa Spread	0.42	0.24	0.21	0.16	0.17
S&P 500	0.44	0.27	0.21	0.16	0.17
S&P 500 Subindex	0.13	0.13	0.14	0.16	0.18
1-Year T-bill	0.21	0.17	0.17	0.14	0.14
10-Year T-bill	-0.27	-0.19	-0.15	-0.15	-0.17
VIX	-0.18	-0.10	-0.15	-0.15	-0.14
Aaa Spread	-0.17	-0.11	-0.14	-0.16	-0.16
Baa Spread					

5. Extending Longstaff (2010)

As data have been obtained for 2009 this year is included as a 'post-crisis' period. The VAR system is that employed by Longstaff (2010):

$$Y_t = \alpha + \sum_{k=1}^4 \beta_k Y_{t-k} + \gamma_k ABX_{t-k} + \varepsilon_t, \quad (3)$$

in which Y_t denotes the financial market measure, as described in Section 3, included as the dependent variable. Thus, there are seven dependent variables and the system is estimated separately for each one. ABX_{t-k} denotes the ABX index included as an exogenous variable. As there are five ratings classes, there are five ABX assets and so the VAR system is estimated for each of these. Four lags are suggested by the Akaike Information Criterion (AIC). Table 5 reports VAR estimation results for the spliced ABX index for 2009.

Table 5 suggests that there is little evidence of contagion in 2009. The two stock market measures are significantly affected by only the AA rated ABX asset, while there is almost no evidence of contagion from the ABX to the 1-year Treasury Bill yield. The two credit spreads are most significantly affected by ABX returns relative to the other financial market variables, which could be due to credit markets rebounding following the liquidity crunch.

Table 5. Spliced ABX Index 2009 VAR Estimation Results

Y	ABX	β_1	β_2	β_3	β_4	R ²	p
1-Year T-bill	AAA	-1.23	1.20	0.53	0.20	0.18	0.40
	AA	0.85	-1.04	1.39	-0.47	0.19	0.27
	A	0.04	0.28	1.35	-1.23	0.23	0.68
	BBB	-0.45	-0.80	1.34	0.63	0.17	0.19
	BBB-	-0.53	-1.04	1.54	0.43	0.19	0.09*
10-Year T-bill	AAA	0.89	0.23	-0.27	0.98	0.18	0.86
	AA	1.42	-1.62	-0.06	-1.07	0.20	0.06*
	A	1.82*	-1.01	0.49	-1.84*	0.26	0.18
	BBB	-0.18	-1.48	1.20	0.50 *	0.16	0.08
	BBB-	-0.33	-1.50	1.31	-0.17	0.19	0.00**
Aaa Spread	AAA	-1.11	-0.43	0.42	-0.72	0.28	0.67
	AA	-0.95	0.51	0.00	-2.08**	0.31	0.02**
	A	-1.01	0.15	-0.83	1.59	0.30	0.47
	BBB	0.82	-0.20	-1.82*	-0.29	0.27	0.00**
	BBB-	0.52	-0.03	-1.77*	0.08	0.26	0.03**
Baa Spread	AAA	-1.44	-0.23	-0.07	-1.37	0.17	0.58
	AA	-0.74	0.92	-0.71	2.75**	0.16	0.01**
	A	-0.52	0.33	-1.55	1.63	0.18	0.27
	BBB	0.60	-0.33	-1.53	-0.09	0.13	0.04**
	BBB-	0.46	-0.13	-1.48	0.22	0.13	0.05*
S&P 500 Subindex	AAA	0.43	-1.01	-0.51	-0.92	0.11	0.24
	AA	1.24	-2.81**	-1.46	-0.10	0.20	0.00**
	A	0.69	-0.74	0.37	-2.32**	0.17	0.14
	BBB	0.41	-0.95	-1.56	-0.55	0.12	0.24
	BBB-	0.16	-0.97	-0.21	-1.68*	0.12	0.13
S&P 500	AAA	0.67	-0.38	-0.55	-0.94	0.04	0.46
	AA	1.34	-3.29**	-0.17	-0.86	0.12	0.00**
	A	1.47	-0.15	0.44	-1.95*	0.12	0.23
	BBB	1.20	-0.82	-1.67*	-0.42	0.05	0.26
	BBB-	0.67	-0.40	-0.57	-1.25	0.04	0.15
VIX	AAA	-1.63	-0.28	0.61	2.15**	0.37	0.08*
	AA	-1.08	1.22	0.55	1.38	0.34	0.19
	A	-0.36	0.68	-1.03	0.93	0.33	0.37
	BBB	-2.53**	-0.39	0.93	0.75	0.35	0.05*
	BBB-	-2.36**	-0.37	0.30	1.26	0.34	0.05*

Note: In the above table *, **, *** denote significance at the 10%, 5% and 1% levels, respectively.

6. VAR Analysis on Traded ABX Indexes

In order to ascertain if splicing the ABX indexes may have had any influence upon the results obtained the VAR framework presented in Equation (3) is applied to two traded ABX indexes, the 06-1 ABX index and the 06-2 ABX index.⁴ Table 6 reports the VAR estimation results for the tranquil 'pre-crisis' period of 2006 for the first ABX index issued, ABX 06-1 index.

⁴ The ABX 07-1 and ABX 07-2 are not analyzed due to the fact that they were issued in January and July 2007, respectively, and so do not provide data for the 'pre-crisis' period of 2006 to analyze as a benchmark case.

Table 6. ABX 06-1 Index 2006 VAR Estimation Results

Y	ABX	β_1	β_2	β_3	β_4	R^2	p
1-Year T-bill	AAA	-1.56	0.78	0.33	0.63	0.08	0.38
	AA	0.40	0.98	-0.29	0.88	0.07	0.45
	A	-1.23	0.61	-1.54	-0.61	0.12	0.55
	BBB	-1.04	0.35	-0.71	-0.49	0.09	0.76
	BBB-	-0.72	1.40	-1.14	-0.23	0.09	0.43
10-Year T-bill	AAA	-0.21	0.78	1.17	1.86	0.10	0.22
	AA	2.22**	3.03**	0.72	0.99	0.16	0.01**
	A	-0.20	0.59	-1.13	-0.52	0.07	0.64
	BBB	-0.25	-0.08	-0.73	0.26	0.06	0.87
	BBB-	0.09	1.06	-1.23	0.41	0.08	0.69
Aaa Spread	AAA	-0.72	0.27	0.23	-1.47	0.36	0.44
	AA	-0.79	-0.46	1.48	-0.10	0.37	0.53
	A	0.45	0.93	3.19**	0.81	0.40	0.02**
	BBB	0.56	1.30	1.51	-0.34	0.39	0.27
	BBB-	0.93	0.61	2.26**	-0.05	0.41	0.05*
Baa Spread	AAA	-0.79	-0.39	-1.20	-2.47**	0.47	0.00**
	AA	-0.87	-1.23	0.99	-0.66	0.45	0.39
	A	-0.14	-0.54	1.43	0.27	0.43	0.42
	BBB	0.23	0.18	1.07	-0.90	0.43	0.62
	BBB-	0.33	-0.71	1.28	-1.23	0.43	0.43
S&P 500 Subindex	AAA	-0.15	2.26**	-1.63	-0.34	0.22	0.12**
	AA	-2.12**	-1.86*	-0.40	-0.63	0.25	0.00
	A	-2.39**	-2.41**	-1.18	-0.95	0.37	0.07*
	BBB	-2.78**	-1.61	-1.54	0.95	0.29	0.01**
	BBB-	-1.93*	-1.13	0.02	-0.17	0.23	0.11
S&P 500	AAA	-0.95	1.66*	-1.46	0.44	0.22	0.54
	AA	-1.51	-1.54	-0.73	0.08	0.22	0.16*
	A	-2.23**	-2.58**	-2.61**	-0.76	0.40	0.05
	BBB	-1.40	-1.36	-0.94	1.27	0.26	0.34
	BBB-	-1.54	-0.71	-0.03	0.37	0.20	0.41
VIX	AAA	1.64	-1.81*	-0.34	-0.58	0.16	0.07*
	AA	0.74	0.28	0.49	-0.16	0.10	0.96
	A	1.66*	1.52	0.87	1.30	0.25	0.31
	BBB	1.36	0.26	-0.79	-0.62	0.14	0.34
	BBB-	1.64	-0.15	-1.23	0.61	0.13	0.00**

Notes: In the above table *, **, *** denote significance at the 10%, 5% and 1% levels, respectively.

It is clear from Table 6 that there was little Granger-Causality from ABX returns to the financial market variables analysed. There is also little evidence of price discovery during this tranquil period, as few of the individual t-statistics are significant. This would suggest that during 2006 these assets behaved mostly independent of each other. Table 7 presents VAR estimation results for the 'subprime crisis' period of 2007 for the ABX 06-1 index.

Table 7 indicates strong evidence of financial contagion during 2007. Almost every asset in the ABX 06-1 index Granger-causes subsequent changes or returns in the financial market variables and the R^2 's are all quite high, particularly relative to those reported in Table 6 for 2006. Turning first to the two Treasury Bill yields, we see that all F-statistics are significant, compared to very little significance in 2006, and there is significant predictive ability of at least three weeks in all cases. All significant t-statistics are positive in sign, suggesting that a

decrease in ABX returns corresponds to a decrease in Treasury yields, thus indicating an increase in the value of Treasury bonds. This would suggest that investors were turning to these 'risk-free' securities during this turbulent crisis period, thus indicating a flight-to-quality to these 'safe haven' assets.

