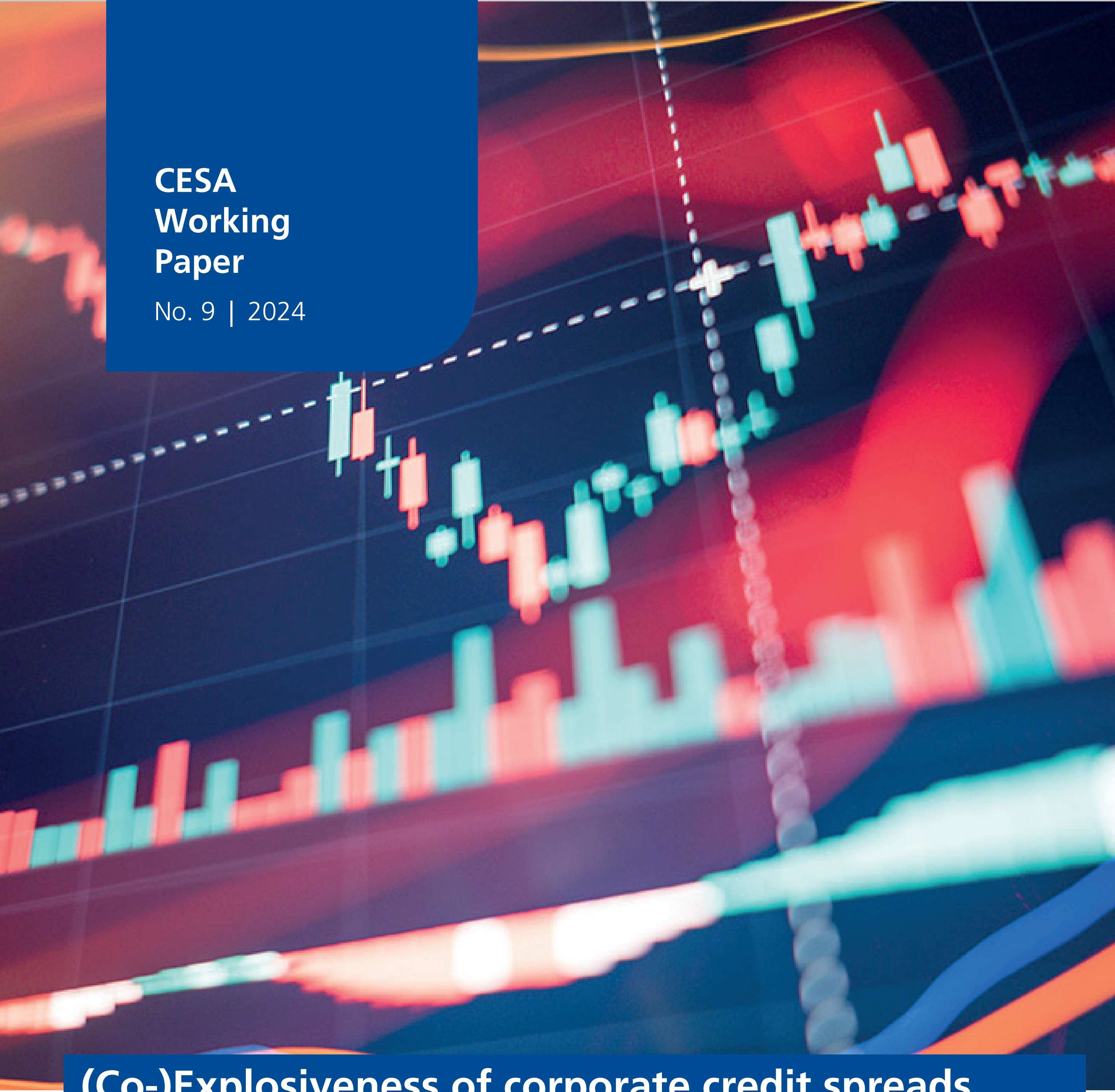

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(Co-)Explosiveness of corporate credit spreads

Marco Kerkemeier[(a)]

a University of Hagen (FernUniversität in Hagen)

FernUniversität in Hagen

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Marco Kerkemeier[a]

[a]University of Hagen†

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Abstract

Financial crisis and exuberances are a companion of financial markets ever since. At latest since the global financial crisis 2007/09 (GFC), there is a growing awareness for the importance of systemic risk in financial markets. In this vein and as a major contributor to the GFC, understanding of dependence structures within the fixed income market in a more detailed way is required. This research deals with the explosiveness and co-explosiveness of different corporate credit spreads within a country and across different countries. Co-explosiveness constitutes a situation in which two explosive time series share the same autoregressive regime and thus, produce a higher systemic risk. Therefore, the markets in Australia, Canada, Euro Area, Japan, UK and USA are analysed between 2000 and 2023. All of the analysed credit spreads show temporary mild explosiveness and the major periods where a clustering of explosive periods takes place are the GFC and the COVID- 19 period. For the full sample period, there is no co-explosiveness between different spreads but at the local level, there is, i.e. GFC and COVID-19. The percentage of credit spread-pairs that show co-explosiveness has declined since the GFC which can be interpreted as an improvement in financial regulation due to Basel III and Solvency II. Another consequence of the reduced co-explosiveness is the higher potential for portfolio diversification.

Keywords: Explosive behaviour, co-explosiveness, financial turmoil, systemic risk, credit spreads

JEL classification: C22, C58, G01, G12, G32

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†**Corresponding author:** University of Hagen, Faculty of Business Administration and Economics, Universitätsstr. 41, 58097 Hagen, Germany, e-mail address: `marco.kerkemeier@fernuni-hagen.de`, phone: +49 2331 987-4641.

1 Introduction

Crises were a companion of financial markets during the last decades. Events such as the burst of the dotcom-bubble, global financial crisis 2007/09 (GFC), and COVID-19 had a major impact on both financial markets and real economic output. Many researchers tried to develop methods to detect and date-stamp such extraordinary periods. Phillips, Wu, and Yu (2011), Homm and Breitung (2012), Harvey, Leybourne, and Sollis (2015), and Phillips, Shi, and Yu (2015) laid the ground for advanced time series-based procedures for detecting the starting and end dates of financial exuberance periods. Such tests are designed to distinguish between 'normal market periods' (unit root processes) and explosive behaviour. While there is lots of research concerning the explosive behaviour of equity markets, e.g., by Diba and Grossman (1987), Phillips, Wu, and Yu (2011), Homm and Breitung (2012), Harvey, Leybourne, and Sollis (2015), Whitehouse (2019), and Kerkemeier, Kruse-Becher, and Wegener (2024), there is less extensive research concerning the explosive nature of bond spreads, i.e. Phillips and Yu (2011), Kruse and Wegener (2019), Wegener, Kruse, and Basse (2019), and Contessi, De Pace, and Guidolin (2020).

The fixed income market, which is much larger compared to the equity market[1], plays a major role for the health of the global financial system. Many institutional investors such as pension funds, insurance companies and asset managers are heavily invested in the bond market – due to their risk profile and regulatory requirements. The fixed income market played a significant role during the GFC, see e.g. Jorda, Schularick, and Taylor (2015) and Contessi, De Pace, and Guidolin (2020), due to which a higher awareness of interconnectedness among financial markets of different countries and asset classes emerged. This higher consciousness for systemic risk and the lack of research concerning bond credit spreads during exuberance periods is where my research comes into play.

This paper does not only investigate the explosiveness of corporate credit spreads but it also analyses the dependence among them. Explosiveness of credit spreads comprises situations in which there is a sharp incline in credit risk.[2] This is of importance to different parties, especially for investors, financial institutions and policy makers. The portfolios of institutional investors which often mainly consist of corporate and government bonds become riskier and frequently risk budgets or limits are hit and thus, portfolio rebalancing has to be done. Additionally, strongly (explosively) rising credit

[1] SIFMA (2024) estimates the outstanding amount of global fixed income markets as approximately \$140.7 trillion vs. \$115 trillion global equity market capitalization in 2023.

[2] I abstract from classifying sharp declines in credit risk as explosive, too because their economic implications are significantly different compared to 'positive' explosive periods. Nevertheless, analysing such situations in an additional study would be insightful.

risk can make it more difficult and/or costly for firms to obtain funding from the financial markets by issuing new bonds or obtaining refinancing from banks. Moreover, from a central bank's view, rising credit risk increases the probability and number of credit, bond and firm defaults which can threaten the stability of the whole financial system. This risk of explosive increases in credit spreads is much more severe compared to linearly increasing ones because it reduces the time for action and can hit the economy stronger.

While explosiveness of single credit risk measures is a threat to the health of the financial system, co-explosiveness of them can be even more severe. Co-explosiveness is defined as a situation in which two or more time series share an explosive process. The three potential situations synchronous co-explosiveness, asynchronous co-explosiveness (lead/lag structure) and no-co-explosiveness can have serious consequences for the stakeholders of financial markets. A (stable) asynchronous co-explosiveness would permit the construction of early warning indicators for upcoming explosiveness in credit spreads. In contrast, a synchronous co-explosiveness would mean a critical threat to the financial system because the benefits of diversification in credit portfolios would melt down and exposes the portfolio to an unintended clustering of credit risks. Such situations can result in failures to pay and bankruptcies. In case of no-co-explosiveness, on the one hand, it would be harder (in contrast to asynchronous co-explosiveness) for investors and central bankers to obtain warning signs from other credit spreads and more separate analyses of the credit market would be required. On the other hand, no-co-explosiveness can reduce the likelihood of a global crisis and thus, increases the diversification potential of different credit risk exposures in a portfolio.

The analysis is run for six different regions, namely Australia, Canada, Euro Area, Japan, UK and USA. For all of them, two different spread categories are considered. First, in line with Phillips and Yu (2011) and Contessi, De Pace, and Guidolin (2020) the spread between BBB- and AAA-rated corporate bonds (BBB-AAA spread) is analysed. It is the difference between the lowest- and highest-rated investment grade bonds' yields. It is of major importance because many institutional investors are only allowed by law to invest in such investment grade bonds. Second, the spread between all investment grade corporate and government bonds is calculated. This is done to account for the often observed flight-to-quality and flight-to-liquidity behaviour of investors during times of turmoil (Beber, Brandt, and Kavajecz, 2009; Constantini and Sousa, 2022).

The analysis consists of three steps. First, it is tested whether there are explosive periods inside the twelve different credit spreads. For this, the generalized supremum augmented Dickey-Fuller

(GSADF) test of Phillips, Shi, and Yu (2015) is used. For all spreads, the null hypothesis of a unit root is rejected in favour of explosive behaviour. The second step is the identification of the start and end dates of explosiveness by applying the backward supremum augmented Dickey-Fuller (BSADF) test; also of Phillips, Shi, and Yu (2015). The majority of explosive periods are clustered around the GFC and the COVID-19 period. The third major step is the analysis of the relationship between the identified periods. To do so, the bivariate co-explosiveness testing framework of Evripidou et al. (2022) is applied. Such a testing procedure is not only able to identify whether explosiveness in two time series is perfectly synchronized but it is also able to identify a lead-lag structure between two time series. The co-explosiveness analysis is done in two different ways. First, the co-explosiveness of different spreads within single countries is analysed and second, the co-explosiveness within the same spread category between different countries is investigated. The analyses reveal that there is no co-explosiveness over the full sample period (5th January 2001 to 29th September 2023). Instead, co-explosiveness can be found in many credit spreads during specific periods such as the GFC and COVID-19. Especially since the GFC, a decline in the percentage of co-explosive corporate credit spread-pairs can be observed which can be linked to improved financial regulations such as Basel III and Solvency II. Such a reduction in co-explosiveness, which implies less interdependencies between credit spreads when they are explosive, can also make the merits of portfolio diversification more valuable because it can better protect against explosive behaviour. Additionally, the lead/lag structure between different credit spreads is changing over time which underlines the high complexity of the fixed income market due to diverse influence factors.

