Testing the Efficiency of the Commercial Real Estate Market: Evidence from the 2007-2009 Financial Crisis

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Abstract

A CMBX contract is essentially a credit default swap on a pool of Commercial Mortgage-Backed Securities (CMBS). Both CMBX and Real Estate Investment Trusts (REITs) can be thought of as derivative contracts on commercial property values. This creates a tight fundamental link: our structural pricing model for CMBX, which is calibrated to REIT stock and option data, explains more than 86% of the daily price variation of CMBX contracts. We use the CMBX pricing model to document two large short-term deviations from market efficiency; consistent with price pressure by banks hedging their CMBS and commercial loan exposure using CMBX contracts. First, the model mispricing significantly predicts subsequent CMBX, but not REIT, price changes. The effect is economically meaningful: a strategy exploiting the predictability has an annualized Sharpe ratio of 2.35, net of transaction costs. Second, we show that following days with CMBS specific news, the CMBX market overreacts relative to the model for two days, which fully reverts over the next two days.

JEL classification: G1, G13, G14

Keywords: CMBX, CMBS, REIT, market efficiency, arbitrage, financial crisis, commercial real estate, capital structure arbitrage

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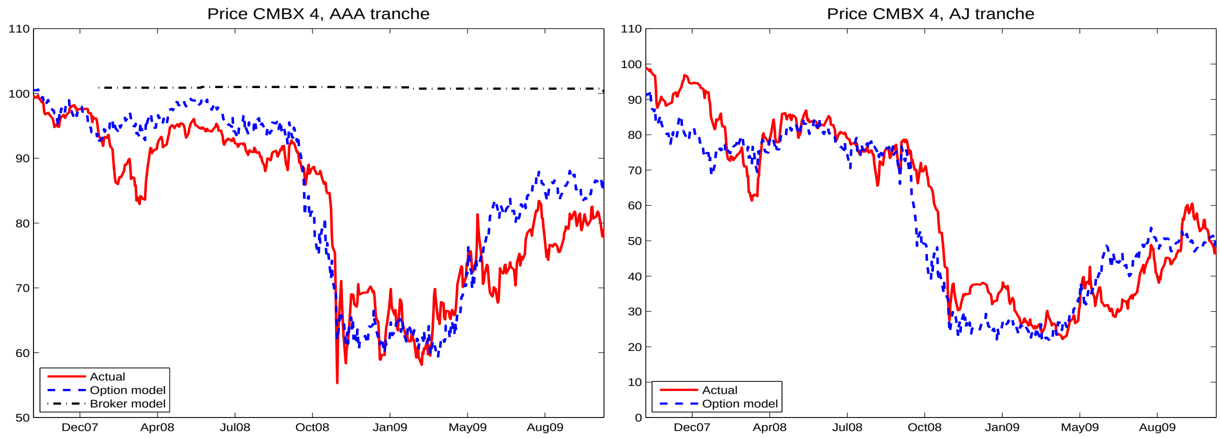
1 Introduction

A CMBX contract is essentially a credit default swap on a pool of Commercial Mortgage-Backed Securities (CMBS). Banks and other financial institutions use CMBX contracts to hedge their exposure to CMBS and commercial property loans; which was particularly relevant during the 2007–2009 financial crisis. The price on a CMBX contract is quoted as \$100 minus the price of protection on \$100 notional. In Figure 1, left Panel, we plot the price for the CMBX 4 AAA index, which references a basket of 25 super-senior CMBS. At the lowest price of \$55 on November 20th, 2008, it cost \$45 per \$100 notional to insure losses on the super-senior CMBS bonds, which are highest up in the capital structure with about 30% credit enhancement through subordinated bonds on the same deal. Remarkably, throughout this entire period, several sell-side analysts at the main broker houses indicated that the super-senior CMBS were money good, even in their worst economic scenario. To illustrate this, we depict in Figure 1, left Panel, dash-dotted line, the model price for the CMBX 4, AAA index reported by JP Morgan Chase in their daily CMBX evaluator report, which is around \$100 throughout.

Figure 1: Actual and Model Price CMBX 4, AAA and AJ tranches

The figure shows the actual, option model, and broker model price for CMBX 4, AAA (left panel), and the actual and option model price for CMBX 4, AJ (right panel) from October 25th, 2007, when CMBX 4 was issued, to October 30st, 2009.



The first contribution of this paper is to show that the volatile and historically low CMBX price during the 2007–2009 financial crisis is in fact largely in line with a structural CMBX pricing model, calibrated to Real Estate Investment Trust (REIT) prices, as is illustrated by the dashed line in Figure 1, left Panel. The second contribution of this paper is to use the model to document that over shorter horizons there are substantial deviations from efficiency in the CMBX market, which we will argue is consistent with price pressure by banks hedging their commercial real estate exposure.

In our model, the collateral value for the loans referenced by CMBX contracts are linked to changes in property values. A loan defaults whenever the collateral value drops below a certain threshold fraction of the loan balance. We allow for both term defaults and maturity defaults. We take into account dispersion across loans in the initial collateral value as a fraction of the loan balance, which is calibrated to the inverse of the reported loan-to-value ratio. We calibrate past changes in property values using past price changes in the iShares Dow Jones Real Estate index Fund.[1] The risk-neutral probability distribution of future changes in property values is calibrated using the 1-year at-the-money options on the same index. The model is evaluated by means of a simple Monte Carlo simulation method. We illustrate the precision of the numerical procedure by comparing the numerically-determined value for a special case of the model to the theoretical value based on the Black and Scholes (1973) option pricing formula that is applicable in the special case.

Two model parameter are interpreted as free parameters, which we set to minimize the sum of the root mean squared error (RMSE) for the two most liquid tranches of the CMBX 4 index: the AAA tranche, which insures deal losses in excess of 30% and the AJ tranche, which insures deal losses between about 12% and 20%. The first free model parameter is the threshold for the ratio of the collateral value to the loan balance ratio, below which a term default occurs. We find an optimal value of 0.3. The second free model parameter is the ratio of the property value volatility to the REIT stock price volatility, for which we find a value of 0.65. Alternatively, one can impute the second free parameter from the average REIT capital structure; in fact the optimized parameter value seems ball park right from that point of view: it is consistent with a $50-50\%$ debt-equity ratio combined with changes in the market value of debt equaling 30% of changes in the market value of equity. The model does a good job pricing both the CMBX 4, AAA and AJ, tranche, see Figure 1, left and right Panel respectively. The RMSE is \$5.41 and \$8.45, and the correlation between the actual and model price is 93% and 94% for the AAA and AJ tranche respectively. We perform several sensitivity tests to using different calibrated model parameters. In each case the model price *dynamics* are hardly affected by using alternative calibrated values. The model price *level*, however, is fairly sensitive to the assumed ratio of property value volatility to REIT stock price volatility. We also consider a model calibrated to S&P stock and option data, instead of REIT stock and option data. The model fit for the AAA tranche is slightly worse; the model fit for the AJ tranche deteriorates more, with a 10% higher RMSE.

We utilize the actual-model price differential to test the efficiency of the commercial real estate market at shorter horizons. We first establish that the model mispricing predicts subsequent CMBX price changes with a Newey-West corrected (25 lags) t-stat of 2.5 and 3.1 for the AAA and AJ tranche respectively. This result is robust to using an expanding calibration of the free model parameters, in which case the model mispricing at a given point in time is then determined using solely data available at that point in time. The model mispricing does not predict the subsequent change in the REIT stock price or the REIT option implied volatility