Table 7. ABX 06-2 Index 2006 VAR Estimation Results

Y	ABX	β_1	β_2	β_3	β_4	R ²	p
1-Year T-bill	AAA	2.00**	3.89**	3.07**	0.65	0.33	0.00**
	AA	3.27**	2.83**	2.25**	0.01	0.44	0.00**
	A	2.57**	1.72*	3.66**	-0.05	0.49	0.00**
	BBB	1.83*	1.18	3.59**	1.23	0.42	0.00**
	BBB-	1.74*	0.39	4.59**	2.06**	0.43	0.00**
10-Year T-bill	AAA	1.78**	4.53*	1.48	0.76	0.23	0.00**
	AA	0.47	4.32**	1.95*	2.16**	0.25	0.00**
	A	2.65**	1.73*	6.77**	1.18	0.34	0.00**
	BBB	3.34**	2.88**	5.91**	2.67*	0.4	0.00**
	BBB-	4.23**	1.82*	4.94**	4.11**	0.42	0.00**
Aaa Spread	AAA	-0.96	-2.06*	-0.81	-2.04**	0.19	0.02**
	AA	-0.77	-2.31**	-2.10**	-3.57**	0.24	0.00**
	A	-1.47	0.18	-3.71**	-1.85*	0.25	0.00**
	BBB	-1.86*	0.06	-2.00**	-2.98**	0.21	0.02**
	BBB-	-2.06**	0.3	-1.67*	-3.08**	0.22	0.01**
Baa Spread	AAA	-2.77**	-3.45**	-2.74**	-5.36**	0.4	0.00**
	AA	-3.18**	-6.76**	-2.72**	-6.89**	0.43	0.00**
	A	-2.62**	-0.37	-5.50**	-3.83**	0.48	0.00**
	BBB	-3.51**	-0.08	-5.04**	-6.71**	0.44	0.00**
	BBB-	-3.33**	0.12	-3.25**	-7.14**	0.44	0.00**
S&P 500 Subindex	AAA	1.6	-0.79	-0.86	1.82	0.37	0.02
	AA	2.27	-1.26	0.93	1.65	0.39	0.00
	A	3.04	-1.54	4.32	-0.04	0.48	0.00
	BBB	3.41	-1.1	3.08	1.17	0.44	0.00
	BBB-	3.21	-0.13	1.96	2.56	0.43	0.00
S&P 500	AAA	1.44	0.6	-0.52	1.32	0.25	0.54
	AA	1.92**	1.34	1.47	1.85*	0.27	0.00**
	A	3.38**	-0.14	4.64**	0.85	0.38	0.00**
	BBB	2.22**	-0.5	3.27**	3.16**	0.32	0.00**
	BBB-	2.76**	0.19	2.04**	3.70**	0.31	0.00**
VIX	AAA	-1.5	-0.79	0.23	-0.6	0.2	0.47
	AA	-1.97*	-2.33**	-2.33**	-1.29	0.25	0.01**
	A	-3.85**	-0.56	-4.55	-0.03	0.35	0.00**
	BBB	-2.47**	0.23	-2.79**	-0.62	0.3	0.05*
	BBB-	-2.08**	-1.25	-2.01**	-1.64	0.25	0.05*

Notes: In the above table *, **, *** denote significance at the 10%, 5% and 1% levels, respectively.

Turning now to the two credit spreads, Table 7 reports that all F-statistics are significant, which is in striking contrast to the results presented in Table 6 for 2006. In all cases ABX returns Granger-cause subsequent changes in both the Moodys' Aaa and Baa spreads by up to four weeks, and all significant t-statistics are negative in sign. This suggests that a decline in ABX returns corresponds to a widening of these corporate spreads during the 2007 crisis period. Table 7 reports that almost all ABX asset returns have significant predictive power for subsequent returns in both the S&P 500 Composite Index and the S&P 500 Sub-index of Financial Firms during the subprime crisis. Almost all ratings tranches of the ABX have

significant forecast ability of up to four weeks ahead during 2007, and all significant coefficients are positive in sign, indicating that a negative shock to ABX returns translates to negative returns in these stock indexes. The results for the VIX index suggest that almost all ABX assets Granger-cause subsequent changes in this index of the markets perception of volatility. The individual t-statistics indicate significant price discovery of up to three weeks during the subprime crisis, and all significant coefficients are negative in sign, suggesting that a shock to ABX returns translates to an increase in the VIX index. Table 8 provides VAR estimation results for the 2008 global crisis period for the ABX 06-2 index. It is clear that evidence of contagion has dissipated relative to the subprime crisis period of 2007.

Table 8. ABX 06-1 Index 2008 VAR Estimation Results

Y	ABX	β_1	β_2	β_3	β_4	R ²	p
1-Year T-bill	AAA	0.48	0.76	2.53**	2.28**	0.13	0.03**
	AA	-0.09	0.24	2.31**	2.10**	0.16	0.02**
	A	-0.05	-0.06	0.45	2.45**	0.13	0.06*
	BBB	0	0.94	0.53	0.02	0.09	0.73
	BBB-	0.03	-0.77	0.99	0.69	0.1	0.05*
10-Year T-bill	AAA	0.47	2.27**	1.21	1.26	0.27	0.00**
	AA	0.92	3.08**	0.65	1.47	0.32	0.00**
	A	0.81	1.78*	-0.89	2.00**	0.22	0.22
	BBB	1.34	1.78*	-1.77*	0.64	0.28	0.19
	BBB-	0.89	1.63	-1.13	0.97	0.23	0.26
Aaa Spread	AAA	-0.05	-2.94**	0.86	0.57	0.4	0.00**
	AA	-0.76	-2.14**	2.89**	0.64	0.43	0.05*
	A	-0.35	-1.03	2.81**	0.11	0.38	0.07*
	BBB	-0.64	-1.27	1.87*	0.25	0.4	0.4
	BBB-	-0.11	-0.92	1.45	0.02	0.37	0.6
Baa Spread	AAA	-0.45	-4.66**	1.39	1	0.3	0.00**
	AA	-0.8	-1.98*	3.33**	1.02	0.33	0.01**
	A	-0.09	-1.02	3.04**	0.32	0.28	0.02**
	BBB	-0.4	-1.24	1.71*	0.41	0.26	0.33
	BBB-	0.6	-1.26	1.41	0.48	0.24	0.5
S&P 500 Subindex	AAA	-2.42**	0.03	-1.27	-1.73*	0.21	0.05*
	AA	-1.24	0.17	-1.48	-1.06	0.15	0.15
	A	-0.16	-0.46	-1.5	0.45	0.1	0.44
	BBB	1.22	-0.86	-1.56	0.28	0.12	0.27
	BBB-	1.16	-1.52	-1.28	-0.06	0.13	0.15
S&P 500	AAA	-3.80**	0.75	0.06	-2.13*	0.32	0.00**
	AA	-2.02**	0.8	-0.25	-1.21	0.24	0.14
	A	-1.02	-0.04	-1.09	0.28	0.13	0.65
	BBB	-0.23	0.25	-1.62	0.48	0.12	0.53
	BBB-	-0.64	-0.38	-0.93	-0.1	0.12	0.75
VIX	AAA	1.86*	-0.87	0.85	1.1	0.12	0.00**
	AA	1.63	0.09	1.14	-0.24	0.13	0.1
	A	1.35	-0.51	0.94	-0.8	0.1	0.61
	BBB	-0.57	-0.06	1.24	-0.86	0.08	0.61
	BBB-	-0.12	0.63	0.55	-0.19	0.06	0.85

Notes: In the above table *, **, *** denote significance at the 10%, 5% and 1% levels, respectively.

Table 8 indicates that, during the global crisis period, the only ABX asset that consistently Granger-causes each financial variable analyzed is the AAA rated tranche, while the two lower rated assets show no significant forecast power at all. One possible reason for

this could be that, during this period liquidity in financial markets had come to almost a complete halt, as had trades in the now perceived to be 'toxic' ABX index. It is probable then that the only ABX asset with any liquidity during this time would be the highest rated tranche, and so that is why we observe most contagion effects emanating from the AAA asset. Table 9 reports VAR estimation results for the 2009 post-crisis period for the ABX 06-1 index.