The remaining structure is as follows: Section 2 gives an overview of the fixed income explosiveness literature and about the work on co-explosiveness. Section 3 describes the used data set while Section 4 explains the methodology to detect co-explosiveness. Section 5 illustrates the analysis and Section 6 concludes.

2 Overview of fixed income explosiveness and co-explosiveness research

2.1 Fixed income spread explosiveness and migration

There is only little research concerning the explosive behaviour of corporate bond spreads. One of the first were Phillips and Yu (2011) who propose a method to detect the migration of explosive processes. They show that the 2007 bubble from the US housing market migrated to the US bond market. Kruse and Wegener (2019) analyse the interplay between mild explosiveness and long-memory behaviour of financial time series. They show that there was no explosive behaviour in the spread between the 10 years French German government bond spread but they find explosive behaviour for the Greece German government bond spread (for the period running from January 2002 to June 2012). Also in 2019, Wegener, Kruse, and Basse (2019) analyse the explosiveness of the spreads between 10 years German government bond yields and each of the following countries' government bond yields: Greece, Ireland, Italy, Portugal and Spain. For their sample running from 5th January 2001 to 24th June 2016 they find mild explosiveness for each bond spread under investigation. Additionally they show that the explosiveness in all spreads, with the exception of the German Irish spread, is driven by the US housing market from which the bubble migrated. Next to this research, the closest study to mine is done by Contessi, De Pace, and Guidolin (2020). They analyse eight different spreads, including the LIBOR-OIS spread, ABCP-treasury spread and Baa-Aaa corporate bond spread for the US. They point out that six out of their eight analysed spreads exhibit periods of mild explosiveness. Additionally, they show that the explosive behaviour during the GFC migrated from short-term to mid- and long-term bond spreads.

2.2 Co-explosiveness research

One of the first formal tests for co-explosiveness has been proposed by Ahlgren and Nyblom (2008) who use a VAR procedure which allows to test for co-explosiveness of more than two different time series. Using this framework, they analyse the explosiveness of the system of time series consisting of wages, CPI, exchange rates and money stock during the Yugoslavian hyperinflation period. Engsted and Nielsen (2012) develop a bivariate autoregressive framework for co-explosiveness which is applied to the multivariate time series consisting of US dividends and stock prices.

A more recent approach has been proposed by Evripidou et al. (2022) who first apply the GSADF- and BSADF-procedure and then use a KPSS-test to evaluate co-explosiveness in a bivariate setting. They have applied their framework to different metal prices. This procedure has also been used by Basse et al. (2023) to investigate if there is co-explosiveness between three different kinds of stock market indices, namely NASDAQ OMX Green Economy Index, MVIS Global Coal, and MSCI World Equity Index. Also in 2023, Montasser, Belhoula, and Charfeddine (2023) analyse if there is co-explosiveness between crude oil and different agricultural commodities. Besides, Bouri, Shahzad, and Roubaud (2019) and Manahov (2024) investigate the co-explosive nature of different cryptocurrencies.

The test of explosiveness migration of Phillips and Yu (2011) and the co-explosiveness test of Evripidou et al. (2022) are related but there are some major differences between them. First and most importantly, the explosiveness migration test is much more restrictive. It only allows for a migration of explosiveness from time series x_t to time series y_t from that time on in which x_t is already in its collapse phase. It is not possible to test if an explosive behaviour from x_t migrates to time series y_t while x_t has still not reached its collapsing point. It is also not able to test for x_t and y_t being explosive simultaneously. In contrast, the KPSS-based test of Evripidou et al. (2022) is able to test for simultaneous co-explosiveness and for a lead/lag co-explosiveness behaviour. Second, the procedure of Phillips and Yu (2011) relies on a slowly varying function which is hard to determine while the KPSS-based co-explosiveness test is easier to implement because it relies on less critical assumptions and parameter settings.

3 Data

The six different markets Australia, Canada, Euro Area, Japan, UK, and USA are analysed between 5th January 2001 and 29th September 2023.[3] The analysis is done based on weekly data which is in line with Wegener, Kruse, and Basse (2019) and Contessi, De Pace, and Guidolin (2020). The bond data are obtained from the Intercontinental Exchange (ICE), see Table 1. The applied indices are of the ICE BofA (Intercontinental Exchange Bank of America) index family. For the analysis, 24 different time series in the format yield to maturity are used. The starting date for each index is chosen in such a way that all four considered indices for each region, i.e. the general corporate bond market index, its AAA and BBB corporate bond indices as well as the government bond index are available. Therefore, the data set starts at the 5th January 2001. The end date is the last trading day of September 2023.

Based on these indices, two spread categories are calculated. These calculations are done separately for each region. On the one hand, I calculate the spread between BBB- and AAA-rated bonds which is in line with Contessi, De Pace, and Guidolin (2020). While AAA-rated bonds are the

[3] This is the largest available sample of high-quality corporate and government bond indices via the Intercontinental Exchange (ICE). Despite of the larger volume of the fixed income market compared to the stock market, the availability of high-quality representative bond indices is limited (this is also true for similar data providers like Bloomberg, Moody's and S&P). This is especially the case for AAA and BBB corporate bond indices for specific countries.

highest-rated bonds available, BBB-rated bonds are the lowest-rated category of bonds which are still part of the investment grade universe. Below investment grade bonds are not considered because many institutional investors are not permitted to invest in them. Thus, such a spread illustrates the credit risk inherent in an investment grade corporate bond portfolio. On the other hand, I consider the spread between the overall corporate investment grade bond market and government bonds (also investment grade) to account for the empirical observable phenomenon that many institutional investors shift their investments during periods of higher uncertainty to government bonds, often termed as flight-to-quality and/or flight-to-liquidity (Beber, Brandt, and Kavajecz, 2009; Constantini and Sousa, 2022).[4]

Table 1: Bond market indices applied in the analysis

Index	**ICE code**	**Start date**	**End date**
ICE BofA Australia Corporate Index	AUC0	2001-01-05	2023-09-29
ICE BofA Canada Corporate Index	F0C0	2001-01-05	2023-09-29
ICE BofA Euro Corporate Index	ER00	2001-01-05	2023-09-29
ICE BofA Japan Corporate Index	JC00	2001-01-05	2023-09-29
ICE BofA Sterling Corporate Index	UR00	2001-01-05	2023-09-29
ICE BofA US Corporate Index	C0A0	2001-01-05	2023-09-29
ICE BofA Australia Government Index	G0T0	2001-01-05	2023-09-29
ICE BofA Canada Government Index	G0C0	2001-01-05	2023-09-29
ICE BofA Euro Government Index	EG00	2001-01-05	2023-09-29
ICE BofA Japan Government Index	G0Y0	2001-01-05	2023-09-29
ICE BofA UK Gilt Index	G0L0	2001-01-05	2023-09-29
ICE BofA US Treasury Index	G0Q0	2001-01-05	2023-09-29
ICE BofA AAA Australia Corporate Index	AC10	2001-01-05	2023-09-29
ICE BofA AAA Canada Corporate Index	F0C1	2001-01-05	2023-09-29
ICE BofA AAA Euro Corporate Index	ER10	2001-01-05	2023-09-29
ICE BofA AA Japan Corporate Index	JC20	2001-01-05	2023-09-29
ICE BofA AAA Sterling Corporate Index	UR10	2001-01-05	2023-09-29
ICE BofA AAA US Corporate Index	C0A1	2001-01-05	2023-09-29
ICE BofA BBB Australia Corporate Index	AC40	2001-01-05	2023-09-29
ICE BofA BBB Canada Corporate Index	F0C4	2001-01-05	2023-09-29
ICE BofA BBB Euro Corporate Index	ER40	2001-01-05	2023-09-29
ICE BofA BBB Japan Corporate Index	JC40	2001-01-05	2023-09-29
ICE BofA BBB Sterling Corporate Index	UR40	2001-01-05	2023-09-29
ICE BofA BBB US Corporate Index	C0A4	2001-01-05	2023-09-29

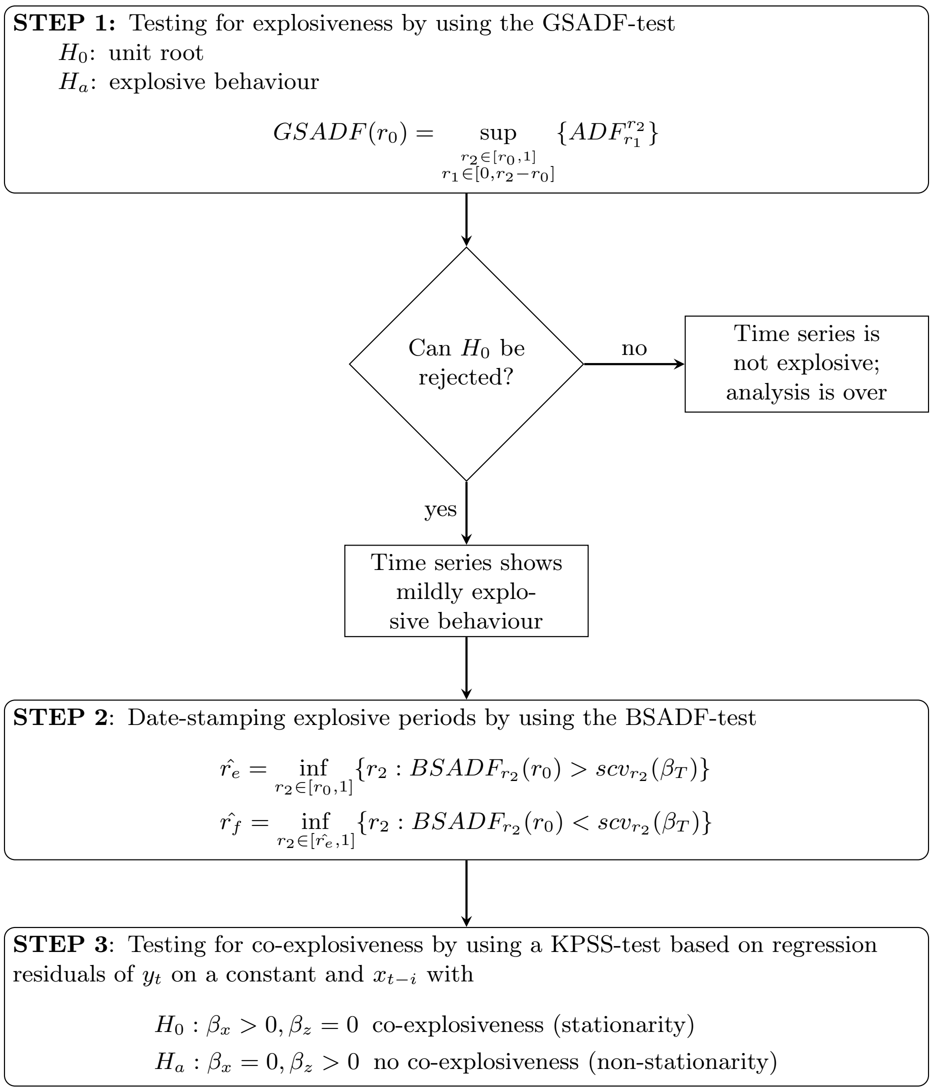
This table provides an overview of all used bond market indices. It consists of all four categories of bond indices. They are sorted alphabetically based on the region they cover. The first column provides the full name of each index and the second the ICE code. In the third and fourth column, the start and end date of each time series are provided. Because ICE stopped the calculation of the AAA Corporate Index for Japan, the ICE BofA AA Japan Corporate Index is used.

[4]Descriptive statistics concerning the used spreads can be found in Appendix A.

4 Econometric methods

Identifying co-explosiveness within two time series is a three-step procedure. First, the univariate time series are tested for mild explosiveness by running the generalised supremum augmented Dickey Fuller (GSADF)-test. If this test identifies explosiveness, the second step is to do date-stamping by applying the backward supremum augmented Dickey Fuller (BSADF)-test. The final step is to run a KPSS-based co-explosiveness-test, see Figure 1.

