Mildly Explosive Dynamics in U.S. Fixed Income Markets*

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Abstract

We use a recently developed right-tail variation of the Augmented Dickey-Fuller unit root test to identify and date-stamp periods of mildly explosive behavior in the weekly time series of seven U.S. fixed income yield spreads between September 2002 and January 2015. We find statistically significant evidence of such behavior in six of these spreads. Mild explosivity migrates from short-term funding markets to more volatile medium- and long-term markets during the Great Financial Crisis. For some markets, we statistically validate the conjecture, originally suggested by Gorton (2009a,b), that the financial panic of 2007 initially migrated from segments of the ABX market to other U.S. fixed income markets.

JEL Classification: G01, C58

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1 Introduction

Yield spreads are widely used in theoretical and empirical modelling in macroeconomics and finance as measures of financial risk. Often, they offer investors a clearer picture of the underlying financial trade-offs than the individual yields (or interest rates) that are used to construct them. Yield spreads can be especially informative of the channels through which financial asset prices affect (or are related to) the real side of an economy, as their magnitude tends to vary following or anticipating the business cycle.[1] As it is extensively documented in the empirical literature, many spreads tend to suddenly spike at times of financial distress.[2] It follows that understanding the dynamics of risk and risk premia incorporated in the prices of securities and corresponding spreads has practical implications for both policymakers and portfolio managers.[3] The ability to identify the particular market segments in which risk premia exhibit unstable behavior at times of crisis may allow policy makers to better calibrate their interventions. By comprehending and, possibly, discerning how such unstable dynamics migrate across the economy, policy makers can evaluate the degree of insularity of individual markets to economic and financial shocks. Moreover, changes in the time evolution of risk premia can suggest investors alternative diversification approaches and may have consequences on the cost of borrowing, the portfolio strategies of different types of economic agents, and the way interest rates and yield spreads are (or should be) modelled for economic and financial forecasting.

Both researchers and practitioners generally view U.S. fixed income markets as the epicenter of the Great Financial Crisis of 2007-09. In this paper, we propose a data-driven econometric exercise characterized by a twofold objective: (i) the identification of the segment of U.S. fixed income markets that represents the core of the Great Financial Crisis;

[1]Gourio (2014) shows that there exists high correlation between bond spreads and real investment. Faust, Gilchrist, Wright, and Zaikrajsek (2013) show that some credit spreads improve forecast accuracy. Hollander and Liu (2016) document significant widening of several credit spreads – namely, the difference between the mortgage loan rate and the 3-month Treasury Bill rate, the difference between the Baa-rated corporate bond rate and the 3-month Treasury Bill rate, and the difference between the Fed funds rate and the 3-month Treasury Bill rate – during the most recent U.S. recessions.

[2]See Krishnamurthy and Muir (forthcoming) for a cross-country perspective and Guidolin and Tam (2013) for a specific view on the Great Financial Crisis.

[3]Among others, see Jacoby, Liao, and Batten (2009) and Batten, Jacoby, and Liao (2014) for a discussion about the relationship between real interest rates and corporate yield spreads.

and (ii) the description of how the financial turmoil developed and spread across markets. We do so by conducting an empirical investigation on the weekly time series of seven yield spreads derived from a variety of instruments and yields in U.S. fixed income markets – that we treat as a class of assets – between the end of 2002 and early 2015. This group of instruments includes the 3-month London interbank offered rate (LIBOR) on unsecured deposits, the 3-month unsecured financial and asset-backed commercial paper (ABCP), the 1-year Aaa adjustable-rate mortgages (ARM), the 5-year Aaa private-label commercial mortgage-backed securities (CMBS), the 20-year Moody's Baa-rated and Aaa-rated corporate bonds, the 20-year Moody's Bbb-rated and Aa-rated corporate bonds, and the 30-year conventional fixed-rate mortgage-backed securities (MBS). Given that the U.S. mortgage market is often identified as the catalyst of the 2007-09 crisis, this list purposely comprises three variables from which mortgage-related risk premia are typically constructed.

This paper builds upon two strands of the empirical literature. The first strand refers to recent empirical work conducted on U.S. fixed income markets and their relation to the Financial Crisis and other macroeconomic fluctuations (see, for example, Guidolin and Tam, 2013; Contessi, De Pace, and Guidolin, 2014; Hollander and Liu, 2016; Del Negro, Giannone, Giannoni, and Tambalotti, 2017). The second strand deals with statistical methods developed to detect episodes of contagion and/or bubbles in market data and to study their transmission across sectors, industries, or economies (see Forbes and Rigobon, 2001, 2002; Dungey and Zhumabekova, 2001; Dungey, Fry, Gonzalez-Hermosillo, and Martin, 2005; Pesaran and Pick, 2007). In this work, we adopt a testing and date-stamping technique, formulated by Phillips and Yu (2011) and refined in Hurn, Phillips, and Shi (2015), to identify the periods over which the seven yield spreads in the sample exhibit mildly explosive behavior. From a statistical point of view, this approach is based on a recursive and rolling right-tail variation of the Augmented Dickey-Fuller (ADF) unit root test in which, under the alternative hypothesis, the time-series process under investigation exhibits (at least locally) a root larger than one. In its original formulation and applications, such an empirical strategy allows for the detection (and the date-stamping of both origination and termination) of bubbles in the time series of an asset price of interest.[4] However, more broadly and depending on the specific context, this strategy can be useful to identify episodes of exuberance, collapse, and adjustment, as well as structural breaks, periods of regime change, or incidents of panic and turmoil in a given market. Once detected in the yield spreads in the sample, we study the propagation of their mildly explosive behavior, which we can view as financial distress, across segments of U.S. fixed income markets.

Overall, we find evidence of mildly explosive behavior in six out of the seven yield spreads in the sample and show that such unstable dynamics peak in the corresponding six underlying U.S. fixed income markets between August 2007 and January 2009 and occur sequentially first in short-term funding markets and later in more volatile medium- and long-term markets. We also detect a pattern of migration of these unstable dynamics during the period of the Great Financial Crisis. In particular, migration occurs from short-term funding markets to more volatile medium- and long-term markets.

Furthermore, we formally investigate the conjecture, originally proposed by Gorton (2009a,b), that the collapse of the synthetic market built on sub-prime residential mortgages could be one of the main diffusion chambers of the Great Financial Crisis, the episode that triggered a chain reaction that spread across other fixed income markets. In other words, we statistically explore the possibility that the financial panic of 2007 initially migrated from specific segments of the market for protection from sub-prime residential mortgages, whose risk is traded via ABX indices, to other fixed income markets. Seen through the lens of models of bank/financial runs with sunspot equilibria, the ABX index drop that occurred in 2007 may have acted as a focal shock that favored the emergence of a (shadow) bank-run equilibrium consistent with the mechanism described in Diamond and Dybig (1983). In this paper, we provide statistical support of Gorton (2009a,b)'s conjecture through the identification of panic transmission from the market of sub-prime residential mortgages to some of the other U.S. fixed income markets in the sample.

[4]For example, Phillips and Yu (2011) interpret the Baa-Aaa corporate yield spread as a measure of the price of risk in bond markets. To the extent to which this interpretation is reasonable, a period of mildly explosive behavior in the time series of such a yield spread, if associated with a widening spread, can be viewed as a bubble in the price of risk in the underlying market.

The rest of this paper is structured as follows. Section 2 summarizes the methodology that we use. Section 3 describes the dataset. Section 4 discusses the results and their interpretation. Section 5 revisits the argument made in Gorton (2009a,b) in the context that we propose. Section 6 concludes.

2 Research Methodology

Failing to recognize unstable dynamics in time-series data, in real time or, at least, as soon as possible after they develop, has potentially serious implications. However, even in retrospect, their identification is not an easy task to accomplish, as it is discussed extensively in the empirical literature, especially in the context of asset prices when such dynamics can be interpreted as bubbles. One strand of this literature, based on a combination of theoretical predictions and time-series estimation techniques, has recently developed tests for the detection of bubbles –or, more generally, mildly explosive behavior– in the data. The main idea, derived from asset pricing theory, follows from the consideration that the existence of a bubble in an observed time series of asset prices can be revealed by its dynamic stochastic properties. If a bubble develops in a given market, prices should inherit and exhibit, at least locally and for a limited time, its explosive dynamic behavior.

Empirical bubble detection strategies are derived, for example, in Phillips and Yu (2011) and Phillips, Shi, and Yu (2015). Their approach, which has been used only rarely in the empirical literature so far, is based on tests able to detect bubbles in the data and to date-stamp their occurrence. These tests use a recursive and rolling right-tail variation of the ADF unit root test in which, under the null hypothesis, the time series of interest has a unit root and, under the alternative hypothesis, the observed time series is, at least locally, a mildly explosive stochastic process with a root larger than one. If the null hypothesis of their test is rejected, one can estimate origination and termination of a bubble, or multiple bubbles. Phillips, Shi, and Yu (2015) show that a specific version of their procedure (based on a recursive flexible window method) can be used –under general regularity conditions– as a date-stamping strategy that can consistently estimate origination and termination of bubbles in long historical time series. Through Monte Carlo simulations, they also demonstrate that their strategy outperforms the approach initially proposed in Phillips and Yu (2011). In particular, they argue that their test significantly improves discriminatory power and leads to non-negligible power gains when multiple bubbles are present in the data.[5]

2.1 Testing for the Presence of Mildly Explosive Behavior

The testing strategy is based on the estimation of the following reduced-form equation,

$$y_t = \mu + \delta y_{t-1} + \sum_{i=1}^{p} \phi_i \Delta y_{t-i} + \varepsilon_t, \tag{1}$$

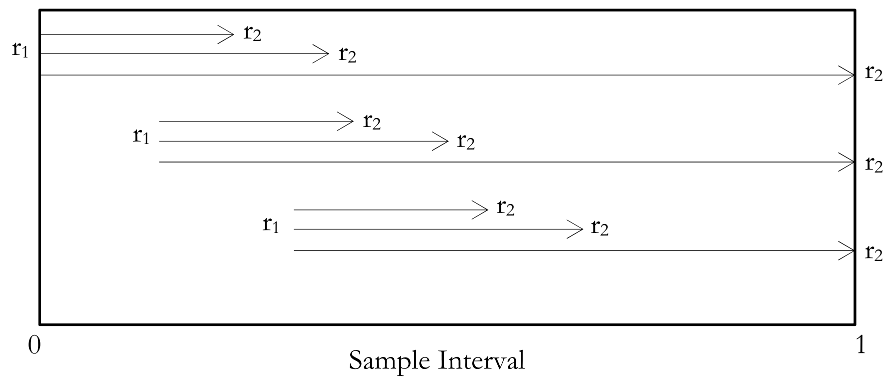
where y_t is the time series of interest, μ is an intercept, p is the maximum number of lags, and ε_t is the error term. Testing for mildly explosive behavior is based on a right-tail variation of the standard ADF unit root test. Formally, we follow Phillips, Shi, and Yu (2015) and consider the statistical hypotheses, $H_0 : \delta = 1$ vs $H_1 : \delta > 1$.