Table 9. ABX 06-1 Index 2009 VAR Estimation Results

Y	ABX	β_1	β_2	β_3	β_4	R ²	p
1-Year T-bill	AAA	1.48	0.13	-0.44	0.25	0.16	0.31
	AA	0.8	-1.4	0.27	0.79	0.19	0.49
	A	1.11	-2.25**	-0.43	0.19	0.21	0.03**
	BBB	1.92*	0.65	-0.44	-0.91	0.2	0.28
	BBB-	0.91	-0.44	-0.47	-0.86	0.17	0.7
10-Year T-bill	AAA	-1.72*	1.04	1.71*	0.92	0.26	0.03**
	AA	-1.58	1.13	1.92*	-0.39	0.32	0.01**
	A	-1.01	0.61	0.85	-0.74	0.18	0.12
	BBB	1.26	0.07	-0.25	-1.44	0.17	0.5
	BBB-	1.95*	0.13	-1.23	2.62**	0.19	0.06*
Aaa Spread	AAA	-0.86	-2.56**	-1.61	-1.63	0.36	0.00**
	AA	-0.21	-2.07**	-1.94*	0.23	0.35	0.02**
	A	0.14	-2.71**	-0.29	1.76*	0.29	0.01**
	BBB	-1.90*	-2.10**	0.88	3.32**	0.33	0.01**
	BBB-	-3.07**	-1.78*	2.68**	5.22**	0.36	0.00**
Baa Spread	AAA	0.35	-2.05**	-1.56	-1.19	0.22	0.00**
	AA	0.4	-1.97*	-1.90*	0.17	0.22	0.00**
	A	0.2	-2.98**	-0.31	1.66*	0.17	0.00**
	BBB	-1.94*	-3.20**	1.08	2.81**	0.22	0.01**
	BBB-	-2.72**	-1.74*	2.02**	2.57**	0.21	0.00**
S&P 500 Subindex	AAA	-0.76	0.04	0.39	-1.75*	0.13	0.02**
	AA	-2.80**	0.44	0.22	-0.74	0.14	0.05*
	A	-2.31**	-0.4	0.23	0.28	0.19	0.02**
	BBB	-2.33**	-1.75*	0.49	0.06	0.19	0.02**
	BBB-	-1.24	0.98	0.33	-1.05	0.15	0.49
S&P 500	AAA	-0.27	0.96	0.26	-0.89	0.04	0.12
	AA	-2.66**	1.37	0.37	0.5	0.09	0.01**
	A	-2.88**	-0.39	0.88	1.11	0.12	0.00**
	BBB	-1.22	-1.38	-0.15	0.27	0.05	0.19
	BBB-	0.01	0.91	-0.15	-0.53	0.02	0.84
VIX	AAA	-0.42	-0.09	-0.48	0.76	0.3	0.82
	AA	0.22	-0.36	-0.08	0.48	0.3	0.96
	A	1.62	1.46	1.18	-0.65	0.41	0.00**
	BBB	-2.16**	1.35	1.65*	1.58	0.37	0.08*
	BBB-	-1.6	0.37	0.9	1.14	0.32	0.35

Notes: In the above table *, **, *** denote significance at the 10%, 5% and 1% levels, respectively.

Comparing Table 9 to Table 8, we see that there is more evidence of contagion during this 'postcrisis' period than during the 'global-crisis' period, which could be due to financial markets rebounding as investors began re-entering the market following the crisis years. The two corporate spreads show most evidence of contagion, which could be due to remaining instability in credit markets following the crisis. There is little evidence of contagion to the two Treasury Bill yields, consistent with investors no longer requiring a 'safe haven' in this post crisis era.

Comparing Table 9 to Table 5, we see slightly more evidence of contagion during 2009 in the traded ABX 06-1 index than in the spliced ABX index. It is also noteworthy that the source of contagion varies among the two indexes, specifically we see the lowest tranche of the spliced ABX index having more of a significant effect on the financial variables than that corresponding tranche in the ABX 06-1 index. This could be due to the fact that the two later issued vintages, the ABX 07-1 and ABX 07-2 indexes, are included in the spliced ABX index and so may the assets in this spliced index may have a different effect upon the financial market variables.

Turning now to the ABX 06-2 index, issued on July 19, 2006, Table 10 reports VAR estimation results for the 'pre-crisis' period of 2006.

Table 10. ABX 06-2 Index 2006 VAR Estimation Results

Y	ABX	β_1	β_2	β_3	β_4	R ²	p
1-Year T-bill	AAA	0.53	-0.23	0.6	-2.07**	0.32	0.03**
	AA	-0.05	-2.09**	-0.35	-2.00**	0.39	0.00**
	A	0.69	1.79*	-1.32	-1.58	0.43	0.13
	BBB	0.8	1.47	-0.33	-1.53	0.31	0.5
	BBB-	1.54	1.74*	-0.36	-2.37**	0.39	0.12
10-Year T-bill	AAA	0.19	-1.81*	-1.67*	-1.05	0.32	0.03**
	AA	-0.59	-4.79**	-1.19	-1.22	0.44	0.00**
	A	-0.46	0.9	-3.84**	-1.15	0.5	0.00**
	BBB	0.55	0.37	-3.46**	-1.52	0.53	0.00**
	BBB-	0.97	0.73	-2.84**	2.94**	0.6	0.00**
Aaa Spread	AAA	0.31	1.42	1.55	0.82	0.55	0.35
	AA	0.76	1.16	0.12	0.51	0.51	0.66
	A	2.77**	0.57	2.97**	0.04	0.66	0.00**
	BBB	3.84**	3.01*	2.93**	-0.05	0.7	0.00**
	BBB-	2.56**	0.94	2.61**	0.42	0.72	0.00**
Baa Spread	AAA	-0.66	1.02	1.01	0.1	0.63	0.59
	AA	0.78	0.96	0.3	0.1	0.61	0.89
	A	3.24**	-0.23	2.21**	-0.18	0.72	0.00**
	BBB	4.60**	3.01**	2.29**	-0.49	0.76	0.00**
	BBB-	2.25**	-0.02	2.26**	-0.28	0.72	0.00**
S&P 500 Subindex	AAA	-3.19**	-1.67*	-1.04	-0.74	0.38	0.00**
	AA	-1.34	-0.66	-0.35	2.65**	0.44	0.00**
	A	0.16	-4.00**	-1.25	1.02	0.46	0.00**
	BBB	0.11	-1.77	-0.87	1.08	0.25	0.03**
	BBB-	0.16	-1.31	0.08	-0.55	0.25	0.00**
S&P 500	AAA	-1.92*	-0.62	-1.76*	-2.64**	0.62	0.00**
	AA	-0.73	-1.14	1.68*	-0.32	0.53	0.01**
	A	1.78*	-2.04**	1.88	1.16	0.59	0.01**
	BBB	2.08**	-0.7	2.54**	1.39	0.54	0.00**
	BBB-	3.02**	-1.04	2.52**	0.02	0.58	0.00**
VIX	AAA	1.12	-2.99**	0.35	0.93	0.74	0.01**
	AA	-1.21	-1.67*	-2.54**	0.09	0.63	0.01**
	A	-1.29	-0.82	-1.83*	-3.10**	0.69	0.00**
	BBB	-0.15	-1.99*	-3.63**	-0.76	0.72	0.00**
	BBB-	-0.45	-0.32	-2.30**	-0.14	0.71	0.00**

Notes: In the above table *, **, *** denote significance at the 10%, 5% and 1% levels, respectively.

Comparing Table 10 to Table 6, it is clear that there is much more evidence of contagion during this pre-crisis period in the 06-2 index than the earlier issuance. One possible reason for this could be that the ABX 06-1 index included deals issued in the second half of

2005, and so would have benefited from the tail-end of the real estate boom. Those deal included in the ABX 06-2 index would have been originated in the first half of 2006, and may have been of poorer quality than those comprising the first vintage. The R^2 's reported in Table 10 are quite high, particularly when compared to those in Table 6. Overall, the results in Table 10 are in striking contrast to those presented for 2006 for both ABX 06-1 and the spliced ABX index, again highlighting the differences between the indexes.

Table 11 provides VAR estimation results for the 2007 subprime crisis period.

Table 11. ABX 06-2 Index 2007 VAR Estimation Results

Y	ABX	β_1	β_2	β_3	β_4	R^2	p
1-Year T-bill	AAA	2.91**	2.58**	3.32**	0.6	0.43	0.00**
	AA	3.18**	1.38	4.88**	-0.85	0.51	0.00**
	A	0.27	0.26	7.35**	0.03	0.53	0.00**
	BBB	-0.09	-0.55	4.32**	1.66*	0.46	0.00**
	BBB-	0.43	-0.8	3.10**	2.79**	0.49	0.00**
10-Year T-bill	AAA	1.05	4.74*	1.14	1.55	0.28	0.00**
	AA	2.43**	1.59	4.42**	1.39	0.32	0.00**
	A	0.86	0.42	5.59**	1.48	0.35	0.00**
	BBB	1.16	0.44	5.68**	1.82*	0.43	0.00**
	BBB-	2.21**	0.68	4.04**	2.43**	0.44	0.00**
Aaa Spread	AAA	-0.57	-1.93*	-1.16	-2.21**	0.22	0.19
	AA	-1.35	-0.22	-3.23**	-1.42	0.21	0.00**
	A	-0.14	-0.01	-3.15**	-1.3	0.22	0.00**
	BBB	-0.28	0.65	-4.40**	-0.85	0.23	0.00**
	BBB-	-0.96	0.93	-2.59**	-1.51	0.25	0.01**
Baa Spread	AAA	-2.52**	-2.51**	-2.36**	-5.00**	0.43	0.00**
	AA	-2.24**	0.16	-4.29**	-3.81**	0.44	0.00**
	A	-0.63	1.07	-4.97**	-3.20**	0.43	0.00**
	BBB	-0.07	1.04	-5.41**	-2.48**	0.43	0.00**
	BBB-	-1.29	1.04	-2.91**	-2.78**	0.41	0.00**
S&P 500 Subindex	AAA	2.45**	-1.52	0.92	1.28	0.42	0.00**
	AA	4.46**	-2.31**	3.30**	0.79	0.48	0.00**
	A	2.69**	-0.21	3.20**	0.82	0.47	0.00**
	BBB	1.67*	0.48	3.38**	1.83*	0.5	0.00**
	BBB-	1.36	1.05	2.23**	1.17	0.47	0.00**
S&P 500	AAA	2.10**	0.53	1.38	1.27	0.27	0.05*
	AA	3.55**	-0.34	3.75**	1.16	0.33	0.00**
	A	0.91	0.29	3.75**	1.43	0.36	0.00**
	BBB	0.98	0.95	2.73**	1.28	0.38	0.00**
	BBB-	1.28	1.55	1.79*	1.22	0.37	0.00**
VIX	AAA	-1.74*	-1.39	-0.87	-0.76	0.23	0.11
	AA	2.95**	-0.51	-2.86**	-0.41	0.29	0.00**
	A	-2.67**	-0.83	-3.59*	-1.27	0.38	0.00**
	BBB	-1.41	-1.93*	-1.62	0.57	0.37	0.00**
	BBB-	-2.27**	-2.17**	-0.53	-0.11	0.38	0.00**

Notes: In the above table *, **, *** denote significance at the 10%, 5% and 1% levels, respectively.