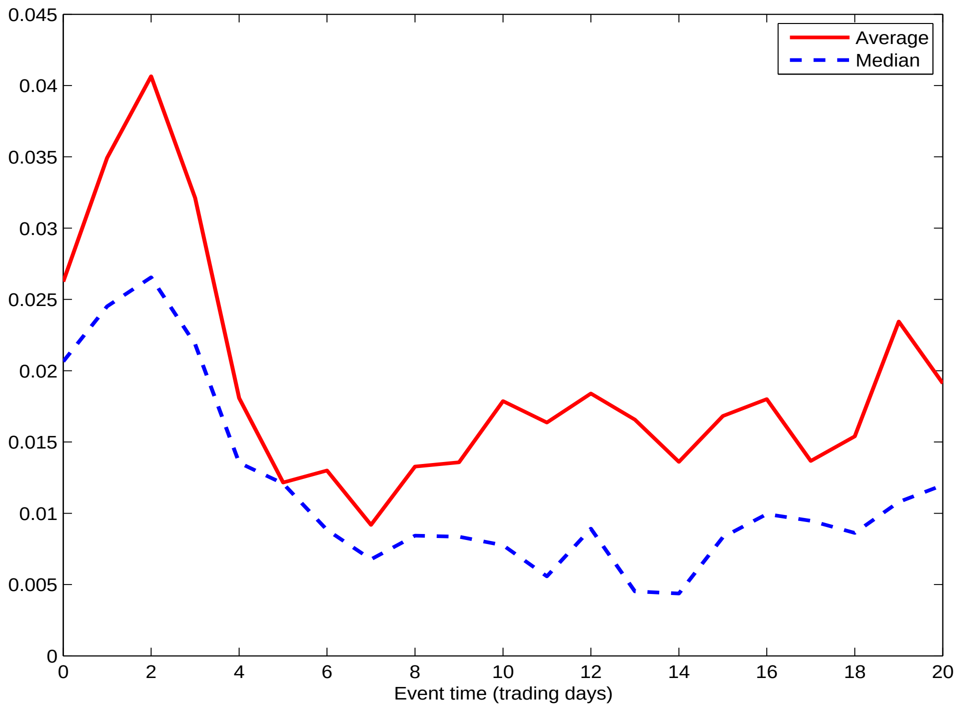
The assess the economic significance of the predictability in CMBX prices, we back test a simple trading strategy exploiting this information. The CMBX position size is proportional to the trading signal, which is minus the model mispricing, with two tweaks: (1) we

[1] Bloomberg ticker: IYR US Equity.

standardize the model error, i.e. deduct the mean and divide by the standard deviation, a common trick to make the strategy more robust to different parameterizations, and (2) we slow down the signal by trading only if the trading signal implies a sufficiently different position from what is already held at a given point in time in the back test and also limited the trade size per day. The CMBX position is hedged with REIT stocks, where the size of the hedge is determined by the empirical beta of CMBX returns to REIT returns. In order to provide a conservative estimate of the strategy performance, we use the expanding calibration of the free model parameters. Also the standardization of the model mispricing and the determination of the hedge ratio is based on an expanding window. This means that all model parameters for the back test are free from a look-ahead bias. We assume realistic transaction cost. The lag between observing the trade signal and portfolio rebalancing is one business day. We find an annualized Sharpe ratio of 2.35 for a $50-50\%$ combination of a strategy based on the AAA and the AJ tranche. To put these figures in perspective, Duarte, Longstaff, and Yu (2007) back test five popular fixed-income arbitrage strategies and find a maximum Sharpe ratio of only 1.20.

Figure 2: Cumulative response to a news announcement at time 0

The Figure shows the average and median cumulative response to a news announcement at time 0. The response is the actual minus model return (change in model mispricing), interacted with the sign of the time 0 return; hence it measures whether the mispricing moves in the same (positive) or opposite (negative) direction compared to the announcement day response.



Next, we use the model to study the response of the CMBX market to news announcements. For the statistical tests we stick to an objective set of news days to prevent data snooping. This set of 28 news days are those for which both (i) Bank of America issued a special CMBS news report, and (ii) Bloomberg made notice of the event. Major announcements include news on high-profile loans transferred to the special servicer, Government programs aimed at reviving the CMBS market, and updates by the rating agencies. We analyze the CMBX market response to news by measuring the cumulative actual minus model return following news days, interacted with the sign of the news announcement day return, which is depicted in figure 2. We find that the two days following the news day, the CMBX market continues to move (on average) in the same direction as it did on the news day itself. This could be either due to initial underreaction or subsequent overreaction. Our results point to overreaction, since the (average) price reverses within five days of the announcement to a price below the closing level of the announcement day.[2] Despite the short sample period and having a cross-section of just one, these results are statistically significant.

The evidence above raises the question why the market efficiency is not arbitraged away instantaneously. A first point to notice is that the strategy exploiting the predictability in CMBX prices requires a fair amount of sophistication. Duarte, Longstaff, and Yu (2007) find evidence that among fixed-income arbitrage strategies, the strategies that require most intellectual capital perform the best; and in fact the strategy that performed best in their study was a capital structure arbitrage, which is the strategy most similar in spirit to the strategy discussed in this paper. We posit that there is a second factor playing a role here. The sample period coincides with the financial crisis and many banks were very concerned with hedging risk exposure to real estate assets, e.g. to satisfy regulatory value-at-risk requirements. These hedging needs may create a temporary price pressure on the instruments used for hedging, like CMBX. This would explain why we only find predictability for CMBX, not for REITs. Also our finding that following news announcements the CMBX market overreact for two days, seems consistent with banks rebalancing their hedge portfolio in a rush following news.[3]

This paper contributes to a growing body of work on the 2007–2009 financial crisis. Much of this work has focused on subprime mortgage-backed securities; early examples include Demyanyk and Van Hemert (2009), Mian and Sufi (2009), and Keys, Mukherjee, Seru, and Vig (2009). Other papers study the ABX indices on US subprime residential mortgages, which are similar in structure to the CMBX indices for commercial mortgage-backed securities. Longstaff (2008) finds contagion in financial markets, with lower-rated tranches of ABX leading the Treasury bond and stock market. Stanton and Wallace (2009) argue that short-selling pressures in the capital markets are central to explaining ABX prices. We complement these various papers on subprime mortgage-backed securities, by looking at the CMBX market, which is particularly interesting for two reasons. First, because CMBX are derivative contracts on commercial property values, we can study relative value to other traded assets that are also directly dependent on commercial property values, like REIT stock and options. Second, while by now it is widely accepted that large losses on subprime

[2] This contrasts studies on US stocks, like Chan (2003), that find that the price continuation (or decrease in price reversal) following news announcements is more consistent with underreaction to news.

[3] The requirement to "reset their hedges" seems to be the favored explanation in broker emails to clients, like the authors of this paper, for the phenomenon that the market tends to move in the same direction for days in a row following important news events.

securities will materialize, the jury is still out on CMBS. For example the delinquency rate on the deals referenced by CMBX 4 was only 3.22% per July 2009; in contrast the delinquency rate for subprime deals referenced by the ABX 07-2, issued around the same time as CMBX 4, was 31.40% per July 2009.[4]

Furthermore, this paper builds on the literature applying the Merton (1974) contingent-claims approach for pricing bonds. Titman and Torous (1989) study a two-factor contingent claims approach to value CMBS. Downing, Stanton, and Wallace (2007) use the Titman and Torus (1989) model to analyze CMBS over the 1996–2005 period and provided an early warning that subordination levels were decreasing over time, while implied volatilities estimates remained roughly constant. Kau, Keenan, Yildirim (2009) study CMBS default probabilities using REIT property-type indices. Also, there is a large literature studying the empirical determinants of commercial mortgage defaults, including VanDell et al (1993), Follain and Ondrich (1997), Ciochetti et al (2002), Ambrose and Sanders (2003), and Ciochetti et al (2003). To the best of my knowledge, none of these papers study the CMBX derivative contract, nor do they test the efficiency of the commercial real estate market during the 2007–2009 financial crisis, like this paper does.

The paper proceeds as follows. In Section 2 we discuss the CMBS and CMBX market. In Section 3 we present the option model, and in Section 4 we discuss the model results. In Section 5 we discuss the main news events that affected the CMBS market and we analyze the CMBX market response to those announcements. In Section 6 we conclude.

2 Overview of the commercial real estate debt market

In this Section we provide a brief overview of the US commercial real estate debt market. We start by discussing commercial real estate loans and commercial mortgage-backed securities. Next we explain the CMBX contracts between a buyer and seller of protection on a basket of securitized commercial mortgages.

2.1 Commercial Mortgage-Backed Securities

Commercial real estate mortgage loans are collateralized by income-producing properties like offices, shopping malls, hotels, and apartment buildings. The dominant contract type is a fixed-rate mortgage that amortizes over 20-30 years, but matures in 10 years, resulting in a large (balloon) payment at maturity. Most commercial mortgages have prepayment or call protection mitigating largely the risk of strategic refinancing when interest and mortgage rates decline, in contrast to agency-backed residential mortgages that allow for prepayment at no or little cost.