We normalize the original sample interval of T observations to $[0, 1]$. The δ coefficient estimated by ordinary least squares over the (normalized) sample $[r_1, r_2] \subseteq [0, 1]$ and its corresponding ADF test statistic are denoted by δ_{r_1,r_2} and ADF_{r_1,r_2}, respectively. We define the (fractional) window size of the regression as $r_w = r_2 - r_1$. The Generalized Supremum Augmented Dickey-Fuller ($GSADF$) test is derived from a recursive procedure in which the ADF test statistic is calculated over (overlapping) rolling windows of increasing sizes and moving starting points (i.e., over a forward rolling and expanding sample). Each estimation in this recursive approach produces an ADF test statistic. The $GSADF$ test statistic is defined as the *supremum* ADF_{r_1,r_2} statistic over all possible windows. Formally,

$$GSADF\,(r_0) = \sup_{\substack{r_2 \in [r_0, 1] \\ r_1 \in [0, r_2 - r_0]}} \left\{ ADF_{r_1,r_2} \right\}, \tag{2}$$

[5] Pavlidis, Yusupova, Paya, Peel, Martnez-Garca, Mack, and Grossman (2016) apply this methodology to empirically detect and date-stamp bubbles in three widely used housing market indicators (real house prices, price-to-income ratios, and price-to-rent ratios) for a large set of countries. They also propose a novel extension of the test to a panel setting.

where r_0 is the smallest sample window width fraction (which initializes the computation of the test statistic, in this paper set to 10%) and 1 is the largest window fraction (corresponding to the full sample size) in the recursion. The recursion mechanism can be represented graphically as



The relevant critical values to be used for testing purposes are produced by means of a simulation based on the following steps. First, we generate a random sample of T observation based on a null model. As in Phillips, Shi, and Yu (2015), the null model is a random walk process with an asymptotically negligible drift,

$$y_t = dT^{-\eta} + \theta y_{t-1} + e_t,\ e_t \sim N\left(0, \sigma^2\right),\ \theta = d = \eta = 1, \tag{3}$$

where η is a localizing coefficient that controls the magnitude of the drift as the sample size, T, approaches infinity, and e_t is a normal error term. Second, we estimate equation (1) by ordinary least squares and store the relevant test statistic ($GSADF$, in this paper). Third, we repeat first and second steps $1,000$ times. Fourth, we calculate the 90% quantile of the distribution of the $GSADF$ test statistic produced from these 1,000 simulations. This quantile is used to test the null of unit root against the alternative of an explosive process. The simulation output includes the p-value for the computed test statistic, here defined as

$$p\left(\widehat{\tau}\right)=\frac{1}{1,000}\sum_{j=1}^{1,000}I\left(\tau_j>\widehat{\tau}\right), \tag{4}$$

where $\widehat{\tau}$ is the sample $GSADF$ test statistic, $I(\cdot)$ is an indicator function that is equal to 1 if the condition expressed in its argument is true and 0 if the condition expressed in its argument is false, and $\{\tau_j\}_{j=1}^{1,000}$ is the sequence of simulated $GSADF$ test statistics.

2.2 Date-Stamping Periods of Mildly Explosive Behavior

If the null hypothesis of the Generalized Sup Augmented Dickey-Fuller test is rejected, a similar procedure can be used, under general regularity conditions, as a date-stamping strategy to consistently estimate origination and termination of periods of mildly explosive behavior. For this purpose, we implement a recursive Supremum ADF test on a backward expanding sample sequence, specular to the recursive sequence that we described in the previous subsection. In this version of the recursion, the end point of each sample is fixed at r_2 (i.e., the sample fraction corresponding to the end point of the window) and the start point is allowed to vary from 0 to r_2-r_0 (i.e., the sample fraction corresponding to the origination of the window). We obtain a sequence of ADF test statistics, $\{ADF_{r_1,r_2}\}_{r_1}\in[0,r_2-r_0]$, and a Backward Supremum ADF test statistic, which is defined as the supremum value of the ADF test statistic sequence over this interval,

$$BSADF_{r_2}\left(r_0\right)=\sup_{r_1\in[0,r_2-r_0]}\left\{ADF_{r_1,r_2}\right\}. \tag{5}$$

Based on the sequence of test statistics, estimates of beginning ($\widehat{r}_e$) and termination ($\widehat{r}_f$) of a period of mildly explosive behavior (as fractions of the full sample) are given by

$$\widehat{r}_e=\inf_{r_2\in[0,1]}\left\{r_2:BSADF_{r_2}\left(r_0\right)>cv_{r_2}^{\beta_T}\right\} \tag{6}$$

and

$$\widehat{r}_f = \inf_{r_2 \in [\widehat{r}_e, 1]} \left\{ r_2 : BSADF_{r_2}(r_0) > cv_{r_2}^{\beta_T} \right\}, \tag{7}$$

where $cv_{r_2}^{\beta_T}$ is the $100(1-\beta_T)\,\%$ critical value of the supremum ADF test statistic based on Tr_2 observations and β_T is a real number between 0 and 1. In other words, the origination date is the observation at which the $BSADF$ statistic exceeds the critical value of the $BSADF$ statistic. Similarly, the termination date is the observation at which the $BSADF$ statistic falls below the critical value of the $BSADF$ statistic. It is worth noting that $GSADF$ test statistic and $BSADF$ test statistic are related to each other,

$$GSADF(r_0) = \sup_{r_2 \in [r_0, 1]} \{BSADF_{r_2}(r_0)\}. \tag{8}$$

2.3 Migration of Mildly Explosive Behavior

A reduced-form procedure for testing migration of mildly explosive behavior from one series X_t to another series Y_t is originally described in Phillips and Yu (2011). Let $\theta_X(\tau)$ be the coefficient of an autoregressive model with an intercept term for the time series $\{X_t\}_{t=1}^{\tau=Tr}$ with $r \in [r_0, 1]$. $\theta_X(\tau)$ can be recursively estimated by ordinary least squares as $\widehat{\theta}_X(\tau)$ (over a recursively increasing window with a fixed starting date that occurs as early as mathematically allowed in the sample). Similarly, we also define $\theta_Y(\tau)$ and $\widehat{\theta}_Y(\tau)$. By allowing for time variation in $\theta_X(\tau)$, we try to capture possible structural changes in the coefficient originating from episodes of turmoil, panic, exuberance, or collapse. The goal is to test the presence of migratory effects on the dynamics of a second time series, Y_t.

The intuition can be described in the following terms. When mild explosivity reaches its peak in X_t (in correspondence of a local maximum in the sequence of $BSADF$ test statistics), we can then test for its transmission to Y_t. Under the alternative of migration, mildly explosive behavior emerges in Y_t as it fades away in X_t. From a modelling point of view, the null generating mechanism of Y_t has an autoregressive coefficient, $\theta_Y(\tau)$, that transitions from a unit root to a mildly explosive root and that is negatively associated with the corresponding recursive autoregressive coefficient for X_t, $\theta_X(\tau)$.

Suppose that the previously described date-stamping procedure identifies mildly explosive behavior in X_t between $\widehat{\tau}_{eX} = T\widehat{r}_{eX}$ and $\widehat{\tau}_{fX} = T\widehat{r}_{fX}$ and in Y_t between $\widehat{\tau}_{eY} = T\widehat{r}_{eY}$ and $\widehat{\tau}_{fY} = T\widehat{r}_{fY}$. Suppose that the two sequences of $BSADF$ test statistics for X_t and Y_t peak at times $\widehat{\tau}_{\rho X} = T\widehat{r}_{\rho X}$ and $\widehat{\tau}_{\rho Y} = T\widehat{r}_{\rho Y}$, respectively, and that $\widehat{r}_{\rho Y} > \widehat{r}_{\rho X}$. Let $m = \widehat{\tau}_{\rho Y} - \widehat{\tau}_{\rho X} = T\widehat{r}_{\rho Y} - T\widehat{r}_{\rho X}$ be the number of observations in the interval $(\widehat{\tau}_{\rho X}, \widehat{\tau}_{\rho Y}]$. Phillips and Yu (2011) show that the notion of migration that we have described in this section can be detected by first running the regression,

$$\left[\widehat{\theta}_Y(\tau) - 1\right] = \beta_0 + \beta_1 \left[\widehat{\theta}_X(\tau) - 1\right] \frac{\tau - \widehat{\tau}_{\rho X}}{m} + error, \text{ with } \tau = T\widehat{r}_{\rho X} + 1, ..., T\widehat{r}_{\rho Y}, \tag{9}$$

over a sample covering the period of collapse in X_t and the coincident emergence of exuberance in Y_t, and then by running the test, $H_0 : \beta_1 = 0$ vs $H_1 : \beta_1 < 0$. An asymptotically conservative and consistent test for these two hypotheses is based on a standard normal test statistic,

$$Z_\beta = \frac{\widehat{\beta}_1}{L(m)}, \text{ where } \frac{1}{L(m)} + \frac{L(m)}{T^\epsilon} \longrightarrow 0, \text{ as } T \longrightarrow \infty \text{ for any } \epsilon > 0, \tag{10}$$

for some slowly varying function $L(m)$, such as $a \log_{10}(m)$ with $a > 0$ and $m = O(T)$.