Here Table 11 provides evidence that almost all ABX assets Granger-cause returns or subsequent changes in the financial variables analyzed, along with significant predictive ability of up to four weeks in the case of the corporate spreads and the one-year Treasury yield. Under the VAR framework, the significance reported in Table 11 indicates contagion in financial markets during the subprime crisis period. However, it should be noted that a high degree of

significance was observed for the 2006 period also, and so we cannot state that there was a significant change in the relationships between the variables, as our definition of contagion requires.

Table 12 reports results for VAR estimation results for the 2008 global crisis period for the ABX 06-2 index.

Table 12. ABX 06-2 Index 2008 VAR Estimation Results

Y	ABX	β_1	β_2	β_3	β_4	R ²	p
1-Year T-bill	AAA	-0.65	0.25	2.79**	2.70**	0.2	0.01**
	AA	-0.43	0.12	0.8	2.10**	0.15	0.12
	A	-0.24	-0.99	1.51	1	0.15	0.04**
	BBB	-0.58	0.02	0.33	-0.82	0.09	0.79
	BBB-	-0.77	-0.34	0.39	-0.46	0.09	0.79
10-Year T-bill	AAA	0.27	2.37*	1.27	1.11	0.27	0.00**
	AA	0.39	1.85	-1.12	2.30**	0.23	0.14
	A	1.08	1.52	-0.35	0.58	0.19	0.19
	BBB	0.8	1.36	-0.94	0.86	0.16	0.58
	BBB-	0.5	0.95	-0.73	0.81	0.14	0.82
Aaa Spread	AAA	-0.22	-2.36**	0.76	0.43	0.4	0.04**
	AA	-0.02	-1.25	2.58**	-0.28	0.38	0.12
	A	-0.57	-0.49	0.94	0.27	0.35	0.71
	BBB	-0.32	-0.42	1.57	0.1	0.35	0.61
	BBB-	0.05	0.07	1.69*	0.31	0.36	0.44
Baa Spread	AAA	-0.41	-2.52**	1.45	0.84	0.3	0.00**
	AA	0.1	-1.28	2.78**	0.21	0.28	0.04**
	A	-0.13	-0.43	1.06	0.91	0.25	0.72
	BBB	0.11	0.13	1.61	0.66	0.25	0.61
	BBB-	0.62	0.65	1.77*	0.84	0.27	0.28
S&P 500 Subindex	AAA	-1.47	-0.27	-0.19	-1.03	0.14	0.65
	AA	-0.41	-0.33	-1.63	0.79	0.1	0.54
	A	0.47	-1.37	-1.33	0.3	0.14	0.34
	BBB	-0.26	-0.25	-0.75	-0.24	0.08	0.92
	BBB-	-0.54	-0.29	-0.75	-0.73	0.1	0.75
S&P 500	AAA	-2.41*	0.14	0.91	-1.44	0.28	0.16
	AA	-1.31	0.47	-1.45	0.57	0.15	0.38
	A	-0.89	-1.1	-0.66	0	0.17	0.76
	BBB	-0.95	0.37	-1.59	-0.15	0.16	0.21
	BBB-	-1.42	0.19	-1.48	-0.83	0.21	0.24
VIX	AAA	1.93*	0.25	-0.18	-0.56	0.13	0.05*
	AA	1.5	-0.44	1.04	-1.27	0.12	0.53
	A	0.94	0.79	-0.01	-0.51	0.09	0.69
	BBB	0.08	-0.33	1.46	-0.08	0.1	0.51
	BBB-	0.78	-0.13	1.33	0.48	0.12	0.34

Notes: In the above table *, **, *** denote significance at the 10%, 5% and 1% levels, respectively.

Again, evidence of contagion dissipates during the 2008 'global crisis' period. However, we observe less significance Table 12 than in Table 8 meaning that there is even less evidence of contagion during 2008 in the later issued ABX 06-2 index than the ABX 06-1 index. In fact, no ABX asset Granger-causes changes in the two stock market measures and any significance observed emanates from the higher rated assets. As explained above, this could again be due to the liquidity crunch leading to a halt in trades of the ABX and Table 12 suggests that the ABX

06-2 index had less predictive power during this time than the ABX 06-1 index, perhaps because this later issuance was hit harder by the crisis than the first vintage. Finally, Table 13 provides results for the 2009 'post-crisis' period for the ABX 06-2 index.

Table 13. ABX 06-2 Index 2009 VAR Estimation Results

Y	ABX	β_1	β_2	β_3	β_4	R ²	p
1-Year T-bill	AAA	4.46**	-0.41	-0.69	0.52	0.24	0.00**
	AA	1.44	-7.16**	2.23**	1.27	0.35	0.00**
	A	-0.45	0.34	-0.12	0.33	0.15	0.98
	BBB	-1.33	-2.23**	3.92**	-2.28**	0.39	0.00**
	BBB-	-1.93*	-1.13	3.81**	-2.65**	0.38	0.00**
10-Year T-bill	AAA	0.13	0.3	1.43	0.18	0.21	0.48
	AA	-0.04	-0.9	2.30**	-1.70*	0.25	0.09*
	A	0.05	0.14	0.01	-0.43	0.14	0.97
	BBB	-0.69	0.54	2.78**	-3.27**	0.29	0.01**
	BBB-	-0.81	0.48	1.90**	-2.31**	0.24	0.1
Aaa Spread	AAA	-2.10**	-1.76*	-1.84*	-0.47	0.37	0.05*
	AA	-0.41	0.05	-2.49**	3.56**	0.34	0.00**
	A	-0.19	-1.78	0.84	1.34	0.29	0.04**
	BBB	1.31	-2.57**	-2.07**	4.33**	0.39	0.00**
	BBB-	1.55	-2.97**	-1.02	2.72**	0.34	0.02**
Baa Spread	AAA	-0.82	-1.44	-2.00**	-0.05	0.22	0.16
	AA	-0.43	0.1	-2.13**	3.41**	0.22	0.00**
	A	-0.61	-1.08	0.77	1.75*	0.17	0.07*
	BBB	0.79	-1.80*	-1.89*	4.64**	0.25	0.00**
	BBB-	0.65	-1.63	-0.69	2.55**	0.18	0.09*
S&P 500 Subindex	AAA	-0.9	-1.02	0.61	-1.41	0.12	0.3
	AA	-1.62	0.37	0.4	-1.80*	0.19	0.01**
	A	-1.26	-1.07	1.39	0.22	0.2	0.12
	BBB	-0.75	-1.13	0.62	-1.05	0.12	0.14
	BBB-	-0.35	-0.37	-0.18	-1.48	0.11	0.11
S&P 500	AAA	-0.67	-0.63	0.76	-0.68	0.04	0.51
	AA	-1.27	0.28	0.99	-1.74*	0.09	0.00**
	A	-1.05	-0.54	2.09**	-0.76	0.08	0.07*
	BBB	0.15	-1.08	1.94*	-2.13**	0.11	0.1
	BBB-	0.46	0.43	0.65	-2.28**	0.08	0.06*
VIX	AAA	-0.57	1.68*	-0.55	0.11	0.32	0.33
	AA	1.45	0.62	-0.04	-0.12	0.33	0.32
	A	1.88*	0.29	-1.53	1.2	0.34	0.00**
	BBB	1.76*	0.01	-2.39**	2.17**	0.4	0.01**
	BBB-	1.02	-0.64	-1.21	2.46**	0.39	0.07*

Notes: In the above table *, **, *** denote significance at the 10%, 5% and 1% levels, respectively.

Table 13 suggests that there was more evidence of contagion in 2009 relative to 2008. Again, this could be due to the markets rebounding following the crisis years. Overall, these results suggest that the two traded ABX indexes were subject to contagion during the crisis of 2007- 2009. Significant price discovery indicates that this contagion was not transmitted through the 'correlated information' channel of contagion as in this channel price changes should be instantaneous and supports the 'risk-premium' channel of contagion. Evidence of contagion dissipates during the 2008 'global crisis' period as liquidity came to a halt, then increases somewhat during the 2009 'post-crisis' period, most likely because of markets rebounding following the crisis.

The results highlight some striking differences between the indexes analyzed. The two traded indexes behave differently, particularly in the tranquil 2006 period, which indicates that these indexes were heterogeneous in nature and thus subject to differing risk profiles. There are also differences between the traded indexes and the spliced ABX index, suggesting that analysis of the spliced ABX index alone may not provide a full picture of what was happening in this market.

7. Testing the Sensitivity of Longstaff (2010)

In order to test the sensitivity of the results presented in Longstaff (2010) and those presented in Section 6 ABX returns are included as an eighth endogenous variable in the VAR system presented in Equation (3) in order to further analyze the relationship between ABX returns and the financial market variables. The p-values of the F-test that $\beta_1 = \beta_2 = \beta_3 = \beta_4 = 0$ are analyzed, that is, a test of whether the financial market variables Granger-cause ABX returns during the sample period. This allows the analysis of how these variables affected the ABX index during the crisis. Table 14 presents the results obtained for the spliced ABX index for each of the four years under consideration, 2006, 2007, 2008 and 2009.