During the first quarter of 2009, 21% of the $3.47 trillion commercial mortgage market was securitized.[5] A commercial mortgage-baked security (CMBS) is backed by a pool of

[4]The delinquency rate is defined as the fraction of loans that are 60 or more days late on payments. Reported figures are from the July 2009 CMBX and ABX monthly reports by JPMC. The delinquency rate for ABX is computed as a percentage of the original balance .

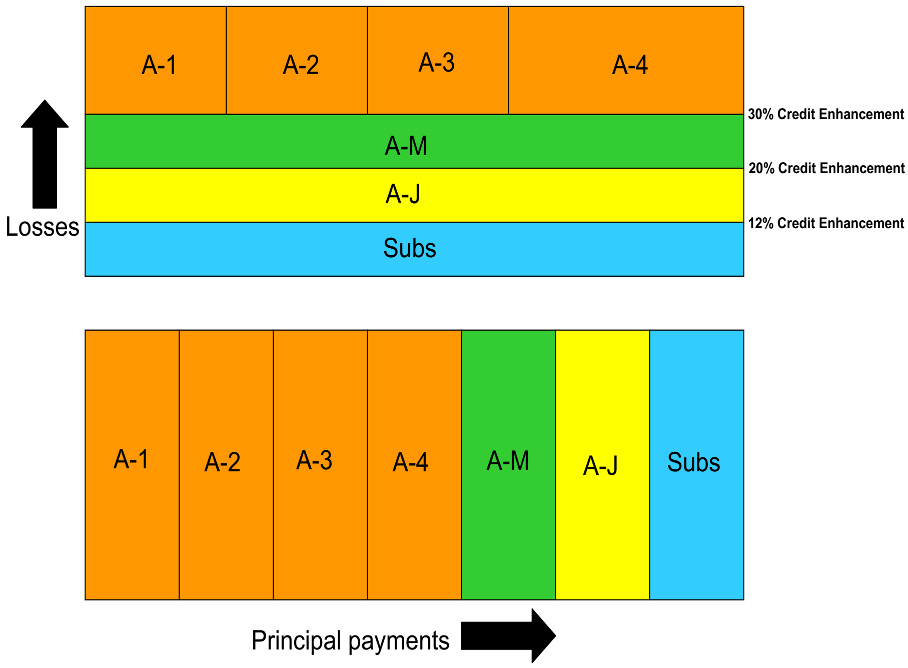
[5]We use data from the Board of Governors of the Federal Reserve System reported at

commercial mortgages, typically diversified across property type and location. The pool is placed in a separate legal entity, or trust, to protect investors from bankruptcy of the mortgage originator. The most common structure is a real estate mortgage investment conduit (REMIC), which allows the trust to be a pass-through entity that is not subject to tax at the trust level.

The conduit issues a range of CMBS (also referred to as tranches) that are different along several dimensions, most importantly with respect to credit enhancement and maturity. In Figure 3 we illustrate a typical CMBS deal.[6] The super-senior tranches (A-1, A-2, A-3, A-4) have 30% credit enhancement (subordination level). Super-senior tranches differ with respect to the timing of principal repayment, the A-1 being the first and the A-4 being the last to receive principal.[7] The mezzanine (A-M) tranche absorbs deal losses between 20% and 30% and the junior AAA (A-J) tranche absorbs losses between 12% and 20%. The A-1, A-2, A-3, A-4, A-M, and A-J tranches all have an AAA credit rating on the issuance date. Only the remaining tranches (Subs), that are further subordinated and absorb losses between 0% and 12%, get an original credit rating below AAA.

Figure 3: Basic structure for the cash flow allocation to different traches

The figure illustrates the basic structure for the cash flow allocation to different tranches. In practise many variations exist.



http://www.federalreserve.gov/econresdata/releases/mortoutstand/current.htm. In comparison, 60% of the $11.0 trillion US residential mortgage market was securitized.

[6]Our example represents a basic structure; in practice many variations to this basic structure exist.

[7]Sometimes only the A1, A2 and A3 exist.

2.2 CMBX Contracts

A CMBX contract is an agreement between a buyer and a seller of protection on 25 reference CMBSs. The buyer of protection pays a fixed coupon each month. The seller of protection pays a floating payment to the amount of the shortfall in the scheduled interest and principal payments, a settlement type referred to as pay-as-you-go.

The basket of reference CMBS and contractual details are standardized and set by Markit, a financial information services company owned by large banks, hedge funds, and employees. When a new standardized CMBX contract is introduced by Markit, also the fixed coupon is set. For buyers and sellers of protection that enter into the CMBX contract at a later date, the same fixed coupon applies; the exchange of an up-front payment allows the contractors to take into account the current market value of protection.[8]

The size of the up-front payment at a given point in time is often translated into either (i) a spread, which allows for a comparison with the CMBS yield spread to swaps, or (ii) a price per $100 notional, which is approximately equal to 100 minus the up-front payment. We used the latter in Figure 1. The correlation between the weekly level (change) of the JPMC 10-year super-senior CMBS spread to swaps and the level (change) of the spread on the CMBX 4, AAA tranches is 97% (87%) from October 25th, 2007 to August 10th, 2009, illustrating the usefulness of the CMBX series for hedging portfolios of less liquid CMBS.

A CMBX series consists of several tranches, each referencing a different set of 25 CMBSs. However, the different tranches of a given series all reference the same 25 underlying deals. The CMBX AAA tranche references super-senior CMBSs with about 30% credit enhancement, where typically the last-pay (A-4 in Figure 3) CMBS are used. The CMBX AJ, AA, A, BBB, BBB- reference CMBS increasingly lower in the capital structure of the 25 deals for a particular series.

CMBX series 1 became effective on March 7th, 2006. Markit initially planned to introduce a new series each half year, but the introduction of CMBX series 6, planned for October 25th, 2008, was postponed due to a lack of new issuance.[9]

3 An options-based CMBX valuation model

An investor selling protection using a CMBX contract will have to compensate the protection buyer in case of defaults on the referenced CMBS, which is most likely to occur when property prices drop. Therefore, in essence the protection seller writes a derivative on property values, creating a fundamental link between the CMBX and the REIT market. REIT stock prices are informative on the current value of properties. REIT option prices contain additional information on the (risk-neutral) probability distribution of future property values. In the CMBX valuation model described below we make explicit this fundamental link between the CMBX and the REIT market.

[8] For more information, see the official March 2006 Markit marketing presentation: http://www.markit.com/assets/en/docs/products/data/structured-finance/Documentation/CMBX_Marketing_Presentation.pdf

[9] See the Markit news announcement on their website: http://www.markit.com/en/products/data/indices/structured-finance-indices/cmbx/news.page?

3.1 Loss model

A CMBX contract with \$100 notional insures losses on 25 constituents, each up to \$4. For a contract insuring the losses between a fraction CE^L and CE^H of notional, the value P is defined as \$100 plus the present value of the fixed payments received by the protection seller, CF^{fixed} per dollar notional, minus the present value of the floating payments made by the protection seller, $CF^{floating}$ per dollar notional. See Equation (1), where the summation is over constituents k and times t. The fixed payments are a fixed annual coupon rate, c, times the fraction of notional outstanding. For simplicity we assume that the underlying loans are interest-only, which means that the fraction of notional outstanding equals one minus the cumulative tranche loss (as a fraction of notional) per the previous period, $L^{tranche}_{t-1,k}$. See Equation (2), where dt is the assumed length of a time-interval. The floating payment equals the change in the cumulative tranche loss, see Equation (3). Finally, the cumulative tranche loss is the proportion of the insured tranche with attachment points CE^L and CE^H of notional that is hit by the cumulative deal loss, $L^{deal}_{t,k}$, see Equation (4).

$$\begin{aligned} P_0\left(CE^L, CE^H\right) &= 100 + 4 * \sum_{k=1}^{25}\sum_{t=1}^{T} PV\left(CF^{fixed}_{t,k} - CF^{floating}_{t,k}\right) &(1)\\ CF^{fixed}_{t,k} &= \left(1 - L^{tranche}_{t-1,k}\right) * c * dt &(2)\\ CF^{floating}_{t,k} &= L^{tranche}_{t,k} - L^{tranche}_{t-1,k} &(3)\\ L^{tranche}_{t,k} &= \frac{\max\left\{L^{deal}_{t,k} - CE^L, 0\right\} - \max\left\{L^{deal}_{t,k} - CE^H, 0\right\}}{CE^H - CE^L} &(4)\end{aligned}$$