Figure 1: Flow chart of the testing steps for co-explosiveness



4.1 Testing explosiveness

The test for explosiveness is done by applying the Phillips, Shi, and Yu (2015) procedure (PSY) which is until now the market standard. The idea is to perform a right-tailed unit root test with forwards and backwards expending windows, so that there are no size and power distortions in case of more than one explosive period which is the case for standard unit root and co-integration tests (Evans, 1991; Flood and Hodrick, 1986). The major idea is to run a right-sided ADF-test based on different data samples. Therefore, the following regression is estimated with expanding starting (r_1) and end values (r_2):

$$\Delta y_t = \mu_{r_1,r_2} + \rho_{r_1,r_2} y_{t-1} + \sum_{i=1}^{k} \phi^i_{r_1,r_2} \Delta y_{t-i} + \epsilon_t \tag{1}$$

with $r_1 \in [0, r_2 - r_0], r_2 \in [r_0, 1]$ and $r_0 = 0.01 + 1.8/\sqrt{T}$. These values are scaled to lay between 0 and 1. Δy_t is the first difference of the credit spread which is regressed on a constant μ_{r_1,r_2}, the first order lag of the credit spread y_{t-1} and k additional lags of the dependent variable Δy_t. The number of additional lags is selected based on the Bayesian Information Criterion (BIC). The corresponding hypotheses are then:

$$H_0 : \rho_{r_1,r_2} = 0 \quad \text{(unit root)}$$
$$H_a : \rho_{r_1,r_2} > 0 \quad \text{(explosive behaviour)}$$

The quantity of interest is the GSADF-test statistic which is the largest value of the ADF statistic over all r_1 and r_2:

$$GSADF(r_0) = \sup_{\substack{r_2 \in [r_0,1] \\ r_1 \in [0, r_2 - r_0]}} \{ADF^{r_2}_{r_1}\}. \tag{2}$$

If $GSADF(r_0) > GSADF_{CV}$, the null hypothesis of a unit root has to be rejected in favour of explosive behaviour. To account for unknown forms of structural changes in both the conditional and unconditional volatility, the wild bootstrap procedure of Phillips and Shi (2020) is applied to obtain the adequate critical value of the GSADF-test statistic ($GSADF_{CV}$). The procedure consists of five steps. First, the ADF regression model is estimated under the hypothesis that ρ is 0 based on the full sample. In the second step, the estimated residuals are multiplied by an $iidN(0, 1)$ variable and then a bootstrap sample is constructed and after that, the PSY test statistic series and based on it, the maximum value is calculated. Next, these two steps are repeated n times. In the last step, the $(1 - \alpha)\%$ quantile of the series of maximum values is calculated and this is the critical value of the test. If there are no explosive periods found in the time series, the time series is considered to do not show explosive credit spreads at any time and therefore drops out of the following date-stamping and co-explosiveness analysis.

4.2 Identification of explosive periods

The previously described approach is able to detect the existence of explosive credit spreads but it does not allow for date-stamping. To locate the beginning and ending of explosiveness, the BSADF-test of Phillips, Shi, and Yu (2015) is applied. It performs ADF-tests based on a backward expanding sample which has a fixed endpoint r_2 but varying starting points r_1:

$$BSADF_{r_2}(r_0) = \sup_{r_1 \in [0, r_2 - r_0]} \{ADF_{r_1}^{r_2}\}. \tag{3}$$

The estimator of the initiation date $\hat{r}_e$ is the first time, where the test statistic exceeds its wild bootstrapped critical value sequence ($scv_{r2}(\beta_T)$), with $\beta_T = 0.05$ being the nominal significance level, and the termination date estimator $\hat{r}_f$ is the date at which the test statistic first lies below its critical value:

$$\hat{r_e} = \inf_{r_2 \in [r_0, 1]} \{r_2 : BSADF_{r_2}(r_0) > scv_{r_2}(\beta_T)\}, \tag{4}$$

$$\hat{r_f} = \inf_{r_2 \in [\hat{r_e}, 1]} \{r_2 : BSADF_{r_2}(r_0) < scv_{r_2}(\beta_T)\}. \tag{5}$$

The date-stamping procedure is – strictly speaking – not required to run the co-explosiveness procedure. Nevertheless, it is beneficial because it allows to define reasonable subsamples for a more granular analysis, i.e. it does not make any sense to test for co-explosiveness in a subsample for a credit spread-pair in which at least one of them do not show any signs of explosive behaviour.

4.3 Testing for co-explosiveness

One speaks about co-explosiveness if two temporary explosive time series are related in such a way so that a linear combination of them is $I(0)$. Therefore, there is an obvious relation between the concepts of co-integration and co-explosiveness. In case of co-integration, the linear combination of two time series which are each $I(1)$, is $I(0)$ (Engle and Granger, 1987). The difference between co-explosiveness and co-integration is now that in case of co-explosiveness, the two time series that share a long-run trend are each explosive what implies that they are $I(\infty)$ and not $I(1)$. But it is important to keep in mind that a co-explosive relationship between two time series implies that there is co-integration in their $I(1)$ regimes (Evripidou et al., 2022).

In case of explosiveness found in both time series under consideration, the KPSS-based testing procedure of Evripidou et al. (2022) is applied. The DGP of the temporary explosive time series y_t is defined as:

$$y_t = \mu_y + \beta_x x_{t-i} + \beta_z z_t + \epsilon_{y,t}. \tag{6}$$

μ_y is a constant, x_{t-i} is a temporary explosive time series with i as a positive or negative integer (or 0) accounting for a potential lead-lag structure and z_t being a latent, unobserved process while $\epsilon_{y,t}$ is a white noise process. Furthermore, the three error terms $\epsilon_{y,t}, \epsilon_{x,t}, \epsilon_{z,t}$ are allowed to be correlated. Based on this DGP, the explosiveness can either be driven by x_{t-i}, z_t or by both of them together. In case of $\beta_x > 0$ and $\beta_z = 0$, y_t and x_{t-i} are co-explosive while in case of $\beta_x = 0$ and $\beta_z > 0$ they are not. The case of $\beta_x > 0$ and $\beta_z > 0$ is implicitly included in the no-co-explosiveness situation and the case of both $\beta_x = \beta_z = 0$ is not considered because that would mean that there is no explosiveness in y_t. Under co-explosiveness, the linear combination $y_t - \mu_y - \beta_x x_{t-i}$ is integrated of order 0. Therefore, co-explosiveness can be examined by testing the estimated residuals of the regression of y_t on x_{t-i} and a constant for stationarity.

The lead/lag parameter i is calculated in line with Evripidou et al. (2022) who choose the i parameter out of the pre-specified range of values I which results in the lowest residual variance ($\hat{\sigma}^2_{\epsilon_y,i}$) of the regression of y_t on x_{t-i} and a constant:

$$\hat{i} = \underset{i \in I}{\arg\min}\, \hat{\sigma}^2_{\epsilon_y,i}. \tag{7}$$

In the next step, this $\hat{i}$ is used to determine the test statistic and its corresponding wild bootstrapped critical value which is needed to test for co-explosiveness. One now might think why to care so much about $\hat{i}$ and not just setting it to a specific value like 0. Evripidou et al. (2022) conduct simulations about the effect of a misspecified lead/lag parameter. They are able to demonstrate in a MC setting that the further away $\hat{i}$ is from the true i in absolute terms, the higher the size of the co-explosiveness test becomes.

To test the regression residuals, a modified KPSS-test of Kwiatkowski et al. (1992) is applied:

$$
\begin{aligned}
S =& \frac{1}{\hat{\sigma}_y^2 (T-|i|)^2} \sum_{t=i\mathbf{1}(i>0)+1}^{T+i\mathbf{1}(i<0)} \left(\sum_{s=i\mathbf{1}(i>0)+1}^{t} \hat{e}_{y,s} \right)^2, \\
\hat{e}_{y,t} &= y_t - \hat{\mu}_y - \hat{\beta}_x x_{t-i}, \\
\hat{\sigma}_y^2 &= \frac{1}{T-|i|} \sum_{t=i\mathbf{1}(i>0)+1}^{T+i\mathbf{1}(i<0)} \hat{e}_{y,t}^2.
\end{aligned}
\tag{8}
$$

T is the number of observations and $\hat{e}_{y,s}$ are residuals obtained from regressing y_t on a constant and x_{t-i}. To account for the likely existing serial correlation in the residuals, $\hat{\sigma}_y^2$ is replaced by the long-run variance estimator of Newey and West (1994). If the KPSS statistic is larger than its wild bootstrapped critical value, the null hypothesis of co-explosiveness has to be rejected.

5 Analysis

The analysis consists of two parts. The first one deals with the identification of temporary explosive processes in each single time series while the second part tests for co-explosiveness.

5.1 Univariate explosiveness tests

Explosiveness detection

To test the credit spreads for temporary mildly explosive behaviour, the GSADF-test is applied. Wild bootstrapped critical values are estimated based on $10,000$ replications and lags are selected based on BIC. The results are displayed in Table 9. It is obvious that the GSADF-test statistics of all twelve time series are highly significant. While eleven spreads are significant at the 1% nominal level, only one spread is significant at the 5% nominal level. Therefore, all spreads show explosive behaviour and are thus, eligible for the next step which is date-stamping the time periods when they exhibit explosive behaviour. So, the findings of the literature for different US spreads during the GFC (Contessi, De Pace, and Guidolin, 2020) and for European government bond spreads during the European Sovereign Debt Crisis (Wegener, Kruse, and Basse, 2019) can be confirmed for other markets and different spreads as well.

In this vein, it is important to recognize that the GSADF-test is not only able to detect traditional positive explosive periods but also negative explosiveness, see Phillips and Shi (2018). For the following date-stamping of explosive periods, it is explicitly stated whether the identified periods are positive or negative. Negative periods are not separately considered during the co-explosiveness testing.

Table 2: GSADF-test results

	GSADF-statistic	**GSADF critical values**		
		90%	95%	99%
Australia				
BBB-AAA	***7.15	3.18	3.69	5.07
Corp-Gov	***8.54	2.60	2.93	3.65
Canada				
BBB-AAA	**4.04	2.78	3.18	4.09
Corp-Gov	***8.37	2.76	3.13	4.05
Euro Area				
BBB-AAA	***5.72	2.82	3.16	4.07
Corp-Gov	***8.26	2.67	3.03	3.82
Japan				
BBB-AA	***6.56	3.24	3.76	5.12
Corp-Gov	***5.07	2.67	3.00	3.80
UK				
BBB-AAA	***9.81	2.91	3.33	4.39
Corp-Gov	***7.64	2.73	3.12	3.99
USA				
BBB-AAA	***6.01	3.05	3.52	4.88
Corp-Gov	***9.88	2.84	3.25	4.31

This table provides the GSADF-test results. In the first column are the analysed spreads. The second column provides the calculated GSADF test statistic and the remaining three columns show the bootstrapped critical values for the 90%, 95% and 99% quantile estimated with $10,000$ replications. The significance levels 10%, 5%, and 1% are illustrated by *, **, and ***. All results are round to two decimals.