Table 14. Spliced ABX Index VAR Estimation Results
Endogenous Variable: ABX Returns

2006					
Dependent Regressor	AAA	AA	A	BBB	BBB-
1-Year T-bill	0.74	0.04**	0.01**	0.12	0.05*
10-Year T-bill	0.31	0.02**	0.01**	0.05*	0.31
Aaa Spread	0.25	0.44	0.14	0.35	0.77
Baa Spread	0.39	0.27	0.12	0.45	0.81
S&P 500 Subindex	0.00**	0.11	0.71	0.68	0.69
S&P 500	0.00**	0.02**	0.15	0.32	0.39
VIX	0.00**	0.04**	0.14	0.43	0.31
2007					
Dependent Regressor	AAA	AA	A	BBB	BBB-
1-Year T-bill	0.13	0.00**	0.00**	0.00**	0.00**
10-Year T-bill	0.42	0.00**	0.00**	0.00**	0.00**
Aaa Spread	0.77	0.43	0.19	0.07*	0.24
Baa Spread	0.61	0.15	0.13	0.03**	0.09*
S&P 500 Subindex	0.14	0.03**	0.07*	0.01**	0.00**
S&P 500	0.21	0.02**	0.06*	0.04**	0.03**
VIX	0.23	0.23	0.14	0.04**	0.02**
2008					
Dependent Regressor	AAA	AA	A	BBB	BBB-
1-Year T-bill	0.74	0.03**	0.00**	0.00**	0.07*
10-Year T-bill	0.7	0.22	0.00**	0.13	0.04**
Aaa Spread	0.11	0.63	0.2	0.00**	0.00**
Baa Spread	0.06*	0.77	0.04**	0.03**	0.05*
S&P 500 Subindex	0.00**	0.2	0.00**	0.22	0.19
S&P 500	0.00**	0.00**	0.00**	0.00**	0.00**
VIX	0.00**	0.00**	0.00**	0.00**	0.02**
2009					
Dependent Regressor	AAA	AA	A	BBB	BBB-
1-Year T-bill	0.00**	0.01**	0.00**	0.27	0.54
10-Year T-bill	0.22	0.04**	0.00**	0.53	0.06*
Aaa Spread	0.1	0.07*	0.22	0.34	0.04**
Baa Spread	0.73	0.1	0.17	0.38	0.07*
S&P 500 Subindex	0.21	0.00**	0.00**	0.19	0.21
S&P 500	0.01**	0.1	0.00**	0.18	0.17
VIX	0.01**	0.88	0.42	0.41	0.3

Notes: In the above table *, **, *** denote significance at the 10%, 5% and 1% levels, respectively.

Turning first to 2006, Table 14 suggests that it is mainly the higher rated tranches that are significantly affected by the financial market variables. The two lower ratings experience relatively little Granger-causality from the financial variables, emanating only from the two Treasury Bill yields. This could be due to the fact that these lower tranches would have been the least liquid in the CDO structure and would also comprise a relatively tiny portion of it. The two corporate spreads have no significant effect on any tranches in the spliced ABX during 2006, unsurprising for a tranquil 'pre-crisis' period.

Comparing this to 2007, we see that the lower rated assets now experience most Granger-causality from the financial market variables, while the highest rated asset is not significantly affected at all. This could be because the markets perception of the BBB and BBB-rated assets during the subprime crisis was that they were equivalent to 'junk' and so would have been most sensitive to contagious effects from volatility, equity, Treasury and fixed income markets.

The results for the global credit crisis period of 2008 are similar to that for 2007, except that the AAA rated asset experience more significant effects from the financial market variables. This could be due to that fact that investors in this market had realized by 2008 that the AAA rated assets in the ABX indexes were not equivalent to other AAA rated assets in financial markets, such as AA rated corporate bonds.

During the post-crisis period of 2009, the spliced ABX index was significantly affected by the financial market variables; however, the lower rated assets do not experience as much Granger-causality as in 2007 and 2008. This could be due to the unpopularity of these products with investors re-entering the market following the subprime and global credit crisis causing these tranches to become almost illiquid.

Table 15 provides VAR estimation for the ABX 06-1 index for each of the four years under consideration.

During 2006 the two lower rated tranches experience very little Granger-causality from the financial market variables, a similar story to that of the spliced ABX index. Again, this could be due to the relative illiquidity of these tranches in the CDO. The higher rated assets, which would comprise a larger proportion of the CDO, exhibit most evidence of significant effects from the financial variables during this pre-crisis period. The one-year Treasury Bill has no significant forecasting power during 2006, which is in striking contrast to the results presented for 2007, when it Granger-causes returns in every ABX asset in the ABX 06-1 index. This relationship did not exist in 2006 and could be indicative of investors flight-to-quality once the crisis hit. The lower ratings again experience more contagious effects during the subprime crisis, however the two corporate spreads have no significant effect at all during this time. Evidence of contagion then dissipates during 2008, much more in this traded index than in the spliced ABX index, before increasing somewhat during the post-crisis year. These results again highlight differences between the spliced ABX index and the traded ABX 06-1 index as we observe differing relationships between the assets in both indexes and the financial market variables included.

Table 15. ABX 06-1 Index VAR Estimation Results
Endogenous Variable: ABX Returns

2006					
Dependent Regressor	AAA	AA	A	BBB	BBB-
1-Year T-bill	0.11	0.33	0.1	0.91	0.17
10-Year T-bill	0.01**	0.08*	0.08*	0.7	0.71
Aaa Spread	0.12	0.18	0.4	0.35	0.93
Baa Spread	0.03**	0.00**	0.72	0.44	0.92
S&P 500 Subindex	0.01**	0.09*	0.22	0.61	0.03**
S&P 500	0.00**	0.04**	0.00**	0.46	0.18
VIX	0.08*	0.00**	0.02**	0.41	0.02**
2007					
Dependent Regressor	AAA	AA	A	BBB	BBB-
1-Year T-bill	0.00**	0.00**	0.00**	0.00**	0.00**
10-Year T-bill	0.11	0.00**	0.07*	0.04**	0.14
Aaa Spread	0.37	0.32	0.63	0.41	0.32
Baa Spread	0.6	0.42	0.25	0.16	0.13
S&P 500 Subindex	0.02**	0.06*	0.00**	0.00**	0.00**
S&P 500	0.08*	0.16	0.00**	0.00**	0.02**
VIX	0.34	0.24	0.07*	0.07*	0.1
2008					
Dependent Regressor	AAA	AA	A	BBB	BBB-
1-Year T-bill	0.85	0.26	0.05*	0.08*	0.04**
10-Year T-bill	0.04**	0.00**	0.04**	0.32	0.31
Aaa Spread	0.69	0.88	0.99	0.37	0.26
Baa Spread	0.05*	0.52	0.99	0.08*	0.07*
S&P 500 Subindex	0.15	0.02**	0.86	0.49	0.66
S&P 500	0.18	0.67	0.62	0.16	0.19
VIX	0.07*	0.53	0.24	0.12	0.1
2009					
Dependent Regressor	AAA	AA	A	BBB	BBB-
1-Year T-bill	0.00**	0.06*	0.05*	0.02**	0.07*
10-Year T-bill	0.11	0.52	0.17	0.82	0.98
Aaa Spread	0.45	0.07	0.2	0.87	0.5
Baa Spread	0.06*	0.03**	0.16	0.96	0.48
S&P 500 Subindex	0.29	0.54	0.01**	0.00**	0.01**
S&P 500	0.49	0.3	0.00**	0.00**	0.05*
VIX	0.3	0.8	0.29	0.01**	0.73

Notes: In the above table *, **, *** denote significance at the 10%, 5% and 1% levels, respectively.

Table 16 reports VAR estimation results for the ABX 06-2 index for each of the four years analyzed.

Table 16. ABX 06-2 Index VAR Estimation Results
Endogenous Variable: ABX Returns

2006					
Dependent Regressor	AAA	AA	A	BBB	BBB-
1-Year T-bill	0.00**	0.00**	0.00**	0.01**	0.00**
10-Year T-bill	0.1	0.00**	0.00**	0.03**	0.04**
Aaa Spread	0.01**	0.01**	0.00**	0.00**	0.32
Baa Spread	0.23	0.01**	0.00**	0.00**	0.03**
S&P 500 Subindex	0.00**	0.00**	0.02**	0.61	0.00**
S&P 500	0.00**	0.06*	0.00**	0.01**	0.00**
VIX	0.00**	0.00**	0.00**	0.03**	0.03**
2007					
Dependent Regressor	AAA	AA	A	BBB	BBB-
1-Year T-bill	0.00**	0.00**	0.03**	0.00**	0.00**
10-Year T-bill	0.00**	0.01**	0.01**	0.00**	0.00**
Aaa Spread	0.42	0.55	0.31	0.06*	0.15
Baa Spread	0.28	0.29	0.2	0.01**	0.02**
S&P 500 Subindex	0.01**	0.00**	0.82	0.07*	0.01**
S&P 500	0.01**	0.00**	0.43	0.02**	0.01**
VIX	0.31	0.19	0.41	0.00**	0.00**
2008					
Dependent Regressor	AAA	AA	A	BBB	BBB-
1-Year T-bill	0.67	0.02**	0.03**	0.06*	0.04**
10-Year T-bill	0.00**	0.00**	0.1	0.19	0.16
Aaa Spread	0.92	0.98	0.09*	0.32	0.46
Baa Spread	0.5	0.97	0.07*	0.46	0.49
S&P 500 Subindex	0.05*	0.96	0.5	0.32	0.49
S&P 500	0.42	0.82	0.03**	0.5	0.49
VIX	0.06*	0.21	0.02**	0.28	0.15
2009					
Dependent Regressor	AAA	AA	A	BBB	BBB-
1-Year T-bill	0.01**	0.00**	0.00**	0.14	0.18
10-Year T-bill	0.00**	0.03**	0.09*	0.04**	0.09*
Aaa Spread	0.25	0.09*	0.12	0.15	0.02**
Baa Spread	0.02**	0.15	0.11	0.13	0.04**
S&P 500 Subindex	0.41	0.04**	0.02**	0.00**	0.00**
S&P 500	0.63	0.01**	0.01**	0.00**	0.00**
VIX	0.62	0.79	0.02**	0.01**	0.01**

Notes: In the above table *, **, *** denote significance at the 10%, 5% and 1% levels, respectively.