Deal losses occur in case of a default. We define $D^i_{t,k}$ as a default indicator function taking the value one if at time t loan i of constituent k defaults. The size of the loss is the (original) weight of loan i in constituent k, denoted w^i_k, times one minus the collateral value per dollar loan amount, $V^i_{t,k}$, at the time of default. See Equation (5).

$$L^{deal}_{t,k} = L^{deal}_{t-1,k} + \sum_{i=1}^{I} w^i_k * D^i_{t,k} * \max\left\{1.0 - V^i_{t,k}, 0\right\} \qquad (5)$$

A term default ($t < T$) occurs if and only if the collateral value per dollar loan amount drops below the term default trigger value, κ^{term}, and the loan has not defaulted before. Similarly, a maturity default ($t = T$) occurs if and only if the collateral value per dollar loan amount drops below the term default trigger value, $\kappa^{maturity}$, and the loan has not defaulted before. See Equations (6) and (7).

$$\begin{aligned} D^i_{t,k} &= 1 \text{ iff} \begin{cases} V^i_{t,k} < \kappa^{term} \\ D^i_{s,k} = 0 \text{ for } s < t \end{cases} \quad \text{for } t < T \text{ (term default)} &(6)\\ D^i_{t,k} &= 1 \text{ iff} \begin{cases} V^i_{t,k} < \kappa^{maturity} \\ D^i_{s,k} = 0 \text{ for } s < t \end{cases} \quad \text{for } t = T \text{ (maturity default)} &(7)\end{aligned}$$

The maturity default trigger value, $\kappa^{maturity}$, will generally be higher than the term default trigger value, κ^{term}, because typically at maturity a large final (balloon) payment is due.

3.2 Dynamics collateral value

The Loan-to-Value (LTV) ratio and the debt-service coverage ratio (DSCR) are the most common ratios to examine the probability of default and expected losses on a CMBS. In the baseline case, we focus on the LTV; in an alternative model calibration we will use the DSCR instead. Specifically, we assume the initial collateral value per dollar loan amount for a particular loan, $V^i_{0,k}$, equals the inverse of the loan-to-value (LTV) ratio. To price a contract at time t, we assume the collateral value change between the contract introduction date 0 and the evaluation date t is equal to the price change on REIT asset values, which in turn is a fixed multiplier times the price change on REIT equity values.

$$V^i_{t,k} = \frac{1}{LTV^i_{0,k}} * \frac{V^{asset}_t}{V^{asset}_0} \tag{8}$$

$$\frac{V^{asset}_t}{V^{asset}_0} - 1 = multiplier * \left(\frac{V^{equity}_t}{V^{equity}_0} - 1 \right) \tag{9}$$

For the risk-neutral dynamics between the evaluation date t and the maturity date T, we assume a standard geometric Brownian motion. The discretized version used in our numerical implementation is

$$\frac{V^i_{t+s+1,k}}{V_{t+s,k}} = \exp\left\{ r^r_t - \rho_t - \frac{1}{2}\left(\sigma^{asset}_t\right)^2 \right\} dt + \sigma^{asset}_t \sqrt{dt}\varepsilon_{t+s+1} \tag{10}$$

$$\sigma^{asset}_t = multiplier * \sigma^{equity}_t \tag{11}$$

where r^f is the risk-free rate, ρ is the dividend yield, σ^{asset}_t is the REIT asset volatility parameter, dt is the time interval size (assumed to be small), and ε is standard normally distributed. Notice that the REIT asset volatility obtains using REIT equity volatility and the same fixed multiplier introduced in Equation (9). Given that we use risk-neutral dynamics for the stochastic variables, we can compute the present value in Equation (1) by discounting at the risk-free rate.

3.3 Simplifying assumptions

While we believe the model above captures some of the main features that drive CMBX prices, it is important to notice that the model is simplified along several dimensions, including the following. First, we do not model amortization of the loan balance and instead assume all loans are interest only. Second, we do not allow for extensions upon maturity, neither do we explicitly model bankruptcy costs; the collateral value has thus the interpretation of the post-bankruptcy cost value. Third, we assume that the percentage change in collateral value is the same for all loans, at a given point in time, in a given scenario. Fourth, tranches are different with respect to the credit enhancement levels, but we do not explicitly model differences with respect to the order of repayment. Hence, the model does not discriminate between first-pay (A1) and last-pay (A4) super-senior AAA tranches, while CMBX AAA tranches only reference last-pay tranches.

3.4 Baseline case parameter values

We calibrate the contract parameters to the CMBX 4 AAA and AJ tranches; which are the two most senior CMBX tranches and are the most liquid. Time 0 refers to October 25th, 2007, the day CMBX 4 was initiated. The maturity date, time T, is assumed to be exactly ten years later, October 25th, 2017. The AAA and AJ tranche have a fixed coupon of $35bp$ and $96bp$ and insure deal losses in the $(30\%, 100\%)$ and $(12\%, 20\%)$ interval respectively.

Table 1: Baseline-case parameter values

This Table reports the baseline-case parameter values. The last two variables are considered free parameters and calibrated to minimize the root-mean squared error of the actual - model price, summed over the AAA and AJ tranche. The sample period start date for calibrating the free parameters is October 25th, 2007. We report values for sample period end dates at quarter year intervals, ranging from the end of 2008Q2 to the end of 2009Q3.

Name	Symbol	Value
Start date	$t = 0$	October 25th, 2007, the introduction date of CMBX 4
Maturity date	$t = T$	October 25th, 2017
Fixed coupon	c	$35bp$, $96bp$ per annum for AAA, AJ tranche of CMBX 4
Lower attachment point	CE^L	29.88%, 12.33% for AAA, AJ tranche of CMBX 4
Higher attachment point	CE^H	100.00%, 20.00% for AAA, AJ tranche of CMBX 4
Number of loans per deal	I	10
Original weight loan	w_k^i	10%, we assume 10 loans per constituent, all of equal size
Initial collateral value	$1/LTV_{0,k}^i$	$(1.04, 0.94, 0.63, 1.13, 0.91, 0.75, 1.23, 1.13, 1.13, 1.09)$
		times the mean value for constituent k
REIT equity return	$V_t^{equity}/V_0^{equity}$	Return on Dow Jones Real Estate Index
REIT equity volatility	σ_t^{equity}	Implied vol. of 1y ATM put on Dow Jones Real Estate Index
Risk free rate	r^f	Swap rate, linearly interpolation between 5- and 10-year rate
Dividend yield	ρ	4.99%
Maturity trigger value	$\kappa^{maturity}$	1.0
Term trigger value	κ^{term}	Distributed $N(\mu, 0.2)$, with $\mu = -\infty, -\infty, 0.2, 0.2, 0.2, 0.3$
Collateral/REIT equity vol	*multiplier*	0.70, 0.70, 0.60, 0.60, 0.65, 0.65

We assume each of the 25 constituents consists of 10 loans of equal size. The initial collateral value of the loans for a particular constituent is on average equal to the average of the reported inverse loan-to-value (LTV) ratio. The distribution of constituent average inverse LTV has a mean of 1.45 and a standard deviation of 0.10.[10]

[10]Based on the November 2008 CMBX monthly report by Citi.

The model has two free parameters, which we calibrate to minimize the sum of the root mean squared error (RMSE) for the AAA and AJ tranche. We calibrate the two free parameters using an expanding window, with end dates at quarter ends from 2008Q2 to 2009Q3.

The term default trigger value is distributed normal. The mean of this distribution is the first free parameter. Using data up to the end of 2009Q3, we find an optimal value of 0.3. Using data only up to 2008Q2, the optimal value is $-\infty$, implying no term defaults. The optimizer chooses the $-\infty$ value to match the relatively high AJ prices before 2008Q2, considering that –as we will show– the AJ model price is higher the lower the trigger value. The standard deviation of the distribution is fixed at 0.2. The maturity trigger is set at 1.0, i.e. losses occur whenever the collateral value is lower than the loan balance at maturity.