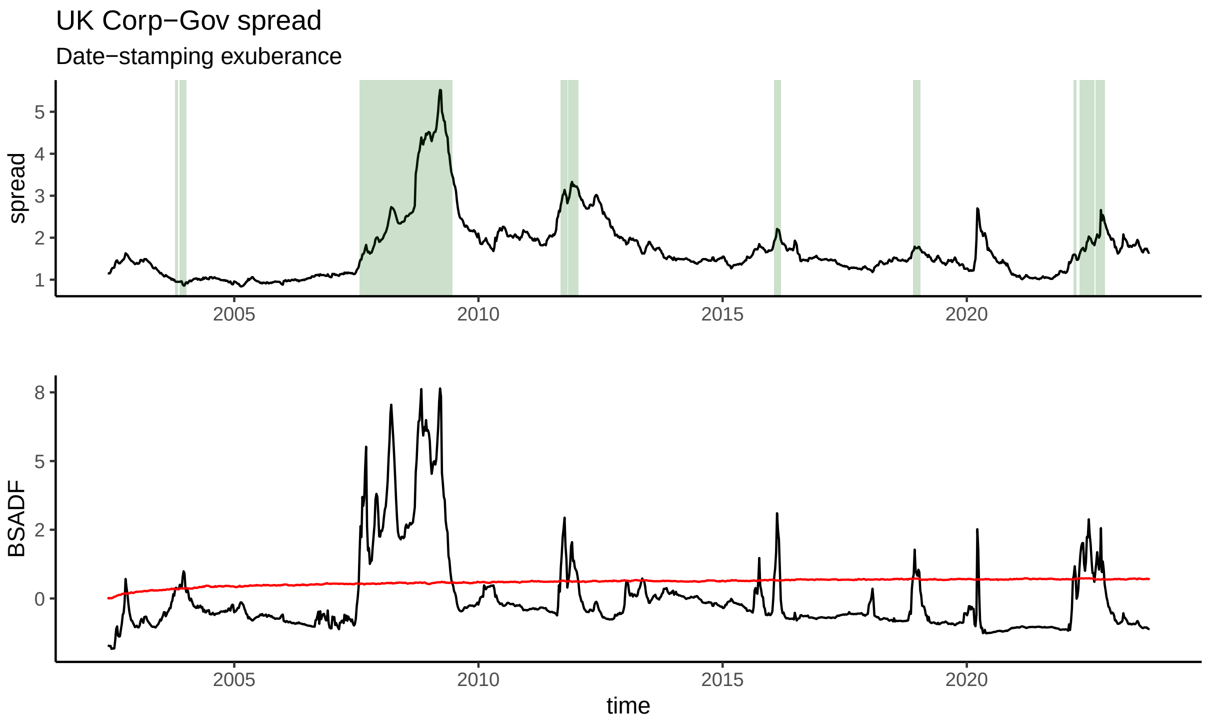
Date-stamping explosiveness

To date-stamp the explosive periods, the BSADF-test comes into play. Lag lengths are chosen based on BIC and tests are run at the nominal 5% level with critical values determined based on a wild bootstrap using $10,000$ replications. In line with Phillips, Shi, and Yu (2015) and Phillips and Shi (2018), I set a minimum number of observations which an explosive period needs to have to be considered as such a period. This is done based on two considerations. First, economically extremely short periods are seldom considered as being explosive and in most cases are not that serious for the stability of the fixed income market because they are short-lived. Most financial stakeholders can deal with such situations well due to the regulatory requirements (e.g., Basel III and Solvency II) concerning capital buffers. Second, it accounts for the fact that no econometric model is perfect and one reduces the influence of financial noise. Therefore, at least three consecutive explosive observations are required.

Exemplary, we have a closer look at the spread between corporate and government bond yields for

UK to illustrate the date-stamping procedure (Figure 2).

Figure 2: Date-stamping of Corp-Gov spread UK

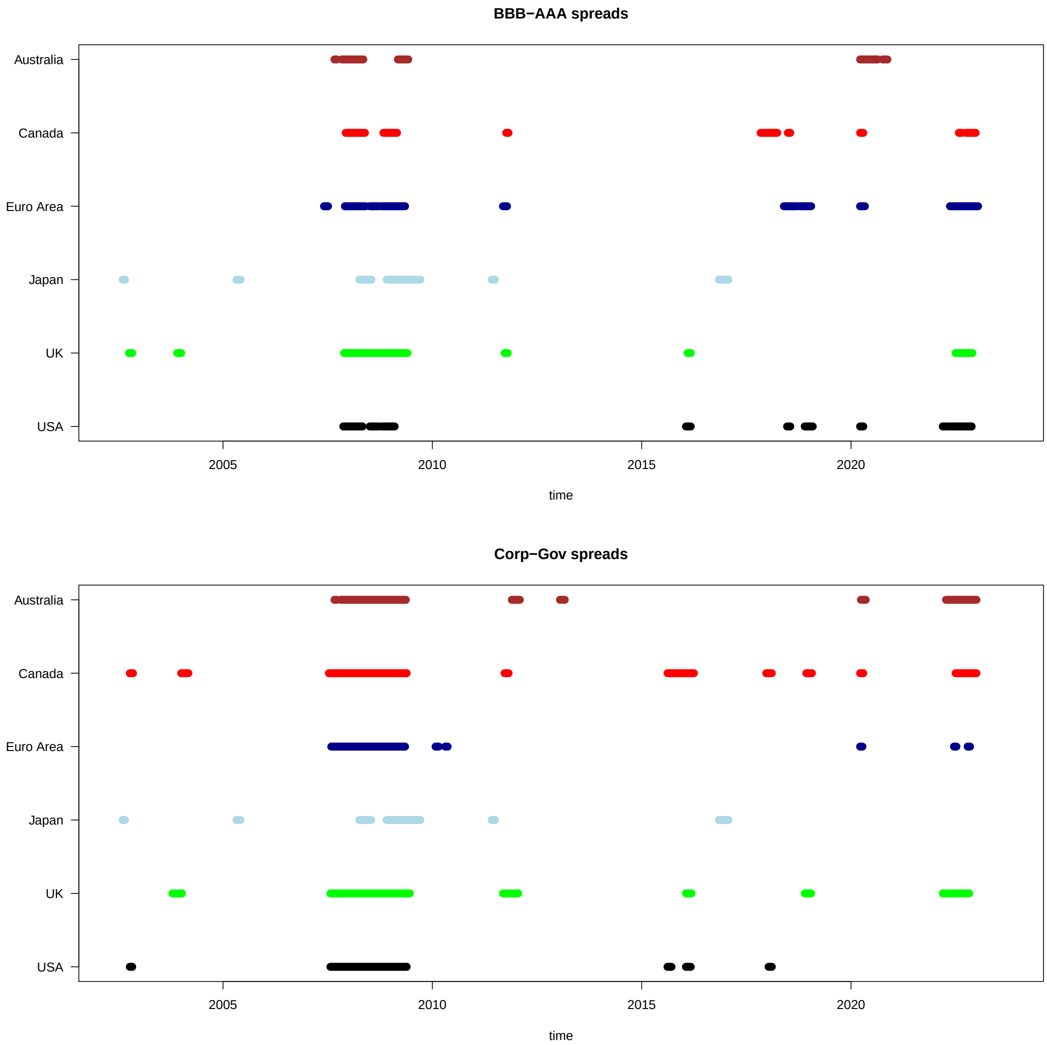


In the lower panel are the BSADF-test statistics (black line) and their corresponding critical values (red line) over the time horizon of the analysis. In the upper panel is the development of the Corp-Gov spread of the UK shown. Every time the BSADF-test statistic crosses its critical values upwards, an explosive episode starts and every time it crosses the critical values downwards, an explosive episode ends. Explosive episodes that consist of at least three observations are highlighted in green in the upper panel.

In the lower panel are the wild bootstrapped critical BSADF value sequence (red line) and the BSADF test statistics (black line). The BSADF statistics are only available from 31st May 2002 onwards until 29th September 2023 because some observations (minimum window size: $T\lfloor 0.01 + 1.8/\sqrt{T}\rfloor$) are needed for calculating the initial test statistic. Every time the BSADF-test statistic crosses its critical value upwards, an explosive episode starts and every time the critical value sequence is crossed downwards, an explosive period ends. In the upper panel are the UK corporate government bond spreads displayed for the same time horizon as the BSADF statistics. All explosive periods that consist of at least three consecutive observations are highlighted in green. The longest most obvious phase of explosiveness is found around the GFC. Additionally, there are some explosive episodes during the COVID-19 pandemic. Next to these major periods, also some minor explosive periods can be found. The same visualizations for all other 23 spreads can be found in Appendix B.

The majority of explosive periods of the twelve spreads cluster around the GFC and the COVID-19 pandemic. But it is also obvious that there is a tendency of explosive behaviour around 2010/11 and between 2016 and 2018[5], see Figure 3. In total, for all six countries' BBB-AAA corporate bond spreads, 48 different periods of explosiveness are identified. While there are five phases for Australia and six for Japan, both Canada and UK exhibit eight phases of explosiveness. The US shows nine periods and the Euro Area twelve. For the second spread of interest, namely the Corp-Gov spread, 42 explosive phases are identified which are distributed over the six regions as follows: Japan (5), USA (5), Australia (6), Euro Area (6), Canada (10), UK (10). A detailed overview of all explosive phases can be found in Appendix C.

Figure 3: Visual overview of explosive periods



In the upper panel are the explosive episodes of the BBB-AAA spreads and in the lower panel are the Corp-Gov spreads. Colourful bars illustrate explosive episodes. Each country gets its own colour.

Based on this date-stamping results it seems to be reasonable to assume that there might be some co-explosive behaviour between different credit spreads. To underpin this observation, the next step

[5]A more detailed description and interpretation of theses periods is taking place in subsection 5.2.

is running co-explosiveness tests.

5.2 Co-explosiveness tests

The co-explosiveness KPSS-framework is run pairwise. Critical values are determined by applying a wild bootstrap procedure with $5,000$ replications. In order to take the correlation of residuals into account, the long-run variance estimator of Newey and West (1994) is applied. The truncation parameter δ is set in line with Basse et al. (2023) to 200/901 and thus, the lag selection parameter for the Bartlett kernel is determined as $\left\lfloor 4\left(\frac{T}{100}\right)^{200/901}\right\rfloor$ with $\lfloor\ \rfloor$ illustrating the integer part (a.k.a. floor). The lead/lag parameter i is allowed to be an integer between -26 and 26, so that x_t can become explosive half a year before or after y_t becomes explosive. Results are provided for the 5% nominal significance level and following Evripidou et al. (2022) also the 2.5% nominal significance level is considered.

The analysis consists of evaluating the bivariate co-explosiveness of BBB-AAA spreads between different countries (30), the bivariate co-explosiveness of Corp-Gov spreads between different countries (30) and the co-explosiveness between these two spreads for each country (12). Therefore, in total there are 72 different co-explosiveness analysis settings. For each spread-pair, the full sample and subsamples of the data set are analysed, see Tables 3, 4, 5. Relevant subsamples are defined by using the outcomes of the date-stamping analysis in line with economic major events.

Subsample definition

The first subsample comprises the global financial crisis 2007/09. To define the starting and end date, the date-stamped explosive periods of the BSADF procedure, information from the Federal Reserve Bank of St. Louis (Federal Reserve Bank of St. Louis, 2009) and of Guillen (2011) are used. To be more conservative and to do not unintentionally drop out explosive periods, the start of the GFC is set to the 2nd April 2007. On this date, one of the biggest subprime mortgage lenders, namely New Century Financial Corporation, filed for bankruptcy. The end point is set to the 18th September 2009. On this day, the US Department of Treasury announced the expiration of the guarantee program for money market funds and described that the risk of systemic failures has been reduced and is not that high anymore.

The second main subsample of interest is the COVID-19 period. The starting and end dates are conservatively set, relying on information from Centers for Disease Control and Prevention (2022) and the World Health Organization (WHO). The earliest observation of COVID-19 is used which is the 12th December 2019 and the end point is set to the 5th May 2023. On this day, the WHO announced that COVID-19 is no longer treated as a public health emergency of international concern (World Health Organization, 2023).

Next to these two major events, two additional periods are defined to account for the observed explosiveness of credit spreads during these times. These are the European Sovereign Debt Crisis and a period of 'General Trouble'. In line with European Commission (2010) and Hobelsberger, Kok, and Mongelli (2022) and the prior date-stamping results, the starting point of the European Sovereign Debt Crisis is set to the 1st January 2010. During this time, the financial mismanagement of the previous years and the resulting pressure on the Greece government became more and more obvious. Defining the end point is much more challenging because there is no consensus in central banks, research and politics about when the European Sovereign Debt Crisis ended – some might even argue that it is still not over. Following Hobelsberger, Kok, and Mongelli (2022) who suggest using an endpoint in July 2013, the end date is set to the 31st July 2013. Last, a period labelled as 'General Trouble' is included to account for the various significant economic events that took place between 2016 and 2019, including the Brexit debate and referendum, the election of Trump, the US-Chinese trade war, etc. It starts at the 1st January 2016 and ends at the 11th March 2019.