Turning first to the results presented for 2006, we see that the financial market variables Granger-cause returns in almost every asset in the ABX 06-2 index. This is striking contrast to the results presented in Table 17 and Table 18, again supporting the idea that these three indexes were not homogeneous assets. During 2007, significance actually declines, as again it is the lower rated that are most significantly affected by the Treasury, fixed income, equity and volatility measures. This significance dissipates during the global credit crisis in 2008 as these assets are affected only by the one-year Treasury Bill yield changes. Again, this could be due to the liquidity freeze. We see increased significance in the post-crisis period, gain probably due to rebounding markets. Overall, these results illustrate that the ABX indexes were also significantly affected by the financial market variables included in the analysis, but the degree to which they

are affected differs among the indexes. The ABX 06-2 index appears to have been sensitive to movements in the financial variables in the pre-crisis period, which is in striking contrast to the relationship between these same variables and the assets comprising the ABX 06-1 index.

8. Principal Component Analysis

In order to reduce the dimensionality of the noisy ABX returns principal component analysis (PCA) is performed on the five assets comprising each index under analysis separately for each of the four years, 2006, 2007, 2008, and 2009.

8.1. Spliced ABX Indexes

Figure 4 plots the time series of the principal components obtained for each of the four years under analysis for the spliced ABX index.

Figure 4. Spliced ABX Index Principal Components

It is clear that all five principal components experienced little movement during the 2006 pre-crisis period, before becoming very volatile during 2007 and 2008. In the 2009 post-crisis period, the absolute values of the principal components decrease but do not revert to the pre-crisis levels. In order to examine the principal components obtained in more detail, Figure 5 presents their relative importance in each of the four years under consideration for the spliced ABX index.

Figure 5 illustrates that, on average, the main principal component fell by almost 40% between 2006 and 2009. This indicates that the importance of the factors driving the variation in the spliced ABX index data changed over the sample period and commonality fell with each subsequent year.

Figure 5. Relative Importance of Spliced ABX Index Principal Components

8.2. Traded ABX Indexes

Principal component analysis is then applied to the two traded indexes under analysis, the ABX 06-1 index and the ABX 06-2 index. Figure 6 plots the time series of the principal components obtained for each of the four time periods for the ABX 06-1 index.

Figure 6. ABX 06-2 Index Principal Components

Figure 6. Continued

Figure 6 illustrates that the five principal components experienced very little movement in 2006, and in fact did not begin to experience volatility until mid-2007, with the onset of the subprime crisis. This continues throughout the global crisis period, before becoming relatively stable by the second half of 2009. Figure 7 presents the relative importance of the principal components in each time period for the ABX 06-1 index.

Figure 7. Relative Importance of ABX 06-1 Index Principal Components

Figure 7. Continued

Figure 7 illustrates that the relative importance of the main principal component remains almost constant between 2006 and 2007 before declining by almost 20% by the end of the sample. Figure 8 plots the time series of the principal components obtained for each of the four time periods for the ABX 06-2 index.

Figure 8. ABX 06-1 Index Principal Components

Figure 8. Continued

Again, we observe little movement in the five principal components until the onset of the subprime crisis in mid-2007. This volatility continues throughout 2008 before declining in 2009. Figure 9 presents the relative importance of the principal components for the ABX 06-2 index for each of the four years under analysis.

Figure 9. Relative Importance of ABX 06-2 Index Principal Components

Figure 9. Continued

Again, the relative importance of the main principal component is quite high in 2006, suggesting a high degree of commonality in the ABX 06-2 index during this pre-crisis year. This commonality then decreases once the index enters the subprime crisis period, and continues to fall until the end of the sample. Overall, these results indicate that the three indexes were all subject to a high degree of commonality during the tranquil 2006 period. For the ABX 06-1 index, this commonality remained throughout the subprime crisis, but both the spliced index and the 06-2 index saw it fall by almost 10% between the two years. Once the global crisis period of 2008 hit, the main principal component in all three indexes fell by almost 10%, and continued to fall through the post crisis period. This suggests that the relative importance of risk factors affecting each index changed between 2006 and 2009 and again highlights differences among the three indexes.

9. VAR Analysis using Principal Components

The VAR analysis is re-performed using the main principal component obtained in place of the noisy ABX returns.

9.1. Principal Component One as an Exogenous Variable

Firstly, the VAR analysis is performed using the main principal component obtained as an exogenous variable, instead of the ABX returns, thus testing if the main principal components Granger-cause subsequent changes or returns in the seven financial market variables. The VAR specification therefore becomes:

$$Y_t = \alpha + \sum_{k=1}^4 \beta_k Y_{t-k} + \gamma_k PC1_{t-k} + \varepsilon_t \quad (4)$$

in which Y_t denotes the financial market measure, as described in Section 3, included as the dependent variable. Thus, there are seven dependent variables and the system is estimated separately for each one. PC_1 denotes principal component 1 as the exogenous variable. As there are five ratings classes there are five ABX assets and the VAR system is estimated for each of these. Four lags are suggested by the Akaike Information Criterion (AIC).

Table 17 reports VAR estimation results for the spliced ABX index. Table 17 suggests that the main principal component for the spliced ABX index Granger-causes changes in the VIX, the two corporate spreads and returns in the S&P 500 sub-index of financial firms in 2006. During the subprime crisis this main principal component Granger-causes changes or returns in every financial market variable analyzed, thus providing some evidence of contagion. This, then dissipates during the following two years. Table 18 reports VAR estimation results for the ABX 06-1 index.

Table 17. Spliced ABX Index VAR Estimation Results
Exogenous Variable: Principal Component 1

2006							
Dependent Regressor	χ	β_1	β_2	β_3	β_4	R^2	p
1-Year T-bill	PC1	-0.92	0.93	-0.61	-0.37	0.68	0.46
10-Year T-bill	PC1	-0.64	0.63	-1.56	0.44	0.08	0.23
Aaa Spread	PC1	1.80*	1.58	2.39**	-0.4	0.43	0.00**
Baa Spread	PC1	1.47	0.4	1.77*	-1.22	0.45	0.01**
S&P 500 Subindex	PC1	-1.51	-1.55	-1.43	0.74	0.25	0.01**
S&P 500	PC1	-1	-1.47	-0.63	0.92	0.21	0.53
VIX	PC1	1.84*	-0.25	-0.93	0.28	0.12	0.04**
2007							
Dependent Regressor	χ	β_1	β_2	β_3	β_4	R^2	p
1-Year T-bill	PC1	-0.28	-0.52	-7.24**	-1.85*	0.49	0.00**
10-Year T-bill	PC1	-1.23	-0.55	-3.83**	-2.13**	0.35	0.00**
Aaa Spread	PC1	0.22	-0.22	2.55**	1.78*	0.22	0.01**
Baa Spread	PC1	0.01	-0.85	5.37**	4.22**	0.47	0.00**
S&P 500 Subindex	PC1	-2.48**	-0.35	-2.62**	-1.6	0.49	0.00**
S&P 500	PC1	-1.31	-1.12	-2.82**	-2.07**	0.41	0.00**
VIX	PC1	2.87**	-2.09**	-0.15	-2.75**	0.24	0.01**
2008							
Dependent Regressor	χ	β_1	β_2	β_3	β_4	R^2	p
1-Year T-bill	PC1	-0.77	-0.99	0.76	1.47	0.13	0.48
10-Year T-bill	PC1	0.35	-0.89	-1.67*	3.01**	0.26	0.05*
Aaa Spread	PC1	-2.64**	-0.59	0.87	-5.37**	0.52	0.00**
Baa Spread	PC1	-2.45**	-0.9	0.28	-4.17**	0.37	0.00**
S&P 500 Subindex	PC1	1.39	1.12	-0.48	1.78*	0.17	0.44
S&P 500	PC1	1.58	0.69	-0.09	1.96*	0.21	0.27
VIX	PC1	-1.16	0.62	-1.16	-2.71**	0.15	0.06*
2009							
Dependent Regressor	χ	β_1	β_2	β_3	β_4	R^2	p
1-Year T-bill	PC1	1.25	-1.15	-1.09	-0.08	0.18	0.35
10-Year T-bill	PC1	-1.03	0.33	0.26	-0.28	0.18	0.89
Aaa Spread	PC1	1.21	0.14	-0.44	-0.03	0.27	0.45
Baa Spread	PC1	1.38	-0.17	0.16	0.62	0.15	0.66
S&P 500 Subindex	PC1	-0.68	1.43	0.42	1.24	0.14	0.03**
S&P 500	PC1	-1.01	0.7	0.39	1.29	0.07	0.17
VIX	PC1	2.10**	0.16	-0.44	-2.36**	0.39	0.05*

Notes: In the above table *, **, *** denote significance at the 10%, 5% and 1% levels, respectively.