The REIT equity return is calibrated to the return on the Dow Jones US Real Estate Index (Bloomberg ticker: IYR US) and the REIT volatility is calibrated to 1-year at-the-money put options on the same index. The dividend yield, ρ, is set at 4.99%, the average dividend yield from August 2004 to July 2009 for the NAREIT Equity index and close to the dividend yield of 4.92% for July 2009.[11] The risk-free interest rate, r^f, is determined using the 5- and 10-year swap rate and interpolating to obtain a swap rate for a $\tau = T - t$ time to maturity

$$\begin{aligned} r^f(\tau) &= w(\tau) R_t^{swap}(5) + (1 - w(\tau)) * R_t^{swap}(10) \\ w(\tau) &= \frac{10 - \tau}{10 - 5} \end{aligned} \quad (12)$$

The multiplier is the second free parameter. Using data up to the end of 2009Q3 we find a value of 65%, which is consistent with a situation with a $50 - 50\%$ debt-equity financing for REITs and debt market value changes being equal to 30% of equity market value changes. Using data up to the end of 2008Q2, we find a value of 70%.

As a technical note, to determine the model mispricing we take out accrued dividends for REITs and accrued coupons for CMBX. This is to prevent REIT prices to have a predictable quarterly jump when the stock goes ex-dividend, and, similarly, to prevent the CMBX price to have a monthly jump when it goes ex-coupon. The REIT accrual is computed using the previous' month dividend, because the size of the upcoming dividend is not known a quarter year ahead of time. The accrual correction has a negligible effect on the presented results, but we considered it theoretically correct. Returns for REIT stocks and CMBX take into account dividend and coupons respectively.

3.5 Numerical Procedure

For each date, for each of the three tranches, and for each of the 25 constituents, we determine the present value of the cash flows under the CMBX contracts in Equation (1) by means of a Monte Carlo simulation method. Using the build-in Matlab random number generator, we simulate 50 random paths for the risk-neutral distribution using Equation (10) with 100

[11] See http://www.reit.com/portals/0/files/nareit/htdocs/library/domestic/Monthly%20Historical%20Returns.xls

steps, i.e. $dt = (T - t)/100$. We double the number of random paths to 100 by using the negated simulated standard normal shocks as well, a method referred to as antithetic variates, aimed at increasing the precision for a given number of paths. We use the same paths for the different dates and tranches to facilitate comparison, but we use a different set of 100 paths for each of the 25 constituents.

It is straightforward to show that we can apply the Black and Scholes (1973) model under alternative parameter values: if there are no defaults prior to maturity, i.e. $\kappa^{term} \sim N(0, 0)$, and the loans underlying a particular deal are identical, i.e. the initial collateral value distribution for deal k has a unit mass at the mean. Comparing the numerical and closed-form Black and Scholes (1973) prices under the alternative parameter values provides a powerful check on the precision of the numerical procedure; we find that the average absolute difference between the numerically-determined and theoretical value is only \$0.05 and \$0.20 per \$100 notional for the AAA and AJ tranche respectively.

4 Model results

We start by presenting the model fit for the baseline-case model. Next we discuss the sensitivity of the fit to different input parameter values. In the last two Subsections we explore to what extent a model mispricing leads to predictability in subsequent CMBX price changes.

4.1 Baseline-case results

In Figure 1, left panel, we plot the actual AAA price versus the value of two models: (i) the options-based model discussed above, (ii) the model of JP Morgan Chase as reported in their daily CMBX evaluator report. We use the 2009Q3 calibration end date for the two free parameters.

In the option model, the AAA tranche absorbs substantial losses and reaches a low model value of \$59.25 on March 30th, 2009. The actual-model price differential is on average $-$\$2.15. The root mean squared error (RMSE) is \$5.41. The correlation between the baseline-case model and actual price is 93%; put differently, the model explains 86% of the actual price variation, measured by the R-squared statistic in a linear ordinary least squares regression with constant.

The broker model is based on economic scenario analysis. In none of the scenarios does the projected deal loss exceed the super-senior AAA credit enhancement level of 30% at any time, and therefore this tranche trades slightly above par throughout the entire sample period. While the broker model may prove to be correct in the sense that the AAA may turn out taking no losses, our results suggest that the broker model then logically also implies REIT stock and/or options were mispriced over the sample period.

We also determined model values using the option model without term defaults triggers and identical loans, which can be evaluated using the closed-from Black and Scholes (1973) option pricing formula (not depicted). On average the actual - model AAA price differential then is $-$\$1.41 and the RMSE is \$5.71. In particular in the November 2008 to April 2009 period when CMBX traded at its lowest values for our sample period, ignoring term defaults leads to underestimating the model price. The correlation between actual and model prices is still 93% though.

In Figure 1, right panel, we present the actual price and option model price for the AJ tranche. The average actual-model differential is $2.69 and the RMSE is $8.45. The correlation between the actual and model price is 94%, or put differently, 88% of the price variation is explained by the model.

4.2 Sensitivity analyses

In Table 2 we present the sensitivity of the average model price to increasing key model parameters by 10%. First, increasing the multiplier variable leads to both a larger decline in REIT property values since the start of the index, Equation (9), and a higher volatility of property values, Equation (11). The average model price for the AAA and AJ tranches decreases by $2.87 and $3.98 per $100 notional respectively. Second, increasing the average term trigger value increases the AAA model price because losses are capped at a lower level. In contrast, the AJ model price decreases because losses at the higher term trigger value still exceed the credit enhancement and the probability of hitting the trigger increases. Third, increasing the standard deviation of the term trigger value by 10% changes the average model price only moderately with the largest change of $0.29 for the AAA tranche. In all three cases, and for each of the two tranches, the correlation (over time) between the price for the model with baseline-case parameters and the alternative model is above 99%.

Table 2: Sensitivity average model value to changes in key model parameter values

The table shows the dollar change in the average model value (per $100 notional) for the AAA and AJ tranche when key model parameter values are increased by 10%.

	AAA	AJ
+10% multiplier	−2.87	−3.98
+10% mean term trigger value	0.53	−1.03
+10% standard deviation term trigger value	0.29	−0.22

As an additional sensitivity test we calibrated the change in property values from the start of the index to the moment of price evaluation to the debt service coverage ratio (DSCR) instead of the inverse loan-to-value (LTV) ratio in Equation (8). The correlation between the model price in the baseline case and the alternative case are above 99% for both tranches.

Next, we consider a specification in which we use a proxy for the long-term volatility of REIT equity, instead of using the implied volatility of 1-year options. The proxy is determined as a linearly-interpolated value between the implied volatility of 1-year at-the-money REIT put options and the volatility of a 10-year at-the-money REIT put option, with the latter determined using the term-structure of volatilities available for S&P at-the-money put options. Specifically, for a maturity τ we have

$$\sigma_t^{equity}(\tau) = w(\tau) * IV_t^{REIT}(1) + (1 - w(\tau)) * IV_t^{REIT}(1) * \frac{IV_t^{S\&P}(10)}{IV_t^{S\&P}(1)} \quad (13)$$

$$w(\tau) = \frac{10 - \tau}{10 - 1} \quad (14)$$

where IV stands for implied volatility. Again, the correlation between the baseline-case and alternative model prices is above 99% for both tranches.

Finally, instead of REIT data, we use S&P 500 data for the stock price and 1-year at-the-money option implied volatility. We re-optimize the sum of the RMSE for the AAA and AJ tranche over the two free parameters per the end of 2009Q3. We find a multiplier of 1.05, larger than the 0.65 for REITs, which is intuitive given the lower volatility of S&P stocks over the sample period. We find a term trigger value of 0.2; compared to 0.3 for REITs. The model fit for the AAA deteriorates just slightly, with an RMSE \$5.58 using S&P data, compared to \$5.41 when using REIT data. One explanation for why the model fit for the AAA tranche does not deteriorate much when using S&P instead of REIT data might be that the AAA tranche only incurs losses in the worst-case economic scenarios and that in such scenarios stocks for different sectors tend to co-move (down) to a great degree. The model fit for the AJs deteriorates by as much as 10%, with an RMSE of \$9.28 using S&P data, compared to \$8.45 when using REIT data. This suggest that using REIT data is preferred to using S&P data. In the next subsection we will explore whether the model calibrated to S&P data contains predictive information over and above the model calibrated to REIT data.