3 Data

All methodologies described in the previous section are adopted to identify periods of explosive behavior in the individual time series in the sample. The objective is to determine the beginning and the end of these episodes of unstable dynamics, and to test for migration across individual fixed income markets. We construct seven interest rate spreads from U.S. fixed income markets. Data are collected from Bloomberg and organized in a sample of weekly observations, as in most of the related literature. Unless otherwise noted, we consider a period that spans between the week of September 27, 2002 and the week of January 16, 2015, for a total of 643 weekly observations. These seven spreads, which we describe in the next paragraph, exhibit some degree of heterogeneity that depends on the fixed income markets to which they refer, the maturity of the underlying securities, and whether or not they were affected by specific policy measures by the Federal Reserve Bank, the United States Treasury, the Federal Deposit Insurance Corporation, or other policy interventions during the Great Financial Crisis. Throughout the paper, we will refer to these spreads using their number and their descriptor, reported in parentheses below.

Spread 1 (3-month LIBOR-OIS). The 3-month LIBOR on unsecured deposits relative to the overnight indexed swap (OIS) rate. The 3-month LIBOR is the interest rate that banks face when they borrow unsecured funds on the interbank market with a 3-month maturity. The OIS rate is the fixed interest rate that a bank receives in 3-month swaps between a fixed rate and a compound interest payment on a notional amount to be determined with reference to the effective federal funds rate. The LIBOR-OIS spread is widely perceived as an indicator of tensions in money markets, a measure of health of the banking system, and an index of risk and liquidity in the money market. It is a standard indicator of liquidity premium of widespread use and was possibly affected by swap arrangements among central banks during the Great Financial Crisis. While there are legitimate concerns that, after the LIBOR scandal emerged in 2008, the use of the LIBOR for analysis may require some caution, existing research suggests that LIBOR rates still remain a good measure of financial distress.[6]

Spread 2 (3-month ABCP-Treasury). The 3-month ABCP relative to Treasury Bills of the same maturity. ABCP experienced a dramatic drop in transaction volumes during the financial crisis, a shortage that made this short-term spread particularly reflective of

[6]Abrantes-Metz, Kraten, Metz, and Seow (2012) compare the LIBOR with other short-term borrowing rates between January 2007 and May 2008. They report some anomalous individual quotes, but eventually conclude that the evidence that they are able to provide is inconsistent with a material manipulation of the U.S. dollar 1-month LIBOR. Kuo, Skeie, and Vickery (2012) show that LIBOR survey responses broadly track alternative measures of borrowing rates. Fouquau and Spieser (2015) find, instead, some evidence of manipulation. See also Duffie and Stein (2015) for additional findings. We acknowledge that evidence is mixed. However, in our analysis, we limit the use of the LIBOR to the computation of only one of the seven spreads in the dataset.

both liquidity risk and credit risk. Later on, still during the Great Financial Crisis, this spread became a direct target of the Asset-Backed Commercial Paper Money Market Mutual Fund Liquidity Facility (which began operations on September 22, 2008, and was closed on February 1, 2010) and the Commercial Paper Funding Facility (which was announced on October 7, 2008, began purchases of commercial paper on October 27, 2008, and was closed on February 1, 2010).

Spread 3 (1-year Aaa ARM-Treasury). The 1-year Aaa ARM relative to Treasury Bills. It is representative of sub-prime rates charged on innovative mortgage contracts and captures the strains more directly associated to the real estate market. It can be seen as a proxy of default risk premium.

Spread 4 (5-year Aaa private-label CMBS-Treasury). The 5-year Aaa private-label CMBS relative to Treasury Bonds. It captures the freezing of the underlying spot market between the summer of 2007 and early 2009, later reversed, at least in part, thanks to the contribution of the Term Asset-Backed Securities Loan Facility (TALF) program (which began operation in March 2009 and was closed for new loan extensions on June 30, 2010, with the final outstanding TALF loan being repaid in full in October 2014). It represents the risk-premium on private-label securitized mortgages, which are often blamed as the root of the real estate crisis. It was not directly affected by Quantitative Easing or other policy programs during the financial crisis. The sample for this spread spans between the week of September 27, 2002 and the week of July 19, 2013 (a total of 565 weekly observations).

Spread 5 (20-year Moody's Baa-Aaa-rated corporate). The 20-year Moody's Baa-rated corporate bonds relative to Aaa-rated corporate bonds. It is a traditional indicator of credit risk, discussed extensively in the literature. It is a corporate default spread, never directly affected by Quantitative Easing or other liquidity programs during the Great Financial Crisis. The sample for this spread spans between the week of September 27, 2002 and the week of March 30, 2012 (a total of 497 weekly observations).

Spread 6 (20-year Moody's Bbb-Aa-rated corporate). The 20-year Moody's Bbb-rated corporate bonds relative to Aa-rated corporate bonds (junk spread). It is similar to

Spread 5, but refers to riskier bonds and is rarely directly affected by policy interventions in the United States. Both Spread 5 and Spread 6 provide information about the cost of funding for businesses and therefore represent a more direct measure of strains in the private non-financial sector.

Spread 7 (30-year Freddie Mac conventional fixed-rate MBS-Treasury). The 30-year Freddie Mac conventional fixed-rate MBS relative to Treasury Bonds. It tends to capture the credit risk of more conventional mortgage products, being representative of the premium on agency mortgage-backed securities. It was affected by Large-Scale Asset Purchases (with short-term interest rates at nearly zero, the Federal Reserve made a series of large-scale asset purchases between late 2008 and October 2014) and Quantitative Easing programs during the Great Financial Crisis.[7]

As they are mostly computed from Treasury yields, these seven spreads reflect the credit-risk and (il)liquidity factors embedded in fixed income markets. From this point of view, the application of the aforementioned econometric methodologies on such yield spreads can help study and characterize the explosive behavior in the price of credit risk plus the cost of illiquidity in each related market. Figure 1 shows the time evolution of the individual interest rates from which the seven yield spreads in the sample are derived. All rates are organized in groups of two and by increasing maturity. The Great Financial Crisis period that is highlighted in each panel by conventional grey bars is identified formally in Contessi, De Pace, and Guidolin (2014). According to these authors, the crisis starts in the summer of 2007 (during the week ending on August 3, 2007) and ends in the early summer of 2009 (during the week ending on June 26, 2009). For convenience, a synthetic description of each spread is provided in Table 1. We report the empirical distribution of each spread in Figure 2. A generally positive and large skewness is associated with a sizeable divergence between mean and median in most spreads. Large excess kurtosis is present in all spreads,

[7]We use yield spreads from two portfolios of securities related to real estates for which the construction of long enough time series is possible. Data for other mortgage rates are also available, among which a 5-year index of private-label Aaa-rated fixed-rate CMBS yields, computed by Bloomberg/Morgan Stanley; an index of 30-year fixed-rate residential prime mortgage rates computed by Freddie Mac; and a portfolio index series for lower-rated private-label MBS and CMBS. However, all these additional time series are too short to be successfully used within the econometric methods adopted in this paper.

but Spreads 3 and 7 (see Table 2). Spreads 1-7 are plotted in the lower part of each panel in Figures 3 and 4.

A feature common to all spreads in the dataset is their substantial increase, approximately located in the middle of the sample. All yield spreads peak in September 2008. Such a simultaneous increase likely depends on a common factor and is, broadly speaking, the reflection of a turbulence in financial markets, which would later become the Great Financial Crisis. Except for Spread 3, all spreads are relatively flat between the beginning of the sample and 2007. Some of them remain close to their historical means (Spreads 2, 5, and 6). Some of them generally fluctuate either slightly above (Spread 7) or slightly below their respective means (Spreads 1, 3, and 4). All of them start widening in 2007, during the initial stages of the Great Financial Crisis as dated in Contessi, De Pace, and Guidolin (2014), when the economic and financial turmoil only appeared to affect markets directly connected to the sub-prime real estate industry (see At-Sahalia, Andritzky, Jobst, Nowak, and Tamirisa, 2012). Worth noting is the fact that these seven interest rate spreads start rising well before fall 2008, the period conventionally referred to as the beginning of the Great Financial Crisis.

The relative increases in yield spreads during the crisis range wildly, but, proportionally, tend to be milder in spreads with longer maturities. As observed in an unreported investigation on several subperiods, variances and interquartile ranges show remarkable rises during the Great Financial Crisis, and return close to pre-crisis levels in the months after June 2009. Related research on fixed income yield spreads also shows that, generally, they do not contain unit roots over their individual full samples (see Batten, Hogan, and Jacoby, 2005).

4 Results

We look for mildly explosive dynamics in the seven interest rate spreads in the sample and then test for their migration from market to market. Table 3 reports the individual outcomes of the recursive right-tail ADF tests that we run. The Schwartz Information Criterion is adopted to select the optimal lag length in all test regressions. In each case, we allow for a maximum of 52 lags. The time series of Spreads 1, 2, 3, 6, and 7 have the same length in the sample. As such, they share the same simulated critical values. The tests on Spreads 4 and 5 are based on different and specific critical values, as their corresponding time series span shorter periods of time.

We find evidence of mildly explosive behavior in all spreads, but Spread 7 (30-year Freddie Mac conventional fixed-rate MBS-Treasury). The periods over which we identify these explosive dynamics are graphically depicted in Figures 3, 4, and 5. In the upper panels of Figures 3 and 4, we report the sequences of spread-specific $BSADF$ test statistics and their corresponding sequences of critical values. Periods of mildly explosive behavior are represented in each case by grey bars. Some of these periods are associated with generally increasing yield spreads (i.e., the price of the risky asset is falling relative to the price of the safer asset in the spread); some of them are, instead, associated with generally decreasing yield spreads (i.e., the price of the risky asset is rising relative to the price of the safer asset in the spread). The statistical procedure allows us to specifically estimate periods of instability, which we summarize in the following chart. We also provide an indication of the general behavior of each spread (increasing, I, or decreasing, D, pattern – i.e., distress or adjustment) over each estimated time frame,

Peaks of instability in the dynamics of each spread occur in correspondence of the global maxima in the sequences of $BSADF$ test statistics. They appear over periods during which yield spreads tend to increase, as emphasized in Figure 5: August 17, 2007 (Spread 1, 3-month LIBOR-OIS); October 12, 2007 (Spread 2, 3-month ABCP-Treasury); March 21, 2008 (Spread 3, 1-year Aaa ARM-Treasury); March 7, 2008 (Spread 4, 5-year Aaa private-label CMBS-Treasury); October 17, 2008 (Spread 5, 20-year Moody's Baa-Aaa-rated corporate); January 9, 2009 (Spread 6, 20-year Moody's Bbb-Aa-rated corporate). Unstable dynamics peak in U.S. fixed income markets between August 2007 and January 2009. These peaks move sequentially from short-term funding markets to more volatile medium- and long-term markets during the crisis period. Note that peaks of instability as we define them and peaks in the yield spreads do not have to (and, in fact, do not) correspond.