Table 18. ABX 06-1 Index VAR Estimation Results
Exogenous Variable: Principal Component 1

2006							
Dependent Regressor	χ	β_1	β_2	β_3	β_4	R^2	p
1-Year T-bill	PC1	-0.81	1.08	-1.01	-0.33	0.09	0.6
10-Year T-bill	PC1	-0.01	0.84	-1.06	0.36	0.07	0.76
Aaa Spread	PC1	0.8	0.84	2.14**	-0.08	0.41	0.09*
Baa Spread	PC1	0.26	-0.53	1.25	-1.14	0.43	0.43
S&P 500 Subindex	PC1	-2.32**	-1.27	-0.44	0.24	0.25	0.04**
S&P 500	PC1	-1.61	-0.9	-0.31	0.68	0.22	0.39
VIX	PC1	1.62	-0.04	-1.01	0.24	0.13	0.03**
2007							
Dependent Regressor	χ	β_1	β_2	β_3	β_4	R^2	p
1-Year T-bill	PC1	-2.01**	-1.01	-3.83**	-1.23	0.46	0.00**
10-Year T-bill	PC1	-3.31**	-2.35**	-6.02**	-2.74**	0.39	0.00**
Aaa Spread	PC1	1.75*	-0.2	2.11**	3.02*	0.23	0.01**
Baa Spread	PC1	3.07**	0.05	4.47**	7.13**	0.46	0.00**
S&P 500 Subindex	PC1	-3.85**	1.02	-3.30**	-1.63	0.46	0.00**
S&P 500	PC1	-2.47**	0.18	-3.19**	-3.38**	0.34	0.00**
VIX	PC1	2.64**	0.5	2.91**	0.88	0.3	0.03**
2008							
Dependent Regressor	χ	β_1	β_2	β_3	β_4	R^2	p
1-Year T-bill	PC1	-0.06	0.07	-0.89	-1.24	0.11	0.44
10-Year T-bill	PC1	-0.87	-2.10**	1.57	-1.57	0.28	0.03**
Aaa Spread	PC1	0.32	1.66*	-2.99**	-0.01	0.4	0.03**
Baa Spread	PC1	0.03	1.86*	-3.23**	-0.4	0.29	0.01**
S&P 500 Subindex	PC1	-0.21	0.63	2.08**	-0.14	0.11	0.32
S&P 500	PC1	1.05	-0.75	1.33	0.08	0.14	0.56
VIX	PC1	-0.81	0.36	-1.09	0.56	0.08	0.83
2009							
Dependent Regressor	χ	β_1	β_2	β_3	β_4	R^2	p
1-Year T-bill	PC1	-1.19	1.42	-0.13	-0.65	0.19	0.46
10-Year T-bill	PC1	1.6	-0.98	-1.77*	0.53	0.31	0.00**
Aaa Spread	PC1	0.23	2.42**	1.59	-0.43	0.34	0.01**
Baa Spread	PC1	-0.31	2.30**	1.55	-0.38	0.21	0.00**
S&P 500 Subindex	PC1	3.25**	-0.34	-0.3	0.83	0.16	0.01**
S&P 500	PC1	2.87**	-1.12	-0.4	-0.39	0.1	0.00**
VIX	PC1	-0.31	-0.04	-0.06	-0.38	0.29	0.98

Notes: In the above table *, **, *** denote significance at the 10%, 5% and 1% levels, respectively.

Here, we observe less significant p-values than in Table 17, the results for the spliced ABX index. Again, once the index enters the 2007 subprime crisis period all F-statistics become highly significant, suggesting that the main principal component of the ABX 06-1 index Granger-caused subsequent changes or returns in the financial market variables, thus, providing some evidence of contagion during 2007. This evidence then dissipates during the global crisis period before increasing again during 2009. Comparing Table 18 to Table 17, we see more evidence of contagion in 2009 in the ABX 06-1 index than in the spliced ABX index. Table 19 reports VAR estimation results for the ABX 06-2 index.

Table 19. ABX 06-2 Index VAR Estimation Results
Exogenous Variable: Principal Component 1

2006							
Dependent Regressor	χ	β_1	β_2	β_3	β_4	R^2	p
1-Year T-bill	PC1	1.23	1.78*	-0.38	2.02**	0.36	0.32
10-Year T-bill	PC1	0.9	0.7	-3.41**	-2.42**	0.58	0.00**
Aaa Spread	PC1	2.88**	1.92*	2.50**	0.13	0.71	0.00**
Baa Spread	PC1	2.97**	1.1	2.05**	-0.42	0.73	0.00**
S&P 500 Subindex	PC1	0.05	-1.59	-0.22	0.03	0.24	0.00**
S&P 500	PC1	2.99**	-0.84	2.28**	0.76	0.55	0.00**
VIX	PC1	-0.13	-1.04	-2.72**	-0.43	0.71	0.00**
2007							
Dependent Regressor	χ	β_1	β_2	β_3	β_4	R^2	p
1-Year T-bill	PC1	-0.48	0.19	-5.29**	-1.65**	0.52	0.00**
10-Year T-bill	PC1	-1.39	-0.52	-6.35**	-2.02**	0.43	0.00**
Aaa Spread	PC1	0.59	-0.58	3.44**	1.48	0.24	0.00**
Baa Spread	PC1	0.68	-1.31	5.05**	3.81**	0.47	0.00**
S&P 500 Subindex	PC1	-3.10**	-0.03	-3.39**	-2.00**	0.49	0.00**
S&P 500	PC1	-1.71*	-0.67	-3.02**	-1.82*	0.38	0.00**
VIX	PC1	2.38**	1.48	2.32**	0.69	0.37	0.00**
2008							
Dependent Regressor	χ	β_1	β_2	β_3	β_4	R^2	p
1-Year T-bill	PC1	0.45	0.53	-1.14	-1.02	0.12	0.38
10-Year T-bill	PC1	-0.69	-1.76*	0.9	-1.36	0.22	0.21
Aaa Spread	PC1	0.16	1.08	-1.9	-0.16	0.37	0.32
Baa Spread	PC1	-0.16	0.99	-2.26**	-0.7	0.28	0.14
S&P 500 Subindex	PC1	0.22	0.94	1.25	-0.07	0.11	0.74
S&P 500	PC1	1.29	0.09	1.01	0.21	0.17	0.58
VIX	PC1	-1.08	-0.09	-0.77	0.45	0.1	0.79
2009							
Dependent Regressor	χ	β_1	β_2	β_3	β_4	R^2	p
1-Year T-bill	PC1	0.79	2.09**	-3.60**	1.71*	0.35	0.01**
10-Year T-bill	PC1	0.58	-0.18	-2.75**	2.89**	0.3	0.02**
Aaa Spread	PC1	-0.9	1.99**	1.96*	-3.95**	0.39	0.00**
Baa Spread	PC1	-0.45	1.52	1.89*	-4.38**	0.25	0.00**
S&P 500 Subindex	PC1	1.51	0.68	-0.91	1.66*	0.14	0.03**
S&P 500	PC1	0.86	0.09	-1.77*	2.75**	0.11	0.1
VIX	PC1	2.25**	-0.03	2.02**	-2.33**	0.38	0.01**

Notes: In the above table *, **, *** denote significance at the 10%, 5% and 1% levels, respectively.

From Table 19, it is clear that there is more significance during the 2006 in the ABX 06-2 index than in the other two indexes analyzed, again highlighting the differences between the three indexes. All F-statistics are highly significant in the subprime crisis period of 2007, again indicating contagion. Interestingly, no F-statistics are significant during the 2008 global crisis period, indicating that the main principal component of the ABX 06-2 index had no significant forecast power during that year. This again could be due to the liquidity freeze. Almost all F-

statistics then become significant in the post crisis period, which again could be due to the markets rebounding.

Overall, these results do provide some evidence of contagion from the main principal component of each of the three indexes to the financial market variables but as we also observe significance in the pre-crisis period we cannot strongly state that there was a significant change in the relationship between the variables analyzed once the crisis hit. The results again illustrate the differences between the three indexes.

9.2. Principal Component One as an Endogenous Variable

In order to test the sensitivity of the results presented in Section 4 VAR analysis is performed using the main principal component obtained as an eighth endogenous variable. Table 20 reports VAR estimation results for the spliced ABX index for each of the four years, 2006, 2007, 2008, and 2009.