4.3 Statistical significance: predictive power model mispricing

Next we study the the predictive power of the actual-model price differential for the subsequent change in the CMBX price, the REIT stock price, and the REIT option implied volatility. To this end we run predictive regressions with a constant and a two-day lagged actual-model price differential as independent variables, see Table 3. As control, we also include the contemporaneous change of the other two assets values as independent variables, i.e. for the regression with the change in CMBX AAA price as dependent variable, the contemporaneous change in the REIT stock price and the REIT option implied vol are added as independent variables. Results are similar when omitting these control variables (not reported).

CMBX price changes are significantly predicted by the actual-model price differential, with the negative sign indicating that when the actual CMBX price is higher than the model price, the actual CMBX price is predicted to go down. This result holds similarly for the 2009Q3 calibration (Panel A) and the expanding calibration (Panel B). Notice that the AAA (AJ) price change is best predicted by the lagged AAA (AJ) mispricing, as one would expect. The Newey-West corrected t-stats (25 lags) on the lagged mispricing for predicting subsequent change in the corresponding CMBX tranche range from 2.2 to 3.1. Inspecting the results with the change in REIT stock price and REIT option implied volatility as dependent variables, no significant predictive relation is uncovered. In sum, we find evidence that a

Table 3: Predictive regressions

The table reports Newey-West corrected t-stats (25 lags); each for a different regression. The dependent variables considered are the change in the CMBX AAA price, CMBX AJ price, REIT stock price, and REIT option implied volatility. The independent variable for which the t-stat is reported is either the model-implied mispricing of the AAAs or the model-implied mispricing of the AJs, lagged by two days. For the regressions with CMBX as dependent variable, we include as controls the contemporaneous REIT stock price change and REIT implied volatility change. For the regressions with REIT stock price (option implied volatility) as dependent variables we include as controls the contemporaneous CMBX price changes (of the tranche for which we use the mispricing) as well as the contemporaneous change in REIT implied volatility (REIT stock price change). T-stats on these control variables are not reported. In each case we include a constant as independent variable.

Panel A: model mispricing based on 2009Q3 calibration

Dependent variable	AAA	AJ	REIT stock	REIT option
T-stat mispricing, using AAA	−2.52	−2.60	0.16	−0.44
T-stat mispricing, using AJ	−1.96	−3.05	1.15	1.34

Panel B: model mispricing based on expanding calibration

Dependent variable	AAA	AJ	REIT stock	REIT option
T-stat mispricing, using AAA	−2.16	−2.04	0.87	0.44
T-stat mispricing, using AJ	−2.11	−3.01	0.43	0.78

non-zero actual-model price differential arises from a mispricing in the CMBX market, not a mispricing in the REIT market.

As an additional exercise, we run a predictive regression for the CMBX AAA and AJ price change using as independent variables both the lagged mispricing of the baseline-case model calibrated to REITs and the lagged mispricing of a model calibrated to S&P 500 data (discussed in the previous Subsection). We include as controls the contemporaneous change in the REIT stock price, REIT implied volatility, S&P 500 stock price, and S&P 500 implied volatility. For the AAA tranche, the t-stat on the mispricing based on REIT and S&P 500 data is -1.18 and -0.47 respectively. For the AJ tranche the t-stat on the mispricing based on REIT and S&P 500 data is -1.85 and -0.03 respectively. This further confirms that the model based on REIT data is preferred. Moreover, the model based on S&P data does not contain much predictive information over and above the model calibrated to REIT data

4.4 Economic significance: performance strategy based on model mispricing

In this Subsection we analyze the economic significance of the predictability in CMBX prices, uncovered above, by means of back testing a simple trading strategy. It is not possible to directly trade on the convergence of the actual-model price differential to zero because the model price is not the price of a traded portfolio of securities; the model is merely calibrated to prices of traded securities. An additional consideration is that options are expensive to trade. For these reasons we prefer a simple strategy trading only CMBX and REIT stocks.

The model view is summarized by the standardized raw signal, S_t^{raw}:

$$S_t^{raw} = -\frac{\left(P_t^{actual} - P_t^{model}\right) - \mu\left(P_s^{actual} - P_s^{model}|s = 0, ..., t\right)}{\sigma\left(P_s^{actual} - P_s^{model}|s = 0, ..., t\right)} \tag{15}$$

with the mean and standard deviation for the standardization determined using data up to time t (hence an expanding window). The standardized value is often referred to as the z-score. It is important that we only use data known at time t for the standardization; the use of future data would result in a severe look-ahead bias. The use of a standardization is a common trick with two main benefits: (i) the back test results are more robust to alternative model calibrations, because the results are invariant to linear transformations of the mispricing, and (ii) it leads to more stable signal values in the face of time-varying volatility. Because of the substantial transaction cost, we define a trade signal which has less turnover. At time t we invest in a CMBX tranche an amount proportional to the trade signal:

$$S_t^{trade} = S_{t-1}^{trade} + 0.2, \text{ if } S_t^{raw} - S_{t-1}^{trade} > 0.5 \tag{16}$$

$$S_t^{trade} = S_{t-1}^{trade} - 0.2, \text{ if } S_t^{raw} - S_{t-1}^{trade} < -0.5 \tag{17}$$

In words, we increase (decrease) the trade signal by 0.2 if the raw-trade signal differential exceeds 0.5 (-0.5). The trade signal value at the start of the back test is set to zero.

The CMBX position is hedged with REIT stocks, with the hedge ratio in the baseline case determined as the slope coefficient (beta) in a regression of overlapping five-day CMBX returns on a constant and the contemporaneous REIT stock returns, using data from time 0 to t (i.e, again an expanding window).[12] We don't set the hedge ratio equal to the delta of the model price because violations of model assumptions, like a constant volatility parameter, likely leads to a biased hedge ratio.[13]

In order to provide conservative back test results, in the baseline case we (i) use the expanding model calibration, (ii) use a trade lag of 2 days, meaning that the trade signal at time t is used for a trade at time $t+1$ leading to a certain strategy return between time $t+1$ and $t+2$. (iii) assume a realistic round-trip transaction cost (bid-ask spread) of \$1 per \$100 notional CMBX.[14] Transaction cost on the REIT hedge are an order of magnitude smaller and ignored in the analysis. We start the back test June 30th, 2008, the earliest date we calibrated the free model parameters. The test runs through October 30th, 2009.

In Figure 4, top Panel, we provide the back-tested returns for a strategy using the AAA tranche (solid line), the AJ tranche (dashed line), and a $50-50\%$ combination of the two strategies (dash-dotted line). Returns are scaled to 10% annual volatility. Both the AAA and AJ tranche perform well standalone, but the combination works substantially better. The reason is that the AAA and AJ strategy have negatively correlated returns, which in turn is a result of opposite trade signal values for the AAA and AJ strategy in the fall of 2008 and in April and May of 2009, see bottom Panel of Figure 4.

In Table 4 we report the annualized net Sharpe ratio of the back test for the baseline case and several alternative specifications.[15] In the baseline case strategies for the AAA and AJ tranche have a net Sharpe ratio of 1.50 and 1.30 respectively, and a $50-50\%$ combination of the two strategies has a net Sharpe ratio of 2.35. To put this in perspective, Duarte, Longstaff, and Yu (2007) back test five popular fixed-income arbitrage strategies and find a maximum Sharpe ratio of only 1.20. Remarkably, this highest Sharpe ratio is for the capital structure arbitrage strategy implemented with Credit Default Swaps; of the five strategies considered the most similar in spirit to the strategy explored in this paper.[16]

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[12]Using five-day, rather than daily, returns is to control for the high fraction of idiosyncratic risk in daily returns and leads to substantially higher hedge ratios compared to using daily returns.

[13]In a previous version of this paper, we did show back test results for the AAA tranche with a hedge portfolio of both REIT stocks and REIT options to obtain a zero delta and vega for the CMBX and hedge combined. The annualized gross Sharpe ratio was 1.7; lower than what we will report in the current paper, but still substantial.