Exemplary case

First, we have a look at an exemplary case to illustrate the applied procedure. As an example, the co-explosiveness between the Corp-Gov spreads of Canada and the UK during the GFC period is considered. The i that goes hand in hand with the lowest residual variance is estimated as $\hat{i} = -2$ and its p-value is 0.04. This means, the explosiveness in y_t can be explained by $x_{t-(-2)} = x_{t+2}$. So, the explosiveness occurred first in the Canadian Corp-Gov spread and later in the UK spread. This observation of an earlier explosiveness in the Canadian market is also consistent with the date-stamping of explosive periods. The explosiveness in Canada starts at the 13th July 2007 while the UK followed at the 27th July 2007. By just looking at the BSADF date-stamping results, the lead of the Canadian market is also two periods. In general, when interpreting the date-stamping and co-explosiveness results one has to be careful. It can be the case that two time series are explosive for exactly the same time period but are not co-explosive at all. While the BSADF-test simply date-stamps the start and end dates of an explosive episode, the co-explosiveness-test evaluates whether the linear combination of both time series is stationary. Therefore, BSADF- and KPSS-test results should always be evaluated in conjunction.

Table 3: Co-explosiveness test results between BBB-AAA and Corp-Gov spreads within countries

		Full Sample		**GFC**		**Euro Debt**		**General Trouble**		**COVID-19**	
y_t	x_{t-i}	$\hat{i}$	p	$\hat{i}$	p	$\hat{i}$	p	$\hat{i}$	p	$\hat{i}$	p
Australia BBB-AAA	Australia Corp-Gov	22	0.01	-26	0.02	0	*0.00*	12	*0.00*	14	0.01
Australia Corp-Gov	Australia BBB-AAA	-22	0.02	26	0.06	-12	*0.00*	4	*0.05*	-26	0.00
Canada BBB-AAA	Canada Corp-Gov	3	0.00	5	0.75	26	0.00	25	0.06	0	0.03
Canada Corp-Gov	Canada BBB-AAA	-2	0.00	-5	0.09	17	0.01	-22	0.01	0	0.04
Euro Area BBB-AAA	Euro Area Corp-Gov	4	0.00	5	0.02	-26	0.00	-24	*0.05*	1	0.00
Euro Area Corp-Gov	Euro Area BBB-AAA	-4	0.00	-4	0.02	26	0.00	26	*0.70*	-1	0.00
Japan BBB-AA	Japan Corp-Gov	7	0.00	12	0.00	0	0.05	26	0.00	-26	*0.00*
Japan Corp-Gov	Japan BBB-AA	-7	0.00	-12	0.00	0	0.04	-26	0.00	26	*0.00*
UK BBB-AAA	UK Corp-Gov	3	0.00	4	0.04	1	0.08	18	0.05	0	0.02
UK Corp-Gov	UK BBB-AAA	-3	0.00	-4	0.00	-1	0.01	-18	0.01	0	0.01
USA BBB-AAA	USA Corp-Gov	2	0.00	4	0.48	1	*0.01*	0	0.00	0	*0.00*
USA Corp-Gov	USA BBB-AAA	-2	0.00	-4	0.05	-1	*0.00*	26	0.16	26	*0.17*

This table displays the co-explosiveness testing results for the BBB-AAA and Corp-Gov spreads within a country. The analysis is run based on a KPSS-test. The full sample results as well as the results for the four subsamples GFC, Euro Debt, General Trouble and COVID-19 are provided. In the first two columns are the dependent (y_t) and explanatory variables (x_{t-i}). Then, for both the full sample and the four subsamples, the estimated lead/lag parameter ($\hat{i}$) and the p-values are shown. The critical values are calculated using a wild bootstrap procedure with $5,000$ replications. p-values larger 5% are in green and larger 2.5% but smaller/equal to 5% are written in blue. Be aware that numbers are round to two decimals. Therefore, a 0.051 would be displayed as 0.05 and is highlighted in green. Situations where at least one of the two time series under consideration is not explosive are written in italics.

Table 4: Co-explosiveness test results between Corp-Gov spreads between countries

		Full Sample		GFC		Euro Debt		General Trouble		COVID-19	
y_t	x_{t-i}	$\hat{i}$	p	$\hat{i}$	p	$\hat{i}$	p	$\hat{i}$	p	$\hat{i}$	p
Australia Corp-Gov	Canada Corp-Gov	0	0.00	0	0.00	1	0.01	0	*0.00*	0	0.00
Australia Corp-Gov	Euro Area Corp-Gov	2	0.00	0	0.00	-26	0.01	3	*0.01*	1	0.04
Australia Corp-Gov	Japan Corp-Gov	-2	0.00	-2	0.00	-26	0.00	26	*0.06*	-26	*0.00*
Australia Corp-Gov	UK Corp-Gov	0	0.00	-1	0.00	1	0.03	5	*0.00*	2	0.00
Australia Corp-Gov	USA Corp-Gov	0	0.00	0	0.00	5	*0.00*	3	*0.01*	-26	*0.03*
Canada Corp-Gov	Australia Corp-Gov	0	0.00	0	0.02	-1	0.01	0	*0.00*	25	0.00
Canada Corp-Gov	Euro Area Corp-Gov	1	0.00	1	0.09	17	0.00	1	*0.00*	0	0.05
Canada Corp-Gov	Japan Corp-Gov	-5	0.00	-6	0.14	19	0.01	26	0.02	26	*0.00*
Canada Corp-Gov	UK Corp-Gov	0	0.00	-2	0.04	0	0.03	23	0.19	1	0.19
Canada Corp-Gov	USA Corp-Gov	1	0.00	0	0.24	2	*0.00*	1	0.01	1	*0.00*
Euro Area Corp-Gov	Australia Corp-Gov	-1	0.00	0	0.05	-18	0.00	-3	*0.20*	-1	0.38
Euro Area Corp-Gov	Canada Corp-Gov	-1	0.00	-1	0.22	26	0.00	-1	*0.04*	0	0.00
Euro Area Corp-Gov	Japan Corp-Gov	-10	0.00	-9	0.62	-26	0.00	26	*0.12*	26	*0.00*
Euro Area Corp-Gov	UK Corp-Gov	-1	0.00	-2	0.01	-14	0.00	1	*0.00*	0	0.00
Euro Area Corp-Gov	USA Corp-Gov	0	0.00	-1	0.02	1	*0.00*	1	*0.14*	0	*0.00*
Japan Corp-Gov	Australia Corp-Gov	2	0.00	3	0.00	-11	0.56	7	*0.01*	26	*0.00*
Japan Corp-Gov	Canada Corp-Gov	5	0.00	6	0.02	-18	0.25	-15	0.07	26	*0.02*
Japan Corp-Gov	Euro Area Corp-Gov	10	0.00	9	0.04	-18	0.06	7	*0.02*	26	*0.00*
Japan Corp-Gov	UK Corp-Gov	3	0.00	2	0.05	-23	0.16	7	0.02	26	*0.00*
Japan Corp-Gov	USA Corp-Gov	5	0.00	7	0.06	-17	*0.18*	8	0.01	26	*0.06*
UK Corp-Gov	Australia Corp-Gov	0	0.01	1	0.00	-1	0.01	-4	*0.00*	-2	0.02
UK Corp-Gov	Canada Corp-Gov	0	0.00	2	0.01	0	0.02	-20	0.18	-1	0.01
UK Corp-Gov	Euro Area Corp-Gov	1	0.00	2	0.00	-26	0.00	0	*0.00*	0	0.00
UK Corp-Gov	Japan Corp-Gov	-2	0.00	-2	0.10	-13	0.00	26	0.04	26	*0.00*
UK Corp-Gov	USA Corp-Gov	1	0.00	1	0.03	1	*0.00*	0	0.00	0	*0.00*
USA Corp-Gov	Australia Corp-Gov	0	0.00	0	0.00	-5	*0.00*	14	*0.12*	26	*0.15*
USA Corp-Gov	Canada Corp-Gov	-1	0.00	0	0.04	-2	*0.00*	-1	0.08	26	*0.11*
USA Corp-Gov	Euro Area Corp-Gov	0	0.00	1	0.01	-1	*0.01*	26	*0.05*	26	*0.11*
USA Corp-Gov	Japan Corp-Gov	-5	0.00	-7	0.42	-26	*0.09*	26	0.02	26	*0.00*
USA Corp-Gov	UK Corp-Gov	-1	0.00	-1	0.03	-1	*0.00*	19	0.23	26	*0.14*

This table displays the co-explosiveness testing results for the Corp-Gov spreads between different countries. The analysis is run based on a KPSS-test. The full sample results as well as the results for the four subsamples GFC, Euro Debt, General Trouble and COVID-19 are provided. In the first two columns are the dependent (y_t) and explanatory variables (x_{t-i}). Then, for both the full sample and the four subsamples, the estimated lead/lag parameter ($\hat{i}$) and the p-values are shown. The critical values are calculated using a wild bootstrap procedure with $5,000$ replications. p-values larger 5% are in green and larger 2.5% but smaller/equal to 5% are written in blue. Be aware that numbers are round to two decimals. Therefore, a 0.051 would be displayed as 0.05 and is highlighted in green. Situations where at least one of the two time series under consideration is not explosive are written in italics.

Table 5: Co-explosiveness test results between BBB-AAA spreads between countries

		Full Sample		GFC		Euro Debt		General Trouble		COVID-19	
y_t	x_{t-i}	$\hat{i}$	p	$\hat{i}$	p	$\hat{i}$	p	$\hat{i}$	p	$\hat{i}$	p
Australia BBB-AAA	Canada BBB-AAA	4	0.00	-26	0.00	22	*0.08*	26	*0.00*	-14	0.13
Australia BBB-AAA	Euro Area BBB-AAA	19	0.00	19	0.10	-26	*0.07*	26	*0.03*	14	0.00
Australia BBB-AAA	Japan BBB-AA	13	0.00	-26	0.00	-18	*0.01*	26	*0.00*	26	*0.00*
Australia BBB-AAA	UK BBB-AAA	14	0.00	13	0.34	0	*0.00*	12	*0.00*	14	0.00
Australia BBB-AAA	USA BBB-AAA	18	0.00	18	0.46	0	*0.00*	20	*0.00*	25	0.00
Canada BBB-AAA	Australia BBB-AAA	26	0.00	-13	0.00	-22	*0.02*	26	*0.00*	15	0.00
Canada BBB-AAA	Euro Area BBB-AAA	1	0.00	0	0.16	26	0.02	-26	0.00	0	0.04
Canada BBB-AAA	Japan BBB-AA	18	0.00	-11	0.00	18	0.00	-26	0.00	18	*0.24*
Canada BBB-AAA	UK BBB-AAA	0	0.00	-1	0.01	26	0.19	23	0.02	0	0.08
Canada BBB-AAA	USA BBB-AAA	1	0.00	0	0.27	26	*0.01*	26	0.00	0	0.13
Euro Area BBB-AAA	Australia BBB-AAA	-19	0.00	-19	0.00	-15	*0.00*	-21	*0.18*	-14	0.00
Euro Area BBB-AAA	Canada BBB-AAA	-1	0.00	0	0.06	-26	0.00	26	0.00	0	0.01
Euro Area BBB-AAA	Japan BBB-AA	-12	0.00	-11	0.00	1	0.00	-26	0.00	18	*0.02*
Euro Area BBB-AAA	UK BBB-AAA	-2	0.00	-2	0.05	0	0.00	-21	0.09	0	0.06
Euro Area BBB-AAA	USA BBB-AAA	0	0.00	0	0.34	0	*0.00*	-13	0.27	1	0.05
Japan BBB-AA	Australia BBB-AAA	-13	0.00	-10	0.01	18	*0.12*	26	*0.01*	-26	*0.01*
Japan BBB-AA	Canada BBB-AAA	3	0.00	12	0.01	5	0.22	26	0.05	-17	*0.17*
Japan BBB-AA	Euro Area BBB-AAA	12	0.00	11	0.01	0	0.51	26	0.01	-16	*0.34*
Japan BBB-AA	UK BBB-AAA	9	0.00	9	0.02	-5	0.51	26	0.01	-22	*0.01*
Japan BBB-AA	USA BBB-AAA	9	0.00	9	0.02	-6	*0.47*	26	0.02	-17	*0.14*
UK BBB-AAA	Australia BBB-AAA	-14	0.00	-13	0.00	-26	*0.00*	18	*0.04*	13	0.00
UK BBB-AAA	Canada BBB-AAA	0	0.00	1	0.00	-26	0.02	-22	0.00	0	0.02
UK BBB-AAA	Euro Area BBB-AAA	2	0.00	2	0.01	0	0.00	26	0.42	0	0.19
UK BBB-AAA	Japan BBB-AA	-9	0.00	-9	0.01	-26	0.00	26	0.00	22	*0.00*
UK BBB-AAA	USA BBB-AAA	1	0.00	1	0.08	0	*0.05*	19	0.12	0	0.11
USA BBB-AAA	Australia BBB-AAA	-18	0.00	-18	0.00	-26	*0.00*	0	*0.00*	20	0.00
USA BBB-AAA	Canada BBB-AAA	-1	0.00	0	0.29	-26	*0.05*	26	0.00	0	0.15
USA BBB-AAA	Euro Area BBB-AAA	0	0.00	0	0.23	0	*0.00*	16	0.03	-1	0.17
USA BBB-AAA	Japan BBB-AA	-9	0.00	-9	0.00	-26	*0.00*	26	0.00	18	*0.02*
USA BBB-AAA	UK BBB-AAA	-1	0.00	0	0.02	0	*0.03*	26	0.00	0	0.29