Spread 1	August 10, 2007 - December 14, 2007	I
(3-month LIBOR-OIS)	March 21, 2008 - April 18, 2008	I
	September 26, 2008 - November 21, 2008	I
	November 11, 2011 - February 3, 2012	I
Spread 2	August 17, 2007 - February 1, 2008	I
(3-month ABCP-Treasury)		
Spread 3	October 15, 2004 - March 24, 2006	D
(1-year Aaa ARM-Treasury)	August 17, 2007 - February 12, 2010	I
	May 21, 2010 - July 29, 2011	D
Spread 4	July 20, 2007 - August 28, 2009	I
(5-year Aaa private-label CMBS-Treasury)	January 8, 2010 - March 12, 2010	D
Spread 5	October 15, 2004 - December 24, 2004	D
(20-year Moody's Baa-Aaa-rated corporate)	February 29, 2008 - January 23, 2009	I
	March 27, 2009 - May 22, 2009	D
	May 13, 2011 - July 15, 2011	D
Spread 6	November 14, 2008 - July 10, 2009	I
(20-year Moody's Bbb-Aa-rated corporate)		

Concordance between the appearance of explosive dynamics associated with generally rising spreads (around July/August 2007) and the initial period of the Great Financial Crisis is evident in the cases of Spreads 1, 2, 3, and 4 – i.e., the short- and medium-term spreads. Isolated explosive behaviors associated with generally decreasing spreads are detected in 2004 and between 2009 and 2011, at least as far as Spreads 3 (1-year Aaa ARM-Treasury, for prolonged periods), 4 (5-year Aaa private-label CMBS-Treasury), and 5 (20-year Moody's Baa-Aaa-rated corporate) are concerned. From a slightly different point of view, the empirical methodology correctly identifies the beginning of the financial crisis in the summer of 2007, during which the 3-month LIBOR-IOS spread (Spread 1) experiences a large increase. Incidentally, in June and July 2007, Standard & Poor's and Moody's Investor Services downgraded over a hundred bonds backed by second-lien sub-prime mortgages, and later put 612 securities backed by sub-prime residential mortgages on a credit watch. Around the same time, Bear Stearns informed investors that it would suspend redemptions from its High-Grade Structured Credit Strategies Enhanced Leverage Fund. At the end of July, Countrywide Financial Corporation filed a Securities and Exchange Commission (SEC) warning signaling "difficult conditions" and Bear Stearns liquidated two hedge funds that had invested in various types of mortgage-backed securities. These events, which caused turmoil in financial markets, correspond to the the first episode of mild explosivity identified in the time series of Spread 1. The last episode of disruption in the 3-month LIBOR-OIS spread occurs between November 11, 2012 and February 3, 2012, a period characterized by widespread and acute sovereign debt crises at the international level.

The date-stamping technique captures a spell of disruption and mildly explosive behavior between August 17, 2007 and February 1, 2008 in the time series of the second short-term spread in the sample (3-month ABCP-Treasury spread). Fitch Ratings downgraded Countrywide Financial Corporation to BBB+, its third lowest investment-grade rating, on August 16, 2007. By that time, Countrywide had entirely borrowed the $11.5 billion available in their credit lines with other banks. During the same week, the Federal Federal Reserve Board voted to reduce the primary credit rate by 50 basis points to 5.75%, thus narrowing the difference with the Federal Open Market Committee (FOMC)'s federal funds rate target to only 50 basis points. The Board of Governors of the Federal Reserve also increased the maximum term of the the primary credit borrowing to 30 days, in a move to facilitate access to liquidity by qualifying banks. The FOMC then released a public statement discussing the turmoil in U.S. financial markets and pointing out that the "downside risks to growth" had "increased appreciably." Despite the fact that the date-stamping technique formally limits the mildly explosive behavior in Spread 2 to the beginning of February 2008, a visual inspection of the yields that we use to construct it (Figure 1) suggests that the adjustment period in the associated fixed income market might have, instead, ended much later, in mid-2009. As Figure 3 shows, the sequence of $BSADF$ test statistics for Spread 2 exceeds the sequence of critical values between the end of 2008 and the first half of 2009, a period during which the spread is particularly large. However, the $BSADF$ test statistic sequence does not remain above the sequence of critical values for long enough to allow the formal detection of distress.

The two spreads in the sample that most accurately track the dynamics in the real estate market (Spreads 3 and 4) are affected by several episodes of turbulence. The 1-year Aaa ARM-Treasury spread (Spread 3) exhibits one episode of mildly explosive behavior associated with an upward-sloping time evolution. This episode covers the entire period of turmoil in the housing market, as it starts on August 17, 2007 and ends in mid-February 2010. Two spells of mildly explosive behavior associated with a downward-sloping time evolution of Spread 3 are also detected. The period between October 15, 2004 and March 24, 2006 is characterized by progressive increases in the Federal Funds Rate.[8] The evolution of Spread 3 over this time frame is consistent with one of the root causes of the housing bubble. Levitin and Wachter (2012) maintain that a disproportionate increase in the supply of housing finance between 2004 and 2006 kept mortgage interest rates particularly low relative to their risk and to other interest rates, such as those associated with safe assets. This expansion of housing finance played an important role in the generation of rising house prices at a time of increasing policy rates. Finally, the period between May 21, 2010 and July 29, 2011 is, arguably, a sharp adjustment that followed the Great Financial Crisis.

The date-stamping algorithm also identifies a period of turbulence in the market of commercial mortgage-backed securities, represented in our sample by Spread 4 – i.e., the 5-year Aaa private-label CMBS-Treasury spread. The time period covering the two combined spells of mild explosivity that we identify (the first – between July 20, 2007 and August 28, 2009 – is associated with a spread increase; the second – between January 8, 2010 and March 12, 2010 – is associated, instead, with a long spread decrease) ends in March 2010, when the Federal Reserve Board increased slightly the discount rate from 0.5% to 0.75%, shortened the maximum maturity for discount window loans, and held the final Term Auction Facility (TAF) auction, citing continued improvement in financial market conditions.[9]

Mild explosivity characterizes the time series of the 20-year Moody's Baa-Aaa-rated cor-

[8]The Federal Reserve began raising the target policy rate in the fall of 2004, after a prolonged period of accommodating monetary policy that followed the recession of 2001.

[9]Under the TAF, the Federal Reserve auctioned term funds to depository institutions that were already eligible to borrow under the primary credit program. All advances were fully collateralized. Each TAF auction was for a fixed amount with a rate to be determined through the auction process, subject to a minimum bid rate. The final TAF auction was conducted on March 8, 2010.

porate spread (Spread 5) during a short spell in the second half of 2004. This spell is associated with a generally downward-sloping trajectory for the spread itself. Furthermore, mild explosive behavior is detected during a long period associated with initially increasing and then decreasing spread dynamics, temporally located between February 29, 2008 (just before the collapse of Bear Stearns) and May 22, 2009, which is approximately the end of the overall disruption in funding markets. Spread 6 (i.e., the junk spread) starts exhibiting instability by the end of 2008, arguably at the peak of the financial crisis, after the bankruptcy of Lehman Brothers, as the financial panic spreads from interbank markets and the shadow banking system to the funding markets for corporations – i.e., to the "real economy."

Finally, we investigate the possibility of migration of explosive behavior from market to market, from a peak of instability to another, by implementing the testing strategy discussed in Section 2. All results are reported in Tables 4, 5, and 6. The global peaks in the sequences of $BSADF$ statistics are reported in each table for each individual spread. We do not report a global peak for Spread 7 (30-year Freddie Mac conventional fixed-rate MBS-Treasury), given that, in this case, we do not detect any statistically significant explosive behavior over the sample. Based on the previously described chronological appearance of these peaks, we test for migration from Spread 1 (3-month LIBOR-OIS) to Spreads 2-6, for migration from Spread 2 (3-month ABCP-Treasury) to Spreads 3-6, and for migration from Spread 3 (1-year Aaa ARM-Treasury) to Spreads 5-6 (the two 20-year corporate bond spreads). We do not formally test for migration from Spread 4 (5-year Aaa private-label CMBS-Treasury) to Spread 3, given that the two respective peaks are too close to each other to allow for a meaningful estimation of the test regression. Variable m in each table represents the number of weekly observations between the peak in the sequence of $BSADF$ test statistics for the spread from which we test migration and the peak in the sequence of $BSADF$ test statistics for the spread towards which migration might be occurring.[10] Starting from the fifth column of each table, we report (i) estimated slope coefficient of each test regression (as described

[10]In one case, when we test for migration from Spread 1 to Spread 2 in Table 4, the value of m is likely to small (only equal to 8) to be associated with a meaningfully estimated test regression.

in Section 2.3), (ii) associated standard error and t-statistic, and (iii) value of $L(m)$ and Z_β computed for different values of parameter a, here allowed to vary discretely from 1/5 to 3.

We detect statistically significant migration from Spread 1 (3-month LIBOR-OIS) to Spread 4 (5-year Aaa private-label CMBS-Treasury), and from Spread 2 (3-month ABCP-Treasury) to Spread 4 and Spread 6 (20-year Moody's Bbb-Aa-rated corporate). These outcomes support the notion that the tensions and turmoil that emerged in short-term funding markets in the second half of 2007 transmitted to the more volatile medium- and long-term real estate derivatives market and corporate junk bond market at some point during the financial crisis. Such evidence is consistent with the aforementioned pattern of instability peaks, sequentially occurring in short-term funding markets first and in more volatile medium- and long-term markets later, between August 2007 and January 2009, a time frame that spans entirely the most turbulent months of the Great Financial Crisis.