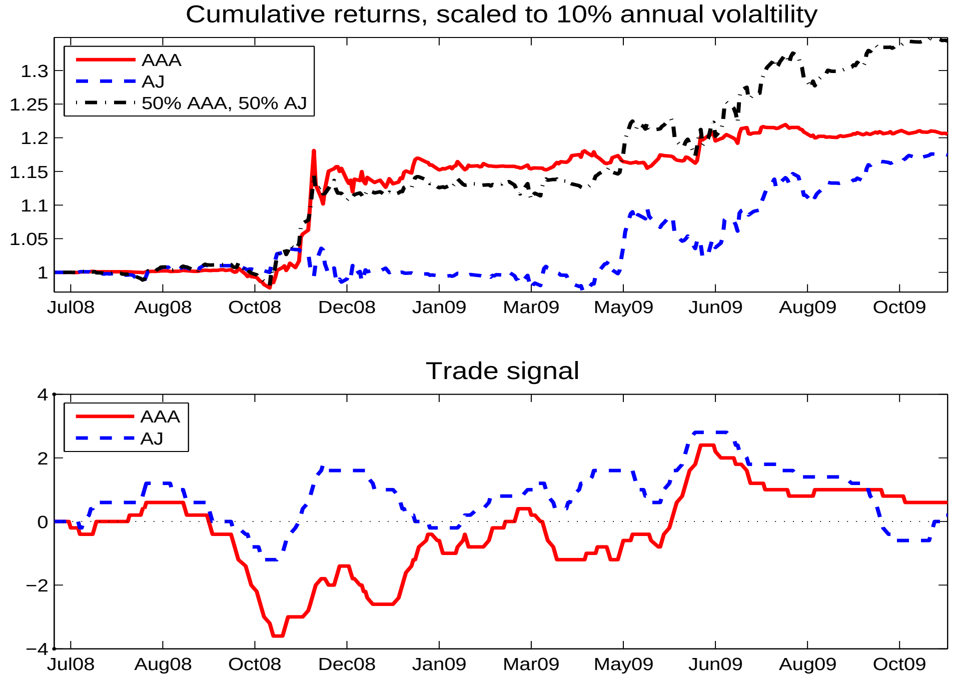
[14]The author traded CMBX during most of the sample period and experienced first hand that a \$1 bid-ask spread applied across all of the main brokers and over the entire sample period. The maximum size brokers were willing to trade at this bid-ask spread did vary over time.

[15]The Sharpe ratio is defined as the mean of the daily return divided by the standard deviation of the daily return, times the square root of 260 to annualize (260 being a typical number of business days in a year).

[16]While the most similar, the capital structure arbitrage strategy is different to our strategy in several important ways. First, Duarte, Longstaff, and Yu (2007) focus on corporate Credit Default Swaps, while the CMBX contract used in this paper references Commercial Mortgage-Backed Securities. Second, they use a public model called CreditGrades which may make the arbitrage trade crowded, while we derive a novel model. Third, in this paper we study relative value between CMBX and REITs, which are derivatives on similar though not identical underlying assets. Finally, the CMBX contract we study is used as a hedge

Figure 4: Back test results

The top Panel of the Figure shows the back-tested returns, net of transaction cost, for a strategy trading the AAA tranche, a strategy trading the AJ tranche, and a 50-50% combination of the two strategies. In all cased, the general commercial real estate exposure is hedged using REIT stocks. Returns are scaled to 10%. The bottom Panel reports the trade signal, to which the CMBX position size in the back test is proportional.



As can be seen in Table 4, results are robust to changing the trade lag from 2 days to 1, 3, or 4 days, calibrating the hedge ratio based on 1-day returns instead of 5-day overlapping returns, using a rolling rather than an expanding window for the determination of the trade signal and beta, halving or doubling the trade trigger, and halving or doubling the trade size. In each case the $50-50\%$ combo strategy has a net Sharpe ratio greater than 2.0. Comparing the baseline-case results in the first row to the results without transaction cost in the second-last row of Table 4, we see a substantial difference between the net Sharpe ratio of 2.35 and the gross Sharpe ratio of 2.75. Hence the good performance of the strategy is in spite of substantial transaction cost. Comparing the baseline-case results with a specification based on a 2009Q3 calibration of the free model parameters (last row in Table 4), we see that the in-sample calibration substantially improves the standalone performance of the AJ strategy. However, using the 2009Q3 calibration also increases the correlation between the AAA and AJ strategy returns. The net effect on the $50-50\%$ combination strategy is a modest increase of the net Sharpe ratio from 2.35 in the baseline case with an expanding calibration to 2.59 in the case of using a 2009Q3 calibration.

5 Response of the CMBX market to news announcements

In this Section, we first provide a general discussion of the main news event relevant for the CMBS market. Next we analyze how the CMBX market responded to those news announcements. The model comes in handy for analyzing the market response to news, because focusing on the actual minus model return (change in the mispricing) is a less noisy return measure and therefore enhances the statistical power for detecting patterns.

5.1 General discussion of the main CMBS news events

In Table 5 we report the main CMBS news events, defined by events that satisfy two criteria (i) Bank of America sent out a special report on the event, (ii) Bloomberg reported the event. We add the second criterion because two of the special broker reports were not on a new topic and no mentioning on Bloomberg could be found around the report issue date. We take this formal approach to the definition of news to prevent data snooping that could bias the statistical tests on the response to news later in this Section.

On August 15th, 2008, news broke that a mortgage loan collateralized by the Riverton apartments in Harlem, New York City was transferred to the special servicer due to imminent default. The loan, referenced by the CMBX 3 series, was particularly worrying because it shun light on the practice of pro forma underwriting, using project rather than realized cash flows for reported multiples as the debt-service coverage ratio (DSCR). As can be seen in Figure 1, this was not yet the moment the CMBX took a nose dive and neither did the REIT market, evidenced by model prices remaining relatively flat as well.

instrument for the distressed commercial mortgages and loans on bank balance sheets, possibly reducing the efficiency of pricing during our sample period –a time of great distress– and increasing arbitrage opportunities.

Table 4: Back-tested net Sharpe ratios

The table shows the net Sharpe ratio of the baseline-case model and several alternative specifications. The sample period for the back test is June 30th, 2008 to October 30th, 2009. For the baseline case model we lag the trade signal by two days, the hedge ratio is determine using a beta based on 5-day overlapping returns, the trade signal and beta are determined using an expanding window starting October 25th, 2009, the trade trigger is a z-score of 0.50, the maximum trade size is the amount corresponding to a z-score of 0.2, round-trip transaction cost are 1free model parameters are calibrated using an expanding window.

	AAA	AJ	Combo
Baseline	1.50	1.30	2.35
Lag = 1	1.57	1.28	2.44
Lag = 3	1.36	1.35	2.22
Lag = 4	1.21	1.51	2.17
Hedge ratio based on non-overlapping daily returns	1.50	1.62	2.69
Rolling, 170d window for trade signal and beta	1.52	2.27	2.14
Trade trigger at z=0.25 instead of z=0.50	1.41	0.96	2.01
Trade trigger at z=1.00 instead of z=0.50	1.30	1.62	2.28
Trade size cap at z=0.10 instead of z=0.20	1.11	1.73	2.14
Trade size cap at z=0.40 instead of z=0.20	1.52	1.10	2.22
Zero transaction cost	1.73	1.56	2.75
2009Q3 instead of expanding calibration	1.62	2.75	2.59

Table 5: Main news events

This Table reports the news announcements for which both (i) Bank of America issued a special report, and (ii) Bloomberg reported the event. The first column presents the title of the report. The second column presents the date and time (EST) Bloomberg reported on the announcement.