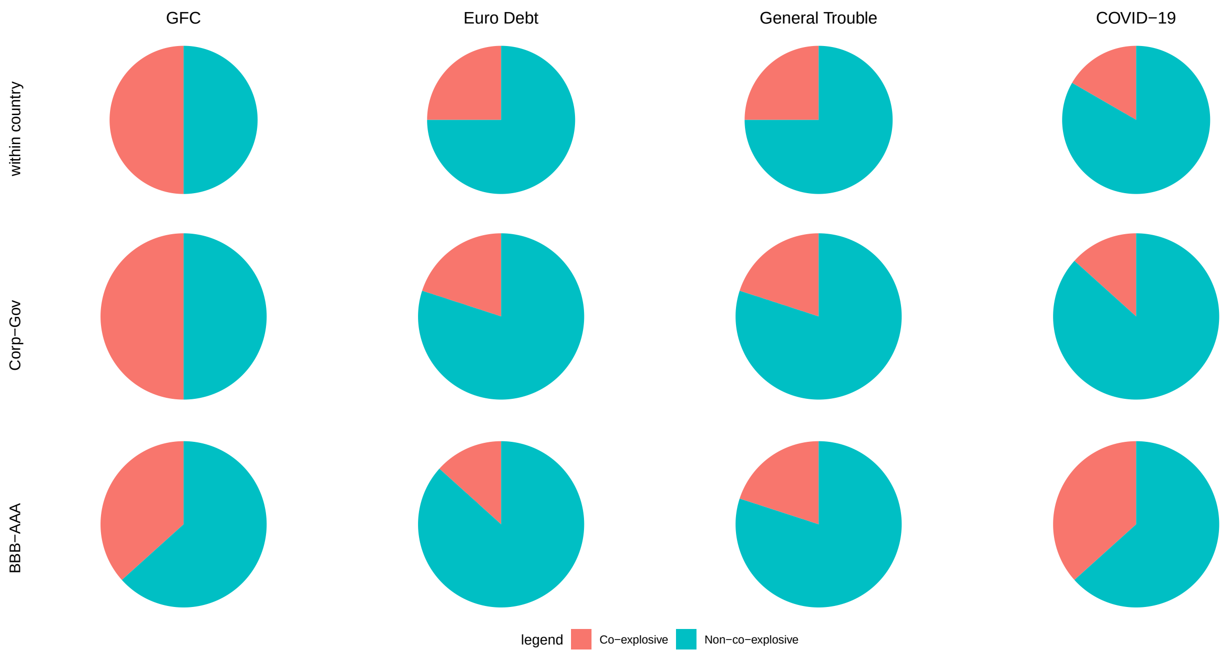
This table displays the co-explosiveness testing results for the BBB-AAA spreads between different countries. The analysis is run based on a KPSS-test. The full sample results as well as the results for the four subsamples GFC, Euro Debt, General Trouble and COVID-19 are provided. In the first two columns are the dependent (y_t) and explanatory variables (x_{t-i}). Then, for both the full sample and the four subsamples, the estimated lead/lag parameter ($\hat{i}$) and the p-values are shown. The critical values are calculated using a wild bootstrap procedure with $5,000$ replications. p-values larger 5% are in green and larger 2.5% but smaller/equal to 5% are written in blue. Be aware that numbers are round to two decimals. Therefore, a 0.051 would be displayed as 0.05 and is highlighted in green. Situations where at least one of the two time series under consideration is not explosive are written in italics.

Co-explosiveness results

The overall results show that the co-explosiveness hypothesis has to be rejected in each of the 72 cases for the full sample of more than 20 years. In contrast, a more granular analysis based on the previously defined four subsamples reveals co-explosiveness for some credit spreads at a local level. Situations where the null hypothesis of stationarity of the residuals cannot be rejected only indicates co-explosiveness when both y_t and x_{t-i} are explosive. If at least one of them is not explosive, stationarity cannot be interpreted as co-explosiveness. For such situations, p-values are provided but are written in italics. This is the case for all three analyses settings, namely BBB-AAA, Corp-Gov and within country analysis. For the GFC, each credit spread shows explosiveness and the co-explosiveness hypothesis cannot be rejected at the 2.5% nominal significance level for 6/12 (within country), 15/30 (Corp-Gov), and 11/30 (BBB-AAA) of the credit spread-pairs under consideration. Thus, there is co-explosiveness in about 44% of the spread-pairs under investigation. This quite high number can be explained by the remarkably high interdependences in the fixed income markets during this time due to an inadequate regulation. Especially Solvency I and Basel II were not able to mitigate clustering risks in the portfolios of large financial institutions. During the European Sovereign Debt Crisis, only 3/12 (within country), 6/30 (Corp-Gov), 4/30 (BBB-AAA) of the spread-pairs show co-explosiveness. This number is much lower compared to the GFC because both US credit spreads and the Australian BBB-AAA spread are not explosive and consequently, each spread-pair including one of these credit spreads cannot be co-explosive. Additionally, the European Sovereign Debt Crisis was more linked to the European Monetary Union compared to the GFC. The period of 'General Trouble' shows co-explosiveness in 3/12 (within country), 6/30 (Corp-Gov), and 6/30 (BBB-AAA) of the spread-pairs. Finally, during the COVID-19 pandemic 2/12 (within country), 4/30 (Corp-Gov), and 11/30 (BBB-AAA) credit spreads exhibit co-explosiveness, see Figure 4.

In general, co-explosiveness can be observed in each of the four subsamples analysed. During the GFC, the percentage of co-explosive credit spread-pairs was the highest and after this episode, the co-explosiveness went down. One exception are the BBB-AAA credit spread-pairs. While the co-explosiveness of them during the European Sovereign Debt Crisis and General Trouble where much lower compared to the GFC, the percentage of co-explosiveness during COVID-19 raised to the same level as during the GFC. This can be explained by the circumstances of the COVID-19 pandemic. While financial institutions where much better prepared for upcoming economic crises compared to the GFC, the producing sector and real economy did not have safety programs that prevent against the influences of a global pandemic. Situations such as supply chain breakdowns hit them hard on a global scale. Thus, it is not surprising, that many BBB-AAA spread-pairs show co-explosive behaviour. In contrast, governments had much more possible courses of action than firms and the countries under consideration took different approaches to tackle the pandemic and to stabilize the economy. Consequently, spreads including a government bond index, i.e. Corp-Gov and within country, do not show an equally high percentage of co-explosiveness compared to the GFC.

Figure 4: Percentage of co-explosiveness per subsample



The plot shows the percentage of co-explosiveness per subsample per spread category. The first row covers the within country spreads, the second row Corp-Gov spreads and the last row shows the BBB-AAA spreads. Red illustrates co-explosiveness and green no co-explosiveness.

But what are the takeaways from the observed local co-explosiveness and the highest percentage of such situations during the GFC? After the GFC, the amount of co-explosive corporate credit spreads went down which can be a sign of functioning regulatory efforts. The reconditioning of the GFC has revealed that too loose financial regulations where a major cornerstone of the crisis, see e.g. National Commission on the Causes of the Financial and Economic Crisis in the United States (2011) and Duffie (2019). As a consequence, the insufficient Basel II regulations which stated minimum capital and risk management requirements for financial institutions, mainly banks, and the Solvency I regulation for insurance firms, have been replaced by Basel III and Solvency II. They require financial institutions to do more serious due diligence of their investment and credit activities and demand tougher risk management approaches. As a consequence, firms that are perceived as riskier may have received funding in the form of credits or bond purchases from banks and other financial institutions in the past, but not now anymore. Therefore, more stable firms which have to fulfil tougher capital requirements and financial covenants, get funding in form of credits and bond purchases. Additionally, financial institutions are not permitted to cluster their risks too much, so that the need for fire sales of bonds which consequently puts price pressure on bonds and increases uncertainty due to an overhang on the sell side, is significantly reduced. Also covered by stricter regulations and directives are rating agencies which in many cases did not fulfil their job during the GFC. Therefore, getting an AAA, BBB, or in general an investment grade rating has become tougher and ratings of the agencies have become more reliable. All in all, the more forward-looking tougher regulations seem to have reduced the systemic risk and thus, the emergence of co-explosiveness between different credit spread-pairs.

The lower percentage of co-explosive credit spread-pairs also results in a higher diversification potential for investors by not only investing in one fixed income class, but also in other ones. Additionally, diversification across borders can decrease the effect of an explosive credit risk in the portfolio. Therefore, from an investors perspective, the diminishing percentage of co-explosiveness is desirable. While less systemic risk and higher diversification potential is beneficial to the financial markets, a reduction in (lead/lag; not simultaneous) co-explosiveness also means that it is hardly possible to obtain early warning signs for explosiveness.

Why not to go dynamic

One now might assume that using a dynamic co-explosiveness testing framework would be desirable. So, e.g., one might apply a KPSS-test dynamically in the same way as a GSADF- or BSADF-test or one might use a left-sided ADF-test in a dynamic fashion. Another idea would be the use of a typical change in persistence procedure like the ones of Leybourne, Kim, and Taylor (2007) and Wagner and Wied (2017). This first intuition should be abandoned because the lead/lag relationship between most credit spreads is changing over time and thus, is not constant. There is lots of circumstantial evidence for this observation. On the one hand, having a look at the four defined subsamples one can see that in general, $\hat{\imath}$ is different for each subsample. Sometimes, even the sign changes. Furthermore, the date-stamping results show that the relationship between the starting points of explosive episodes for different spread-pairs changes over time, too. On the other hand, there are lots of economic reasons for a changing relationship between credit risk spreads. First, the regions under investigation have different currencies and thus, their own central banks. While some monetary policies might be similar, the central banks act with a focus on their own rather than other currencies and inflation rates. These policies may result in changing exchange rates over time and a different risk perception of investors during the decades. Second, each country has its own government with different political orientations/parties. These governments follow different fiscal policies and have different government budgets and deficits and thus, risk premiums may change differently over time. Third, the economies of the considered regions consist of different businesses and firms. This differentiation in the economic constitution results in different drivers of credit risk. So, shocks to specific branches unfold in different magnitudes. Taking these points in mind there is lots of ad-hoc evidence for a changing $\hat{\imath}$. But the author is aware of that the development of a formal statistical test to underline the finding of time-varying lead/lag parameters would make the circumstantial evidence even stronger and would be meaningful – but that is another independent paper. Using a dynamic approach with fixed $\hat{\imath}$ over time would consequently lead to biased results.[6] In contrast, re-estimating $\hat{\imath}$ at each point in time would be computationally infeasible and hard to interpret in an economically meaningful way.