5 The Panic of 2007 Revisited

The ABX is a credit default swap (CDS) contract that pools lists of exposures to mortgage backed securities. The ABX.HE is a set of indices that tracks credit default swaps on U.S. residential mortgage-backed securities (see, for example, Reserve Bank of Australia, 2008; Fender and Scheicher, 2009; Gorton, 2009a,b, for more detailed discussions). Four groups of ABX indices were issued every six months between January 2006 and 2008. Each index tracks credit default swaps on a fixed sample of twenty residential mortgage-backed securities, predominantly based on sub-prime mortgages issued in the previous six months. Each group of indices include five sub-indices, each of them corresponding to a different rating class of residential mortgage-backed securities, namely AAA, AA, A, BBB, and BBB-. However, one should note that the rating of the underlying securities in any given ABX index could change later. Classes BBB and BBB- represent the investment grades for the riskiest sub-prime mortgage loans, with BBB- class being the riskiest. We plot these five sub-indices in the five charts of Figure 6. As of 2007, these sub-indices became closely monitored barometers for changes in U.S. sub-prime debt markets on Wall Street, and as such they came to represent a focal point for market participants.

The ABX.HE.06-1 indices represent the first issuance of these kind of data and refer to tranches of twenty residential mortgage-backed securities issued in the second half of 2005. In the rolls that were released every six months in the subsequent two years, due to the deepening of the sub-crime crisis, the number of issuances had dropped so much that ABX indices could not be constructed anymore starting from 2008. While each ABX.HE index contract were issued in a fixed notional amount in which the twenty underlying tranches are equally weighted, during the life of the contract the notional amount would decline, typically due to write-downs or payments. In practice, ABX.HE indices functioned like a credit default swap allowing investors to buy or sell insurance on the underlying tranches of residential mortgage-backed securities, therefore providing both hedging and trading opportunities. As pointed out in Gorton (2009a,b), given that ABX.HE indices traded based on price rather than spread, and given that the premium rate on each index was fixed at its launch, the market prices of such indices adjust to reflect changes either in risk aversion or in the market evaluation of the default risk related to the underlying residential mortgage-backed securities. In particular, a price reduction below par can be interpreted as an increase in the market cost of protection relative to the same cost at launch of the product.

Gorton (2009a,b) argue that the ABX.HE indices provided a rare source of information regarding the pricing of sub-prime securities in the initial phases of the Great Financial Crisis. Reportedly, many investors used these indices as a point of reference to evaluate their (potentially very heterogeneous) holdings of real-estate-related securities. The visible contraction of the ABX.HE indices at the beginning of 2007 prompted several financial institutions to report large credit write-downs on sub-prime related securities. Gorton (2009a) considers this event the *de facto* beginning of the panic of 2007-08. Later investigations rationalized this episode as a financial panic akin to bank runs. However, in this particular crisis, such a panic also affected the shadow banking system (see Bernanke, 2012) rather than the regulated commercial bank sector.

In this section, we formally test Gorton (2009a,b)'s conjecture that the collapse of ABX indices, occurred between 2007 and 2009, triggered a reaction in other financial markets in the United States, including fixed income markets. Such a reaction was likely determined by a signaling mechanism about the state of the market of mortgage-backed securities, which quickly and significantly deteriorated in the initial phases of the Great Financial Crisis. We statistically test for the migration of financial distress from the ABX market to fixed income markets after taking data from the first roll of ABX indices, which provides the longest time series for empirical analysis. While data on spreads constructed from each individual ABX index and LIBOR rates are also available, they often hinge on assumptions that are difficult to justify or interpret. In our opinion, the price of the index represents a more transparent variable to adopt. We apply our empirical strategy on the BBB index only, namely the ABX.HE.BBB.06-1 index, which is related to tranches of residential mortgage-backed securities issued in the second half of 2005 and rated BBB.

As explained in the technical section, running the recursive methodology for the detection of mildly explosive behavior in time-series data requires an initial window of observations to be used to initialize the procedure. The date that Gorton (2009a) identifies as the beginning of the panic in the ABX market is temporally located in the last week of July 2007. The application of the technique consumes data points in the ABX.HE.BBB.06-1 index through the second half of 2007, as we use a 10% initial window for the recursion and given that the weekly data for the indices in the sample only span the period between the week of January 19, 2006 and the week May 14, 2015 (a total of 487 observations). Therefore, based on Gorton (2009a)'s considerations, we exogenously impose the beginning of the distress affecting the ABX.HE.BBB.06-1 index in the week of July 27, 2007. As a robustness check, we also collect daily data for the ABX.HE.BBB.06-1 index between January 19, 2006 and May 14, 2015 (a total of 2,434 observations) and run the right-tail ADF test described in Section 2, allowing for a maximum lag of 30 observations. We find statistically significant evidence of mild explosive behavior in the time series of this index even when we run a test with a size of 1%. When the index starts collapsing at the beginning of 2007, mild explosivity peaks for the first time (a global maximum of 6.213 in the sequence of $BSADF$ test statistics) on February 12, 2007 and for the second time (a local maximum of 5.865, the third largest in the sample) just a few months later, on July 27, 2007, in the same week that we exogenously identify and adopt when testing for panic transmission.

Starting from that weekly observation, we test for panic transmission to other fixed-income markets, and only to those represented by yield spreads which, based on our previous analysis, exhibit peaks in the sequence of $BSADF$ test statistics after the week of July 27, 2007. Empirical outcomes are reported in Table 7 and show evidence of transmission from the ABX.HE.BBB.06-1 index to medium- and long-term real estate derivatives and corporate junk bond markets (Spreads 4 and 6), thus statistically validating Gorton (2009a,b)'s argument. The instability in the ABX market transmitted directly to the riskiest mortgage-related fixed income market and to the riskiest corporate bond market in the sample. A mechanism of panic and propagation is therefore formally detected during the Great Financial Crisis using the described methodology.

6 Conclusions

This study contributes to the understanding of the time-series behavior of yield spreads related to U.S. fixed income markets between 2002 and 2015, with a particular focus on the turbulent years of the Great Financial Crisis. Based on the availability of data at the weekly frequency, we construct a panel of seven yield spreads derived from a variety of instruments and yields in U.S. fixed income markets and identify periods of mildly explosive behavior in the dynamics of their time series. Six out of these seven spreads are characterized by spells of statistically significant mild explosivity, which, depending on the context, can be interpreted either as periods of financial turmoil and distress or periods of adjustment. From a temporal point of view, the spells that we are able to estimate exhibit a degree of concordance with the Great Financial Crisis. Such concordance is particularly evident in the case of short-term spreads and in the case of those spreads in the sample that capture the risk(s) associated with the real estate market.

We also find evidence of instability/distress migration across markets. During the Great Financial Crisis, mild explosive dynamics migrate from markets associated with short-term funding (3-month LIBOR-OIS spread and 3-month ABCP-Treasury spread) to markets represented by spreads constructed from medium- and long-term fixed income assets in both the real estate derivatives market and the corporate junk bond market.

Finally, we investigate Gorton (2009a,b)'s idea that the ABX index may have provided information about the developments of the real estate market just before the beginning of the crisis in 2007 and that this information may have triggered a panic that spread across financial markets. We test for the migration of mildly explosive behavior from the ABX market to the segments of fixed income markets represented by the seven yield spreads in the sample. We indeed find statistical evidence of migration, particularly towards risky fixed income markets linked to real estate securities and corporate bonds.

These findings suggest that there exist avenues of migration of financial distress that might be amenable to policy intervention, at least to the extent to which that financial turmoil can be detected early in the data.

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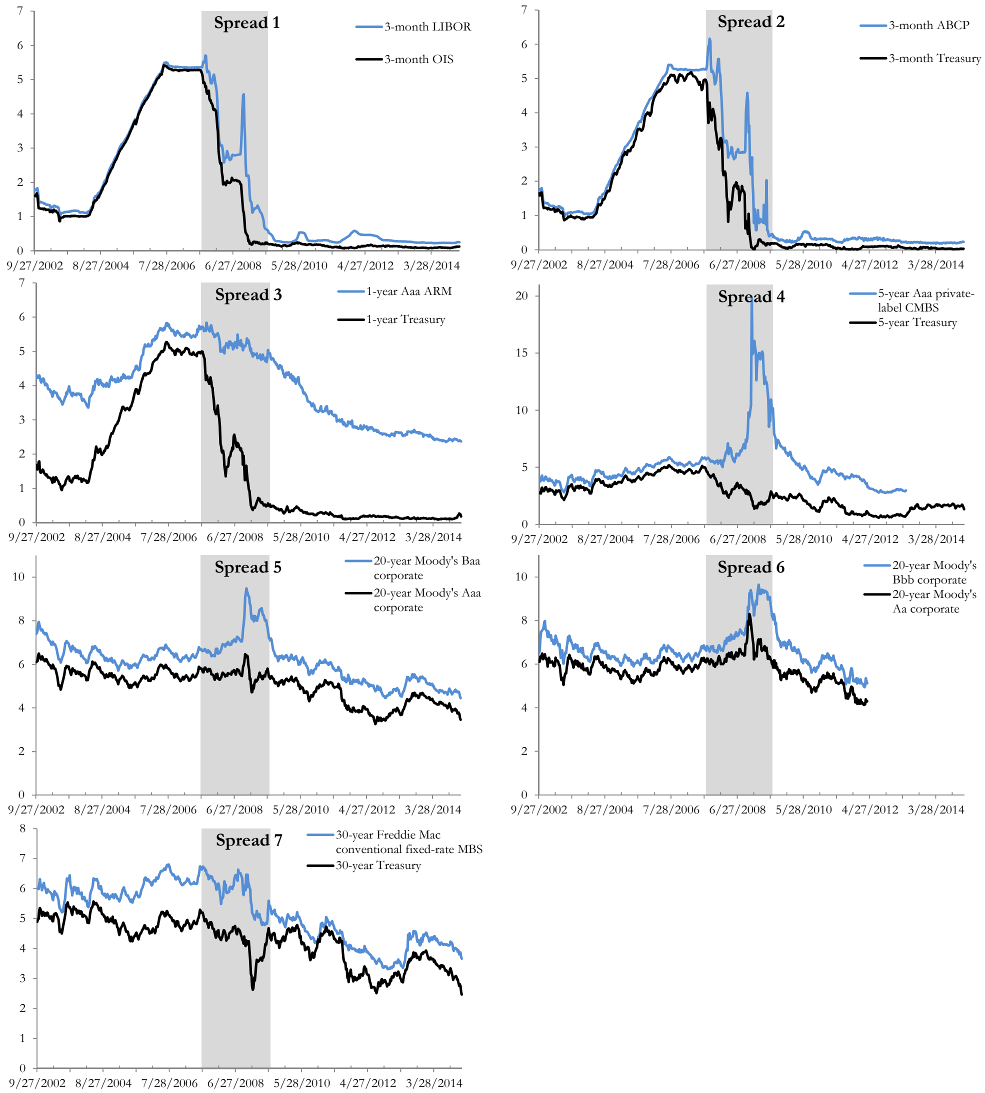
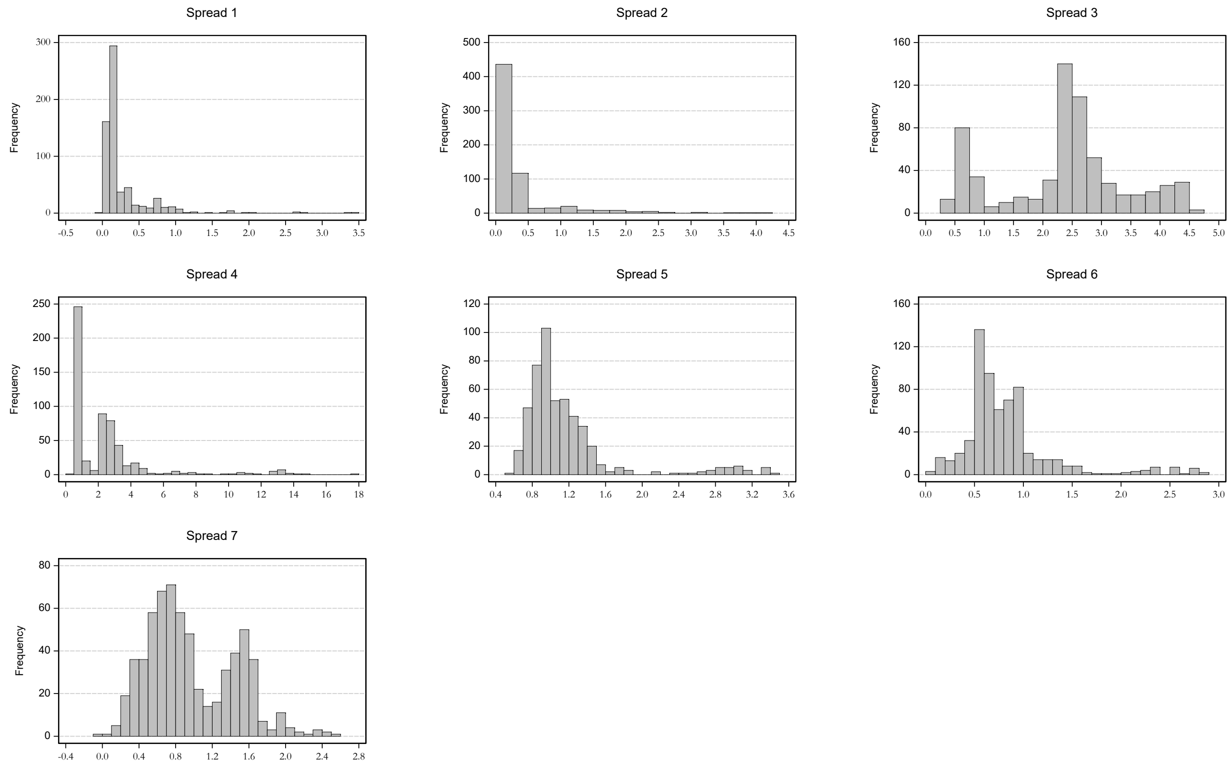
Figure 1: Individual Yields