Title report	**Date, Time Bloomberg**
Riverton Apartments - Big CMBX.3 Loan - In Trouble	20080815, 01:50:29
Peter Cooper & Stuyvesant Two Loans Cause Downgrade	20080922, 17:26:31
Peter Cooper & Stuyvesant Two Loans Cause More Downgrades	20081016, 09:46:04
GGP CMBS Loans: Balloon Loan Pays Down, ARD Loan Extends	20081020, 03:22:42
Fitch Follows and lowers ratings on PCV & Stuy Town	20081029, 16:36:55
Circuit City to close 155 stores	20081103, 16:59:15
JPMCC 2008-C2 (CMBX.5): 2 Big Loans 30-days Delinquent	20081118, 13:45:05
MLMT 2008-C1: DBSI Loans To Special Servicing	20081121, 11:18:24
Maguire Says GG10 Hope Street Loan is Current	20090115, 06:44:46
BACM 2006-3: Big Interest Shortfall on Boscov's Loans	20090108, 07:58:08
Goody's Files for Bankruptcy Protection Again	20090114, 08:33:29
Peter Cooper / Stuy Town Update	20090122, 13:53:59
Treasury launches program for Distressed Legacy Assets	20090323, 08:01:52
S&P follows suit - says recent vintage downgrade risk is high	20090406, 15:06:01
TALF: Clarification by the Treasury Caps Max Leverage	20090406, 13:05:47
Fitch's turn and S&P follow-up	20090408, 11:53:56
CMBX 5: Appraisal reductions lead to interest shorfalls	20090414, 17:15:25
GGP files for bankruptcy includes many CMBS loans	20090416, 01:58:14
TALF for new issue CMBS	20090501, 14:01:53
Legacy CMBS TALF Guidelines Better than expected	20090519, 14:00:07
S&P proposal puts CMBS Legacy TALF in jeopardy	20090526, 14:42:14
S&P finalizes methodology change	20090626, 12:23:16
CMBS TALF Update - July 16th first legacy subscription	20090702, 16:12:41
Peter Cooper / Stuy Town deals on watch by Moody's (again)	20090714, 16:40:10
NY Fed announces accepted and rejected TALF collateral	20090722, 18:46:29
TALF Extended	20090817, 09:02:12
TALF Round 2: 83 Accepted, 3 Rejected	20090826, 18:39:29
New guidelines on modification rules for REMICs	20090915, 11:44:53
Legacy TALF round 3: All accepted	20090923, 17:22:16
Legacy TALF round 4: 5 rejected, 81 accepted	20091027, 22:07:45

During September 2008, several news events occurred that were negative for the stability of the financial system and economy, including the news that Lehman Brothers filed for bankruptcy protection on September 15, 2008. Implied volatilities rose to unprecedented levels after that, e.g. the VIX index rose from 25.66 on September 12, 2008 to 80.06 on October 27th, 2008. As can be seen in Figure 1, the model price, calibrated to implied volatilities, declines in this period much more than the actual price does. This lead to a brief period of large positive mispricing.

Mid November 2008 the CMBX market got several news announcements it responded very negatively to, after which the CMBX 4 AAA tranche traded at a negative mispricing according to our model, with a local minimum of −\$6.62 on November 20th, 2008. First, on November 12th, 2008, U.S. Treasury Secretary Henry Paulson announced his plan to scrap an effort to use Troubled Asset Relief Program (TARP) funds to buy distressed mortgage assets.[17] Next, on November 18th, two large loans on the Promenade Shops at Dos Lagos and the Westin portfolio, referenced by the CMBX 5 series, were reported to be 30-days delinquent and were transferred to the special servicer.

In the spring of 2009 good and bad news announcements took turns. Good news came from the Government that expanded the Term Asset-Backed Loan Securities Facility (TALF) to include new and later also legacy CMBSs. Also the Public-Private Investment Program (PPIP) was introduced. The bad news came predominantly from S&P, which became more strict on credit ratings for CMBS. The direct consequence of a downgrade is twofold. First, some institutions have a requirement to only hold assets of a certain rating level, or have to hold more capital for securities of a lower rating. Second, for a CMBS to be eligible for funding under the TALF program, it cannot be downgraded. The first in a series of S&P announcements was a request for comments on a new rating methodology on May 26th, 2009. Three weeks later on June 15th, 2009, the CMBX 4, AAA mispricing reached its lowest level of the entire sample period at −\$14.33.

5.2 Short-term market response to news

Next we analyze the market response to the news announcements included in Table 5 during the first four weeks after the announcement. Because our model explains a substantial fraction of the variation in CMBX prices, we focus on changes in the model mispricing following news announcements, providing us with a less noisy return measure that may be better suited to detect statistically significant patterns.

We define the change in the mispricing, $\tilde{R}_t$, as the actual return minus the model return, Equation (18). On an announcement day, event time 0, the sign of the change in the mispricing, $sign\left(\tilde{R}_0\right)$, measures whether the market considered the news as good (sign is 1) or bad (sign is −1), relative to the model based on REIT data. To measure whether on subsequent days the market moves in the same or opposite direction, we introduce the signed change in mispricing, $\tilde{R}_t^{sign}$, Equation (19). Now the cumulative response at event time t,

[17]This event is not included in Table 5 because no special report was issued.

$\tilde{R}_t^{cum}$ is the sum of signed mispricing changes from time 0 to event time t, Equation (20).

$$\tilde{R}_t = R_t^{actual} - R_t^{model} \tag{18}$$

$$\tilde{R}_t^{sign} = \tilde{R}_t * sign\left(\tilde{R}_0\right) \tag{19}$$

$$\tilde{R}_t^{cum} = \sum_{s=0}^{t} \tilde{R}_t^{sign} \tag{20}$$

For each event time, we determine the average and median signed change in mispricing across events, then apply Equation (20) to compute the average and median cumulative response, which we plot in Figure 2. We omit the last news day of Table 5 from our set of news days, because at the time of writing we do not have sufficient days of data following this news announcement.

On the day of the announcement, the average change in signed mispricing is 2.6%. The average cumulative response reaches a peak two days later at 4.1%. This could be consistent with either initial underreaction or subsequent overreaction to news. The sharp decrease in the cumulative response two to five days after the news announcement points to overreaction. Also the median cumulative response peaks two days after the announcement and fully reverts in the subsequent three days, suggesting the pattern is not explained by extreme outliers.

We proceed by investigating the statistical significance of the overreaction to news on the days following a news announcement. In Table 6 we show the t-stats for the beta coefficient of the following two regression specifications

$$\tilde{R}_t = \alpha + \sum_{lag=1}^{6} \beta_{lag} \tilde{R}_{t-lag} D_{t-lag} + \sum_{lag=1}^{6} \gamma_{lag} \tilde{R}_{t-lag} + \varepsilon_t \tag{21}$$

$$\tilde{R}_t = \alpha + \sum_{lag=1}^{6} \beta_{lag} sign\left(\tilde{R}_{t-lag}\right) D_{t-lag} + \sum_{lag=1}^{6} \gamma_{lag} sign\left(\tilde{R}_{t-lag}\right) + \varepsilon_t \tag{22}$$

where $\tilde{R}$ is as above the change in the mispricing defined as the actual minus model return, and D is a dummy taking a value of one on a news day. T-stats are Newey-West corrected with 10 lags included. Notice that the beta coefficients measure the effect of news on price continuation and reversal *in addition* to general short-term price continuation and reversal. The results in Table 6 indicate that the return continuation the first two days following a news announcement is significant. The three days after that, the mispricing reverts significantly. None of the γ coefficients is significant and omitting the γ terms leads to very similar significance for the β coefficients.

6 Conclusion

Our test results for the efficiency of the commercial real estate market over the October 2007 – October 2009 period are mixed. On the one hand, the general price swings experienced

Table 6: Response to news

The table shows the t-stat for the coefficients of two multiple regressions. The dependent variable in both cases is the change in mispricing at time t. For the first specification the independent variables are a constant and the change in mispricing at a lag of 1 to 6 days, with and without interaction with a dummy taking the value of one if at time $t - lag$ there was a news announcement. For the second specification the independent variables are a constant and the sign of the change in mispricing at a lag of 1 to 6 days, with and without interaction with a dummy taking the value of one if at time $t - lag$ there was a news announcement. Only the t-stats on the dependent variables with interaction with the news dummy are reported. None of the other variables are significant.

	Using $R_{t-lag}D_{t-lag}$	Using $sign\left(R_{t-lag}\right)D_{t-lag}$
Variable	T-stat	T-stat
β_1	2.53	1.98
β_2	2.50	1.30
β_3	-2.41	-1.32
β_4	-3.45	-2.75
β_5	-2.74	-2.11
β_6	0.13	-0.31

by the CMBX 4, AAA and AJ indices are largely explained by our structural option model, which is calibrated to REIT stock and option data. On the other hand, at shorter horizons, we document predictability in CMBX prices relative to REIT prices that is both statistically significant and economically meaningful.

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