As a consequence, it would be more meaningful to apply a dynamic analysis based on the previously defined four subsamples. But also this procedure is not recommended because the subsamples are too short to get meaningful results when taking into account the needed minimum window size of such a dynamic procedure which has to be adjusted by the lead/lag parameter because due to this, some observations get lost.

Boundary solutions

Taking a closer look at the generated single results, it is obvious that $\hat{\imath}$ close to the defined boundaries of ± 26 deserve some explanation. For the full sample and the GFC, most $\hat{\imath}$ are far away from the boundaries. For the other three subsamples, namely the European Sovereign Debt Crisis, General Trouble and COVID-19, close-to- or at-the-boundary solutions can be observed more often. This is especially true for the Corp-Gov spreads during COVID-19 and BBB-AAA spreads during the General Trouble. This finding illustrates a trade-off that is hard to solve. The defined four subsamples have a duration between approximately 2.5 and 3.5 years which manifests into approximately 130 to 182 weekly observations. A boundary solution of $|\hat{\imath}| = 26$ would result in a loss of 26 observation points. Increasing the potential range I of the lead/lag parameter would further reduce the observations to analyse. The smaller the number of observations, the higher can be the influence of noise and biases can be a result of the estimation. Therefore, $\hat{\imath}$ is set to a reasonable economic range which still leaves enough observations to apply the KPSS-based co-explosiveness

[6]This has been done by the author but is not published for brevity.

test.

Single results

For the GFC for the within country analysis, the co-explosiveness between the BBB-AAA and Corp-Gov spreads for the countries Canada, UK and the US are driven by the Corp-Gov spread. For the BBB-AAA spread-pairs that are co-explosive and involve the US spread, $\hat{\imath} \in \{0, 1\}$ which implies that the crisis outspread extremely fast. This is of no wonder because the Canadian, UK and European markets during this time were highly connected to the US market. One interesting exception is the lead/lag parameter of 18 for the case of regressing Australia on the US. This seems to be contradictory when taking the BSADF-test results into account. A similar finding of such high lead/lag parameters can also be made by regressing Australia on the Euro Area or UK. One potential explanation can be that the lead/lag parameter is dynamic rather than constant for this period and thus, estimating just one $\hat{\imath}$ can bias the results. Having a closer look at the Corp-Gov spreads during the GFC, it also becomes obvious that co-explosiveness pairs that involve the US, show the dominant role of the US. The lead/lag parameters are so that explosiveness is simultaneously or driven by the US.

During the COVID-19 pandemic, the two co-explosive credit spreads of Canada are simultaneously co-explosive. For the four Corp-Gov spread-pairs and eleven BBB-AAA spreads which are co-explosive, the lead lag parameter is quite low with $\hat{\imath} \in \{-1, 0, 1\}$.[7] This seems to be a reasonable finding because due to COVID-19 requirements/regulations, the market was hit as a whole. Supply chain issues, lockdowns and similar measures hit different economies and countries in a similar timely fashion. During the other two subsamples (European Sovereign Debt Crisis and General Trouble), the picture is not that clear and more specific.

Robustness test

In addition to the previous analysis, also some robustness tests are run. Two additional spread measures, namely the BBB Corp-Gov and AAA Corp-Gov spreads are considered. The explosiveness of both BBB Corp-Gov and AAA Corp-Gov spreads is distributed over time in a similar way than the BBB-AAA and Corp-Gov spreads. The majority of explosive episodes cluster around the GFC and COVID-19 pandemic and additionally, some explosive periods can be found around the European Sovereign Debt Crisis and the time period of General Trouble. In total there are 33 explosive phases for the AAA Corp-Gov spread and 45 episodes for the BBB Corp-Gov spread, see Appendix D. As an additional analysis, BBB Corp-Gov and AAA Corp-Gov spreads within a country are tested for

[7] There is one exception with $\hat{\imath} = -14$. This is the case for Australia BBB-AAA regressed on Canada BBB-AAA.

co-explosiveness. Like before, there is no co-explosiveness at the global level but instead, there is co-explosiveness at the local level for different subsamples. For the GFC 5/12 of the credit spread-pairs are co-explosiveness and each of the credit spreads is explosive. So, the results here are similar to the main analysis. During the remaining three subsamples, $1, 2$, and 5 spread-pairs are co-explosive.

6 Conclusion

This research has demonstrated that explosiveness in credit spreads is no one hit wonder that only took place during the global financial crisis 2007/09. Instead it is observable during different periods – usually linked to major economic turmoil. While explosiveness in single credit spreads seems to be the rule rather than an exception, co-explosiveness is not observable during longer time periods. It is only visible for some specific cases and the lead/lag relationship between different credit spreads changes over time so that change in persistence procedures are not applicable. Also because of this, it is hard to predict explosiveness in y_t based on x_{t-i}. The percentage of co-explosive relations between different credit spreads were the highest during the GFC and after it, they declined – likely due to the stricter regulatory initiatives like Basel III and Solvency II. The reduction in co-explosiveness is also beneficial for portfolio construction because investors can protect their portfolio against explosiveness by diversification.

The finding of no full sample co-explosiveness is in contrast to Evripidou et al. (2022) who find co-explosiveness for different metals. This difference is not surprising because while metals are in general homogeneous goods and are needed for production, credit spreads are more heterogeneous and have more country specific influences. Thus, the high complexity and numerous influence factors of fixed income markets cannot be grasped by a KPSS-based co-explosiveness test. The consequence for financial market participants such as investors, financial institutions and central banks is that predicting explosiveness in one time series based on a co-explosive relationship with another one is hardly possible due to the changing nature of the lead/lag relationship between different credit spreads. Instead, a more granular, more spread and country specific analysis is required.

Of course, there is room for more research. So, it would be informative to have a closer look at the co-explosiveness between the credit risk of different bond maturities, e.g., short-, medium-, and long-term bonds. Another interesting extension to the analysis would be to investigate whether there is a common factor that drives the explosiveness in the different credit spreads. Therefore, a procedure similar to those in Liu, Phillips, and Yu (2023) and Horie and Yamamoto (2024) could be applied. Finally, a formal test to determine changes/breaks in the lead/lag parameter i and procedures how to handle them would be of great value.

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Appendix

This part contains tables and figures which provide additional information but for which there was no space in the main part of the paper. Section A provides descriptive statistics of the four spread categories considered. In Section B, the date-stamped explosive episodes are visualized for all 24 spreads, sorted by region. Section C shows the starting and end dates of the identified explosive episodes for the two main spreads of interest, namely the BBB-AAA and Corp-Gov spreads, while Section D covers the GSADF- and BSADF-test results as well as the co-explosiveness results of the robustness tests (BBB Corp-Gov and AAA Corp-Gov spreads).

A Descriptive statistics of spreads

The descriptive statistics for the spreads are provided in Table 6.

Table 6: Descriptive statistics of spreads

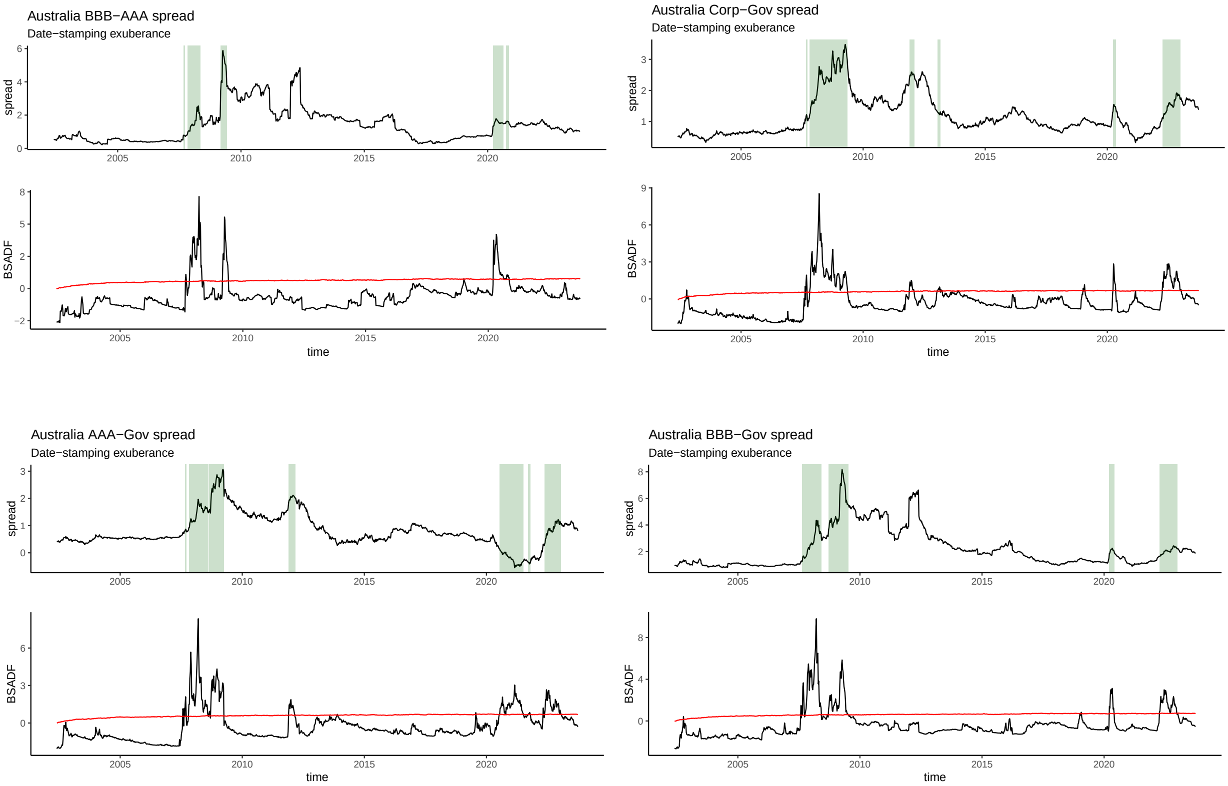
	μ	σ	s	k	min	$5\%q$	med	$95\%q$	max
Australia									
BBB-AAA	1.34	1.02	1.47	5.14	0.22	0.35	1.13	3.63	5.89
Corp-Gov	1.13	0.63	1.22	4.10	0.25	0.43	0.93	2.48	3.48
AAA-Gov	0.77	0.59	0.92	4.48	-0.55	-0.17	0.59	1.93	3.06
BBB-Gov	2.12	1.43	1.53	4.83	0.78	0.89	1.54	5.15	8.17
Canada									
BBB-AAA	1.29	0.48	0.20	2.77	0.27	0.56	1.36	2.06	3.16
Corp-Gov	1.27	0.50	0.80	5.28	0.35	0.49	1.29	1.94	3.38
AAA-Gov	0.53	0.55	1.12	5.99	-0.46	-0.25	0.50	1.33	3.24
BBB-Gov	1.81	0.70	0.87	6.48	0.39	0.63	1.88	2.68	4.83
Euro Area									
BBB-AAA	1.13	0.70	1.81	6.94	0.31	0.45	0.91	2.55	4.36
Corp-Gov	0.61	0.52	2.48	11.18	-0.16	0.05	0.49	1.54	3.25
AAA-Gov	0.00	0.41	-0.72	6.01	-1.52	-0.85	0.09	0.43	1.68
BBB-Gov	1.13	0.76	2.83	13.09	0.37	0.51	0.87	2.23	5.24
Japan									
BBB-AAA	0.32	0.47	2.55	11.47	-0.37	-0.18	0.26	1.25	2.82
Corp-Gov	0.15	0.21	1.18	4.95	-0.14	-0.10	0.10	0.47	1.01
AAA-Gov	0.15	0.17	0.58	3.03	-0.15	-0.10	0.12	0.45	0.67
BBB-Gov	0.47	0.53	2.04	8.88	-0.20	-0.06	0.40	1.41	3.10
UK									
BBB-AAA	1.45	0.83	2.54	11.28	0.59	0.78	1.15	2.97	6.45
Corp-Gov	1.67	0.72	2.17	9.11	0.84	0.96	1.48	3.00	5.52
AAA-Gov	0.71	0.36	2.37	14.00	0.10	0.24	0.66	1.17	3.19
BBB-Gov	2.16	0.99	2.97	14.26	1.18	1.34	1.90	3.75	8.15
USA									
BBB-AAA	1.26	0.62	1.48	6.50	0.42	0.59	1.09	2.25	4.33
Corp-Gov	1.75	0.87	2.71	12.75	0.78	0.89	1.55	3.02	6.39
AAA-Gov	1.01	0.58	3.64	21.52	0.33	0.49	0.94	1.74	6.13
BBB-Gov	2.27	1.06	2.57	12.25	1.04	1.20	2.05	3.68	8.02

This table provides the descriptive statistics of each spread series. These statistics are the mean (μ), standard deviation (σ), skewness (s), kurtosis (k), minimum (min), 5% quantile ($5\%q$), median (med), 95% quantile ($95\%q$) and the maximum (max).