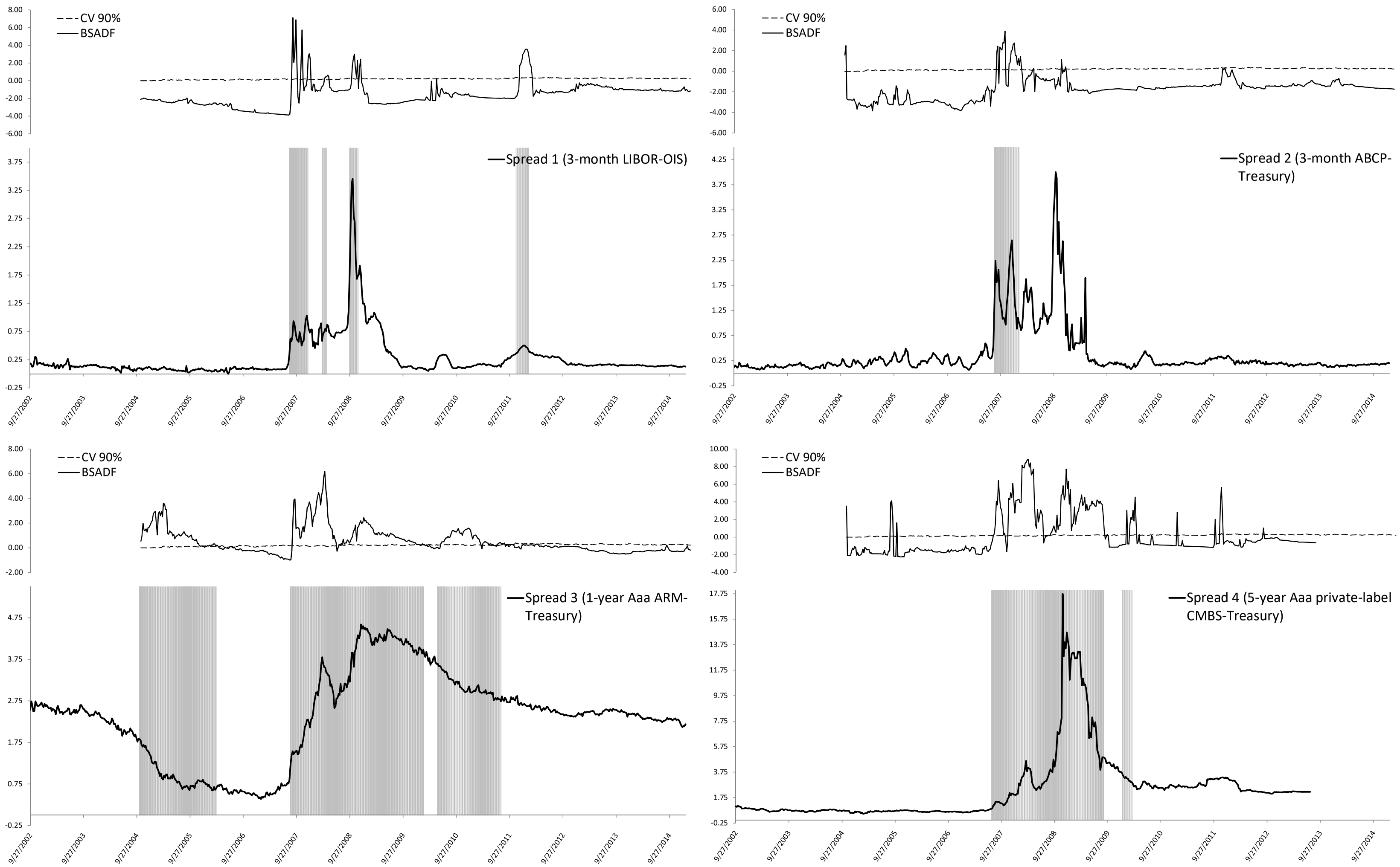
Notes. These graphs represent the yields used to construct the seven spreads described and analyzed in this paper. Shaded areas represent the Great Financial Crisis period, as dated in Contessi, De Pace, and Guidolin (2014). The crisis starts during the week ending on August 3, 2007 and ends during the week ending on June 26, 2009.

Figure 2: Empirical Distributions of Yield Spreads



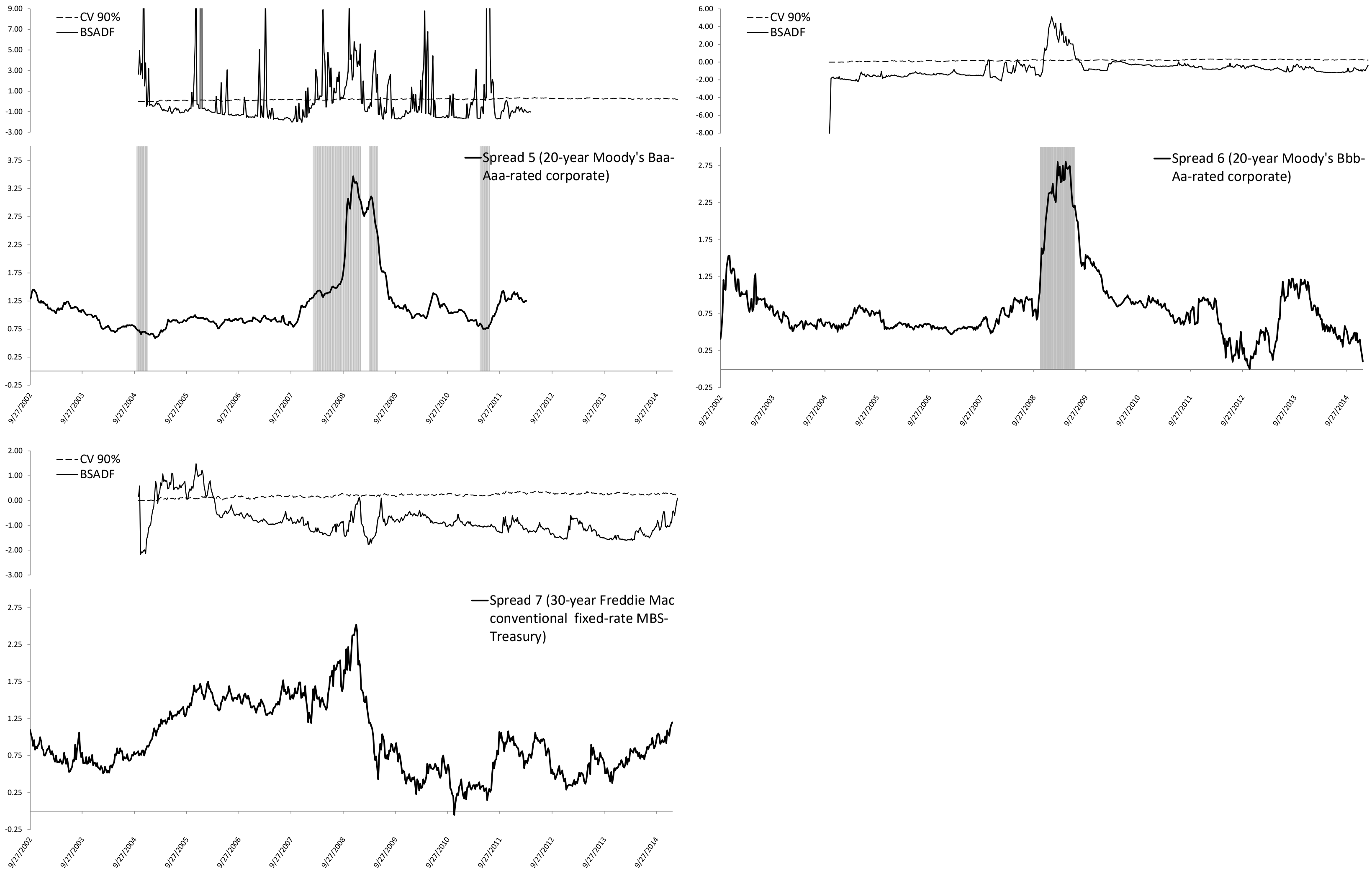
Notes. Sample for Spreads 1, 2, 3, 6, and 7: week of September 27, 2002 to week of January 16, 2015 (a total of 643 weekly observations). Sample for Spread 4: week of September 27, 2002 to week of July 19, 2013 (a total of 565 weekly observations). Sample for Spread 5: week of September 27, 2002 to week of March 30, 2012 (a total of 497 weekly observations).