Table 20. Spliced ABX Index VAR Estimation Results
Endogenous Variable: Principal Component 1

2006							
Y	X	β_1	β_2	β_3	β_4	R ²	p
PC1	1-Year T-bill	1.30	1.31	0.18	-1.99*	0.18	0.08*
	10-Year T-bill	0.84	2.18**	0.94	-1.41	0.18	0.19
	Aaa Spread	0.93	-0.20	0.26	1.08	0.16	0.68
	Baa Spread	1.06	0.33	0.62	1.06	0.18	0.74
	S&P 500 Subindex	1.01	0.09	-0.57	0.40	0.13	0.72
	S&P 500	1.68	-0.31	-1.23	-0.52	0.16	0.3
	VIX	-1.46	-0.34	1.26	0.32	0.16	0.42
2007							
Y	X	β_1	β_2	β_3	β_4	R ²	p
PC1	1-Year T-bill	3.08**	0.36	3.36**	-0.2	0.53	0.00**
	10-Year T-bill	1.68*	-1.31	1.80	-0.31	0.42	0.00**
	Aaa Spread	-1.66*	0.03	-0.54	0.01	0.29	0.24
	Baa Spread	-1.88*	-0.54	-1.17	-0.15	0.35	0.21
	S&P 500 Subindex	2.15**	0.45	1.24	0.79	0.37	0.13
	S&P 500	1.63*	0.15	1.71*	1.1	0.4	0.11
	VIX	-1.67*	0.68	-1.64	-1.53	0.43	0.07*
2008							
Y	X	β_1	β_2	β_3	β_4	R ²	p
PC1	1-Year T-bill	3.48**	-2.85**	1.29	-0.30	0.19	0.00**
	10-Year T-bill	-0.25	-1.94*	0.81	1.74*	0.13	0.11
	Aaa Spread	-0.72	0.75	0.03	-1.11	0.1	0.10
	Baa Spread	-1.84*	0.38	0.33	-0.3	0.08	0.29
	S&P 500 Subindex	1.20	-2.57**	-0.04	1.13	0.29	0.07**
	S&P 500	5.12**	-2.48**	3.68**	0.86	0.37	0.00**
	VIX	-3.15**	2.30**	-3.19**	-1.78*	0.37	0.00**
2009							
Y	X	β_1	β_2	β_3	β_4	R ²	p
PC1	1-Year T-bill	-2.80**	-1.12	5.73**	1.52	0.39	0.00**
	10-Year T-bill	-0.37	-1.46	1.84*	0.57	0.23	0.02**
	Aaa Spread	0.87	2.42**	-0.43	0.64	0.21	0.01**
	Baa Spread	0.39	1.12	-1.11	0.59	0.2	0.17
	S&P 500 Subindex	0.64	-1.46	-0.78	-0.44	0.19	0.32
	S&P 500	0.38	-2.57**	-0.97	-0.2	0.25	0.02**
	VIX	0.1	2.16**	2.11**	0.85	0.23	0.03**

Notes: In the above table *, **, *** denote significance at the 10%, 5% and 1% levels, respectively.

During 2006 and 2007, only the Treasury Bill yield have a significant effect upon the main principal component of the spliced ABX index. During 2008 and 2009, we observe increased significance but overall, there is little evidence of contagion. Table 21 reports VAR estimation results for the ABX 06-1 index.

Table 21. ABX 06-1 Index VAR Estimation Results
Endogenous Variable: Principal Component 1

2006							
Y	X	β_1	β_2	β_3	β_4	R ²	p
PC1	1-Year T-bill	0.66	-0.4	1.29	-1.1	0.08	0.35
	10-Year T-bill	0.12	0.97	0.73	-0.29	0.06	0.72
	Aaa Spread	1.18	0.28	0.61	0.79	0.07	0.83
	Baa Spread	1.11	0.62	0.67	0.81	0.07	0.86
	S&P 500 Subindex	1.02	1.35	0.34	1.6	0.1	0.12
	S&P 500	1.93*	0.39	-0.34	0.88	0.11	0.25
	VIX	-1.72*	-1.01	0.06	-1.04	0.12	0.04**
2007							
Y	X	β_1	β_2	β_3	β_4	R ²	p
PC1	1-Year T-bill	2.01**	0.6	3.01**	0.15	0.34	0.00**
	10-Year T-bill	1.69	0.28	1.97*	-1.09	0.22	0.05*
	Aaa Spread	-1.93*	-1.78*	-1.37	-0.28	0.13	0.35
	Baa Spread	-2.09**	-1.75*	-1.79*	-0.5	0.26	0.15
	S&P 500 Subindex	0.94	-1.48	1.80	0.28	0.29	0.00**
	S&P 500	0.32	-1.62	2.23**	0.5	0.33	0.00**
	VIX	-0.17	1.5	-1.96*	-1.75**	0.34	0.07*
2008							
Y	X	β_1	β_2	β_3	β_4	R ²	p
PC1	1-Year T-bill	0.67	0.55	2.04**	1.26	0.23	0.08*
	10-Year T-bill	0.51	1.54	2.05**	0.76	0.22	0.00**
	Aaa Spread	-0.48	-0.17	0.26	0.03	0.14	0.93
	Baa Spread	-0.67	0.32	0.87	0.32	0.17	0.75
	S&P 500 Subindex	0.32	0.85	-0.85	-0.00	0.16	0.89
	S&P 500	0.56	1.05	0.09	-0.31	0.18	0.67
	VIX	-2.36**	-0.48	-0.06	-0.36	0.21	0.12
2009							
Y	X	β_1	β_2	β_3	β_4	R ²	p
PC1	1-Year T-bill	1.09	1.55	0.78	0.33	0.2	0.03**
	10-Year T-bill	0.49	0.74	1.46	1.18	0.14	0.51
	Aaa Spread	0.32	0.57	-0.14	-0.91	0.14	0.12
	Baa Spread	0.5	1.4	-0.45	-1.93*	0.15	0.03**
	S&P 500 Subindex	-1.08	-0.6	-1.1	-0.65	0.13	0.60
	S&P 500	-1.5	-0.46	-0.49	-0.8	0.13	0.33
	VIX	1.05	-0.21	-0.43	-0.5	0.12	0.72

Notes: In the above table *, **, *** denote significance at the 10%, 5% and 1% levels, respectively.

Table 21 shows that most significance occurs during the subprime crisis period of 2007, indicating that contagion occurred from the Treasury, equity, volatility and fixed-income variables analyzed the main principal component of the ABX 06-1 index. Table 22 reports VAR estimation results for the ABX 06-2 index.

Table 22. ABX 06-2 Index VAR Estimation Results
Endogenous Variable: Principal Component 1

2006							
Y	X	β_1	β_2	β_3	β_4	R ²	p
PC1	1-Year T-bill	0.12	0.32	-1.11	-2.33**	0.41	0.00**
	10-Year T-bill	-0.31	0.31	-0.31	-2.39**	0.28	0.02**
	Aaa Spread	1.56	0.86	0.68	1.74*	0.33	0.02**
	Baa Spread	1.6	1.32	1.12	1.93*	0.43	0.00**
	S&P 500 Subindex	1.02	1.37	1.07	-0.15	0.24	0.08*
	S&P 500	3.67**	1.06	-0.05	-0.8	0.34	0.00**
	VIX	-1.43	-0.73	0.21	1.11	0.29	0.03**
2007							
Y	X	β_1	β_2	β_3	β_4	R ²	p
PC1	1-Year T-bill	2.44**	1.23	4.68**	0.14	0.44	0.00**
	10-Year T-bill	1.93*	-0.39	2.17*	-0.88	0.34	0.00**
	Aaa Spread	-1.81*	-0.94	-0.96	0.27	0.23	0.25
	Baa Spread	-2.12**	-1.19	-1.49	0.27	0.3	0.13
	S&P 500 Subindex	1.57	0.48	1.12	0.88	0.24	0.08*
	S&P 500	1.37	1.06	1.83*	1.23	0.33	0.03**
	VIX	-1.48	0.55	-1.63	-1.64	0.35	0.02**
2008							
Y	X	β_1	β_2	β_3	β_4	R ²	p
PC1	1-Year T-bill	1.38	0.23	1.86*	1.57	0.19	0.01**
	10-Year T-bill	0.89	1.21	1.62	1.17	0.19	0.05*
	Aaa Spread	-0.93	-0.78	0.16	-0.25	0.11	0.75
	Baa Spread	-0.88	-0.14	0.96	0.03	0.12	0.69
	S&P 500 Subindex	-0.25	0.57	-0.54	0.33	0.09	0.94
	S&P 500	0.36	0.97	0.2	0.32	0.11	0.76
	VIX	-2.32**	-0.74	-0.06	-0.73	0.19	0.13
2009							
Y	X	β_1	β_2	β_3	β_4	R ²	p
PC1	1-Year T-bill	0.77	0.74	2.51**	-1.09	0.31	0.03**
	10-Year T-bill	1.53	-1.89*	1.87	0.8	0.36	0.13
	Aaa Spread	-1.08	1.76*	-0.63	0.81	0.34	0.11
	Baa Spread	-1.11	2.04**	-1.37	-0.1	0.34	0.12
	S&P 500 Subindex	-2.61**	0.06	-2.20**	0.86	0.32	0.00**
	S&P 500	-3.66**	0.33	-1.41	0.33	0.32	0.00**
	VIX	2.69**	0.76	0.67	-1.06	0.29	0.01**

Notes: In the above table *, **, *** denote significance at the 10%, 5% and 1% levels, respectively.

Comparing Table 22 to Table 20 and Table 21, we observe more significance in almost each of the years analyzed, suggesting that the main principal component of the ABX 06-2 index was more sensitive to the financial variables analyzed.

10. Conclusions

This paper analyzes contagion from the U.S. subprime mortgage-backed securities market, using the ABX.HE indexes to represent this market, via the VAR framework presented in Longstaff (2010). The analysis in Longstaff (2010) is extended to include a post-crisis period of 2009 and is applied to two traded ABX indexes. The sensitivity of these results are then tested by including ABX returns as an eighth endogenous variable in the VAR system. Principal component analysis is performed on the three indexes under consideration and the main principal component is included in further VAR analysis.

The results indicate evidence of contagion from the ABX indexes during the crisis of 2007-2009 but the source and intensity of this contagion varies among indexes. This highlights the differences among the three ABX data sets analyzed and suggest that splicing the ABX index may have an impact upon the results obtained. It also provides evidence that the traded ABX indexes were heterogeneous assets and were subject to varying sensitivities to risk factors during the crisis.

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