Figure 3: Yield Spreads, Sequences of $BSADF$ Test Statistics, and Sequences of Critical Values



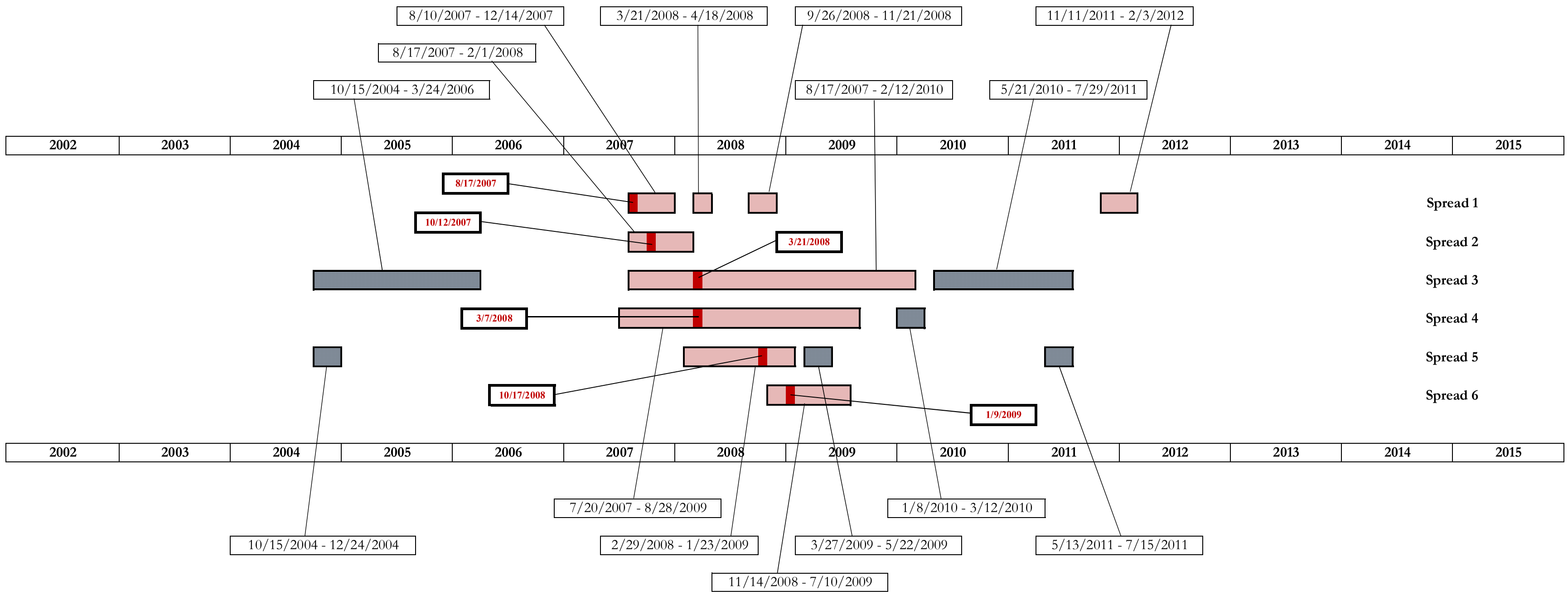
Notes. Shaded areas represent periods of mildly explosive behavior.

Figure 4: Yield Spreads, Sequences of $BSADF$ Test Statistics, and Sequences of Critical Values (continued)



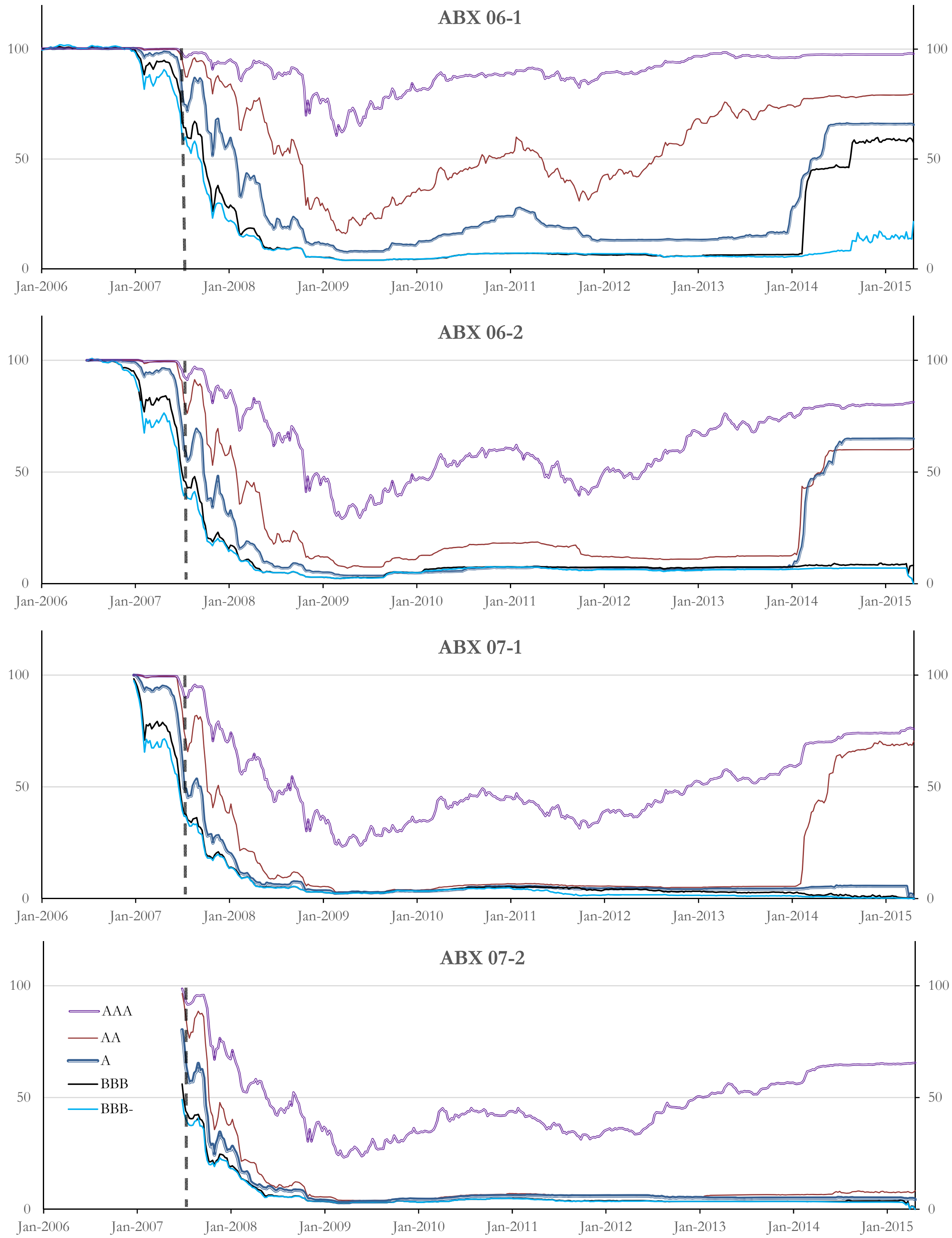
Notes. Shaded areas represent periods of mildly explosive behavior.

Figure 5: Time-Line of Estimated Periods of Mildly Explosive Behavior



Notes. Shaded areas represent periods of mildly explosive behavior associated with a generally rising yield spread. Shaded and textured areas represent periods of mildly explosive behavior associated with a generally falling yield spread. Instability peaks (global maxima in the sequences of $BSADF$ test statistics) are highlighted in a darker shade.

Figure 6: ABX Indices



Notes. This graph plots the four groups of ABX indices issued in 2006:H1, 2006:H2, 2007:H1, and 2007:H2. These indices are disaggregated by rating. The vertical dashed line represents the date identified in Gorton (2009a) as the collapse of the ABX.HE.BBB.06-1 index. In our weekly dataset, this date corresponds to the week of July 27, 2007.

Table 1: Description of the Yield Spreads

Variable	Upper Yield	Description	Lower Yield	Description	Weekly Observations
Spread 1	3-month LIBOR	3-Month London Interbank Offered Rate: Based on USD	3-month OIS	3-Month U.S. Overnight Index Swap	643
Spread 2	3-month ABCP	90-Day AA Unsecured Financial Asset-Backed Commercial Paper	3-month T-bill	3-Month Treasury Bond Yield	643
Spread 3	1-year Aaa ARM	FHLMC: 1-Year Adjustable Rate Mortgages: U.S.	1-year T-bill	1-Year Treasury Note Yield at Constant Maturity	643 (1568)
Spread 4	5-year Aaa private-label CMBS	Morgan Stanley U.S. Fixed Rate CMBS Conduit AAA Avg Life 5Y	5-year Treasury	5-Year Treasury Note Yield at Constant Maturity	565 (890)
Spread 5	20-year Moody's Baa-rated corporate	Moody's Baa Coporate Bonds Yields, based on corporate bonds with remaining maturities of at least 20 years.	20-year Moody's Aaa-rated corporate	Moody's Aaa Coporate Bonds Yields, based on corporate bonds with remaining maturities of at least 20 years.	497 (1422)
Spread 6	20-year Moody's Bbb-rated corporate	BFV USD Composite BBB 20 Year - discontinued on March 30, 2012	20-year Moody's Aa-rated corporate	BFV USD Composite AA 20 Year - discontinued on March 30, 2012	643
Spread 7	30-year Freddie Mac conventional fixed-rate MBS	Contract interest rates on commitments for fixed-rate 30-year mortgages	30-year Treasury	30-Year Treasury Note Yield at Constant Maturity (% p.a.)	643 (1568)

Table 2: Summary Statistics for the Yield Spreads

	Spread 1	Spread 2	Spread 3	Spread 4	Spread 5	Spread 6	Spread 7
Mean	0.2734	0.3716	2.3590	2.4049	1.1679	0.8263	0.9641
Median	0.1456	0.1940	2.4700	2.1200	1.0000	0.7140	0.8300
Maximum	3.4528	4.0020	4.5900	17.7300	3.4700	2.8070	2.5200
Minimum	-0.0002	0.0650	0.3900	0.4800	0.5900	0.0022	-0.0500
Std. Dev.	0.3781	0.5123	1.0749	2.6479	0.5435	0.4728	0.4759
Skewness	4.2081	3.5685	-0.1338	2.8347	2.5407	2.0939	0.5892
Kurtosis	27.0038	17.8135	2.4637	11.9703	9.3461	8.3188	2.6726
Observations	643	643	643	565	497	643	643

Notes. Sample for Spreads 1, 2, 3, 6, and 7: week of September 27, 2002 to week of January 16, 2015 (a total of 643 weekly observations). Sample for Spread 4: week of September 27, 2002 to week of July 19, 2013 (a total of 565 weekly observations). Sample for Spread 5: week of September 27, 2002 to week of March 30, 2012 (a total of 497 weekly observations).

Table 3: Right-Tail Augmented Dickey-Fuller (ADF) Tests

Spread	GSADF Test Statistic	Sample	Size of Test	Critical Values Spreads 1, 2, 3, 6, 7	Critical Values Spread 4	Critical Values Spread 5
Spread 1	7.110***	9/27/2002-1/16/2015	1%	2.673	2.679	2.810
Spread 2	3.881***	9/27/2002-1/16/2015	5%	2.195	2.162	2.160
Spread 3	6.182***	9/27/2002-1/16/2015	10%	1.986	1.973	1.940
Spread 4	8.810***	9/27/2002-7/19/2013				
Spread 5	109.535***	9/27/2002-3/30/2012				
Spread 6	5.102***	9/27/2002-1/16/2015				
Spread 7	1.481	9/27/2002-1/16/2015				

Notes. *** denotes statistical significance at the 1% level. Schwarz Information Criterion is used when selecting optimal lag in the test regressions. 52 weeks is maximum lag length considered when performing automatic lag length selection. Critical values are simulated using 1,000 replications. Initial window size: 10% of the full sample.

Table 4: Tests of Migration from Spread 1 (3-month LIBOR-OIS)

	Peak of the BSADF Test Statistic	Migration to	m	β_1	Standard Error	T-Stat	L(m)					Z_β				
							a=1/5	a=1/4	a=1/3	a=1	a=3	a=1/5	a=1/4	a=1/3	a=1	a=3
Spread 1	8/17/2007															
Spread 2	10/12/2007	Spread 2	8	0.922	1.733	0.532	0.181	0.226	0.301	0.903	2.709	5.104	4.083	3.063	1.021	0.340
Spread 3	3/21/2008	Spread 3	31	-0.191	0.042	-4.564	0.298	0.373	0.497	1.491	4.474	-0.640	-0.512	-0.384	-0.128	-0.043
Spread 4	3/7/2008	Spread 4	29	-1.407	0.451	-3.119	0.292	0.366	0.487	1.462	4.387	-4.811***	-3.849***	-2.886***	-0.962	-0.321
Spread 5	10/17/2008	Spread 5	61	0.311	0.054	5.775	0.357	0.446	0.595	1.785	5.356	0.872	0.698	0.523	0.174	0.058
Spread 6	1/9/2009	Spread 6	73	-0.185	0.089	-2.071	0.373	0.466	0.621	1.863	5.590	-0.496	-0.397	-0.298	-0.099	-0.033
Spread 7	11/18/2005															

Notes. Critical values for one-sided (left-tailed) test of migration (see details in Section 2): -2.326 (1% level test), -1.645 (5% level test), -1.282 (10% level test). m: number of weekly observations between the observation immediately after peak of mildly explosive behavior in Spread 1 and peak of mildly explosive behavior in other spreads. L(m)=a*log(m). *** denotes statistical significance at the 1% level; ** denotes statistical significance at the 5% level; * denotes statistical significance at the 10% level.

Table 5: Tests of Migration from Spread 2 (3-month ABCP-Treasury)

	Peak of the BSADF Test Statistic	Migration to	m	β_1	Standard Error	T-Stat	L(m)					Z_β				
							a=1/5	a=1/4	a=1/3	a=1	a=3	a=1/5	a=1/4	a=1/3	a=1	a=3
Spread 1	8/17/2007															
Spread 2	10/12/2007															
Spread 3	3/21/2008	Spread 3	23	-0.173	0.049	-3.546	0.272	0.340	0.454	1.362	4.085	-0.636	-0.509	-0.382	-0.127	-0.042
Spread 4	3/7/2008	Spread 4	21	-0.953	0.407	-2.341	0.264	0.331	0.441	1.322	3.967	-3.602***	-2.882***	-2.161**	-0.720	-0.240
Spread 5	10/17/2008	Spread 5	53	0.194	0.154	1.258	0.345	0.431	0.575	1.724	5.173	0.563	0.450	0.338	0.113	0.038
Spread 6	1/9/2009	Spread 6	65	-0.914	0.121	-7.581	0.363	0.453	0.604	1.813	5.439	-2.521***	-2.017**	-1.512*	-0.504	-0.168
Spread 7	11/18/2005															

Notes. Critical values for one-sided (left-tailed) test of migration (see details in Section 2): -2.326 (1% level test), -1.645 (5% level test), -1.282 (10% level test). m: number of weekly observations between the observation immediately after peak of mildly explosive behavior in Spread 2 and peak of mildly explosive behavior in other spreads. L(m)=a*log(m). *** denotes statistical significance at the 1% level; ** denotes statistical significance at the 5% level; * denotes statistical significance at the 10% level.

Table 6: Tests of Migration from Spread 4 (5-year Aaa private-label CMBS-Treasury)

							L(m)					Z_β				
	Peak of the BSADF Test Statistic	Migration to	m	β_1	Standard Error	T-Stat	a=1/5	a=1/4	a=1/3	a=1	a=3	a=1/5	a=1/4	a=1/3	a=1	a=3
Spread 1	8/17/2007															
Spread 2	10/12/2007															
Spread 3	3/21/2008															
Spread 4	3/7/2008															
Spread 5	10/17/2008	Spread 5	32	1.210	0.071	17.007	0.301	0.376	0.502	1.505	4.515	4.019	3.216	2.412	0.804	0.268
Spread 6	1/9/2009	Spread 6	44	-0.036	0.040	-0.901	0.329	0.411	0.548	1.643	4.930	-0.109	-0.087	-0.065	-0.022	-0.007
Spread 7	11/18/2005															

Notes. Critical values for one-sided (left-tailed) test of migration (see details in Section 2): -2.326 (1% level test), -1.645 (5% level test), -1.282 (10% level test). m: number of weekly observations between the observation immediately after peak of mildly explosive behavior in Spread 4 and peak of mildly explosive behavior in other spreads. L(m)=a*log(m). *** denotes statistical significance at the 1% level; ** denotes statistical significance at the 5% level; * denotes statistical significance at the 10% level.

Table 7: Tests of Migration from ABX.HE.BBB.06-1

	Peak of the BSADF Test Statistic	Migration to	m	β_1	Standard Error	T-Stat	L(m)					Z_β				
							a=1/5	a=1/4	a=1/3	a=1	a=3	a=1/5	a=1/4	a=1/3	a=1	a=3
ABX BBB	7/27/2007[a]															
Spread 1	8/17/2007															
Spread 2	10/12/2007	Spread 2	11	6.623	6.606	1.003	0.208	0.260	0.347	1.041	3.124	31.799	25.439	19.079	6.360	2.120
Spread 3	3/21/2008	Spread 3	34	0.411	1.048	0.393	0.306	0.383	0.510	1.531	4.594	1.343	1.075	0.806	0.269	0.090
Spread 4	3/7/2008	Spread 4	32	-2.268	1.318	-1.720	0.301	0.376	0.502	1.505	4.515	-7.534***	-6.028***	-4.521***	-1.507*	-0.502
Spread 5	10/17/2008	Spread 5	64	0.036	3.759	0.010	0.361	0.452	0.602	1.806	5.419	0.101	0.081	0.060	0.020	0.007
Spread 6	1/9/2009	Spread 6	76	-10.528	3.449	-3.052	0.376	0.470	0.627	1.881	5.642	-27.988***	-22.390***	-16.793***	-5.598***	-1.866**
Spread 7	11/18/2005															

Notes. Critical values for one-sided (left-tailed) test of migration (see details in Section 2): -2.326 (1% level test), -1.645 (5% level test), -1.282 (10% level test). m: number of weekly observations between the observation immediately after the exogenously determined peak of mildly explosive behavior in ABX BBB and peak of mildly explosive behavior in other spreads. L(m)=a*log(m). *** denotes statistical significance at the 1% level; ** denotes statistical significance at the 5% level; * denotes statistical significance at the 10% level.

[a] Peak is exogenously imposed as described in Section 5.

Highlights:

- We test for the existence of mildly explosive behavior in seven U.S. fixed income yield spreads.
- We find evidence of mildly explosive behavior in all but one spread.
- We find evidence of migration of mildly explosive behavior from spreads representing short-term funding markets to spreads with longer maturity in the real estate derivatives market and corporate junk bond market.
- We empirically validate Gorton (2009a,b)'s conjecture that the financial panic of 2007-09 initially spread from the ABX index to other fixed income markets.