B Identified explosive periods

In this section, for each of the 24 credit spreads, the spreads are shown together with their BSADF statistics and their corresponding critical values.

Figure 5: Australian explosiveness over time



The picture displays the explosiveness date-stamping for each of the four spreads calculated. Each spread has its own grid. In the lower panel of each grid are the BSADF-test statistics (black line) and their corresponding critical values (red line) over the time horizon of the analysis. In the upper panel of each grid is the development of the spread shown. Every time the BSADF-test statistic crosses its critical values upwards, an explosive episode starts and every time it crosses the critical values downwards, an explosive episode ends. Explosive episodes that consist of at least three observations are highlighted in green in the upper panel.

Figure 6: Canadian explosiveness over time

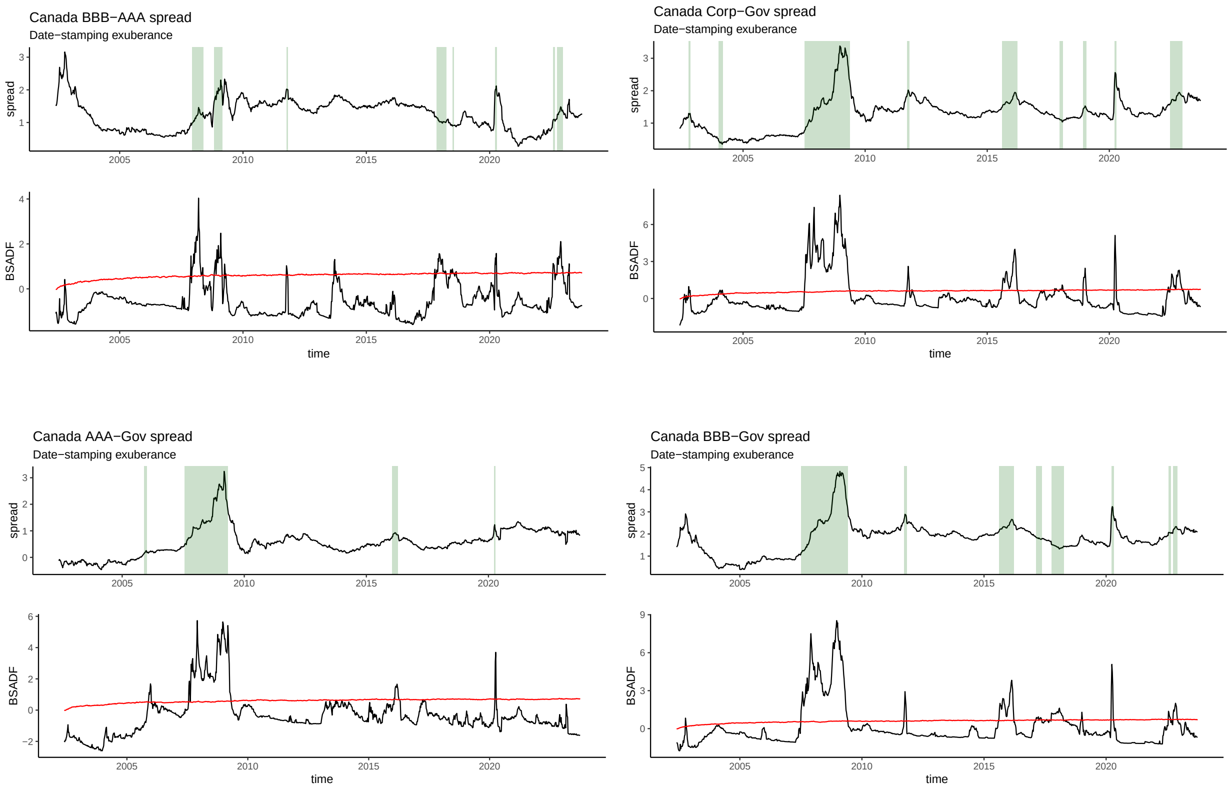


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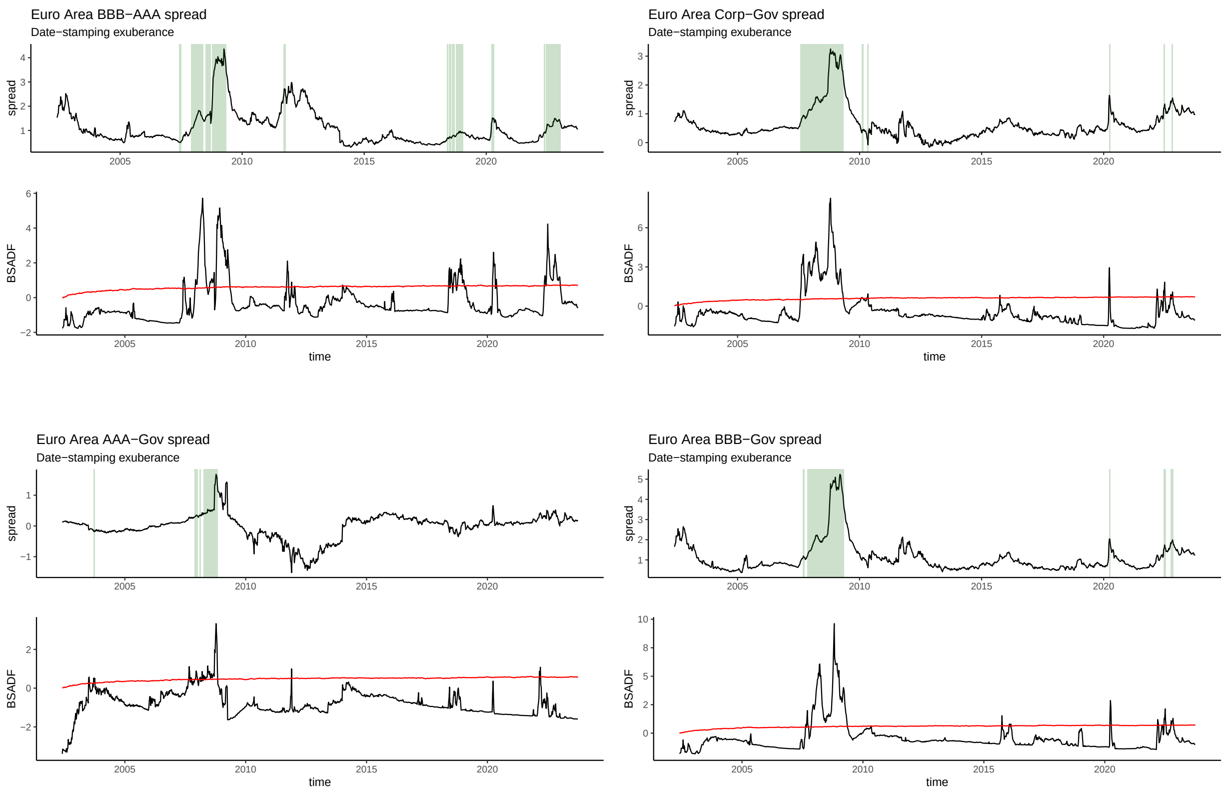
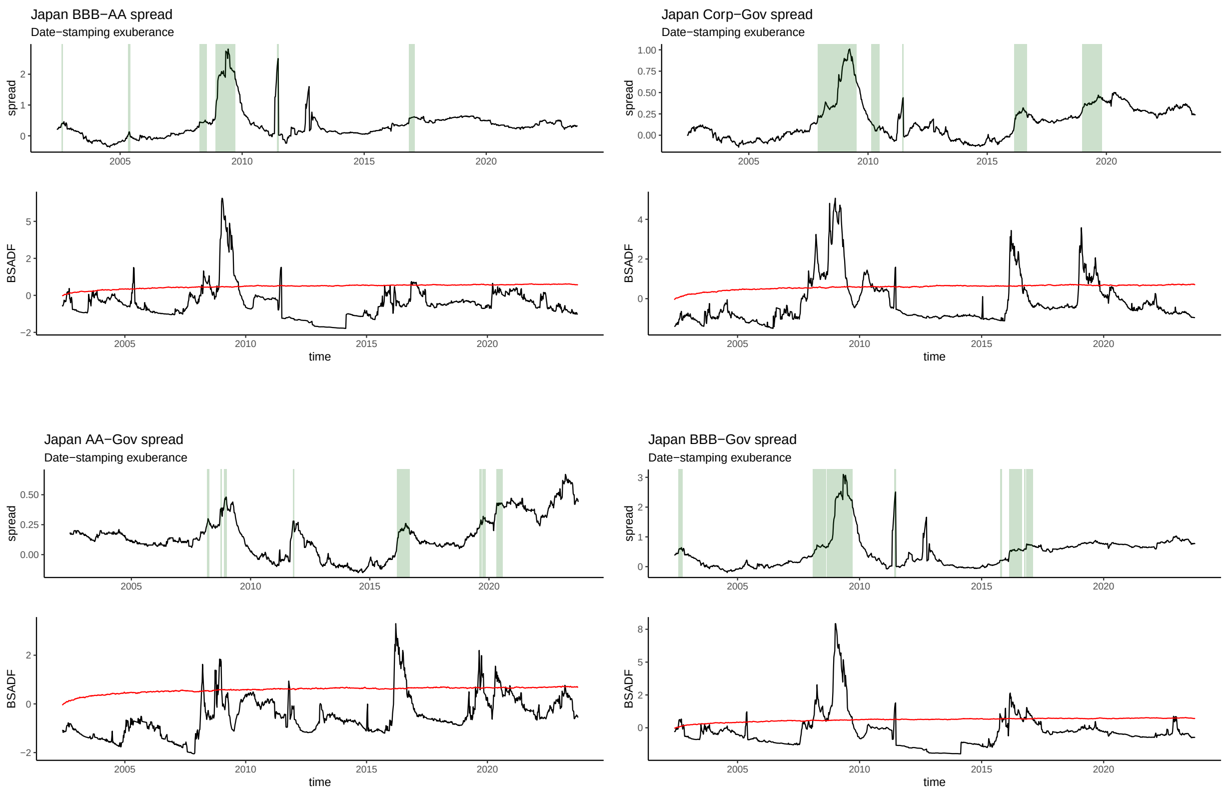
Figure 7: Euro Area explosiveness over time



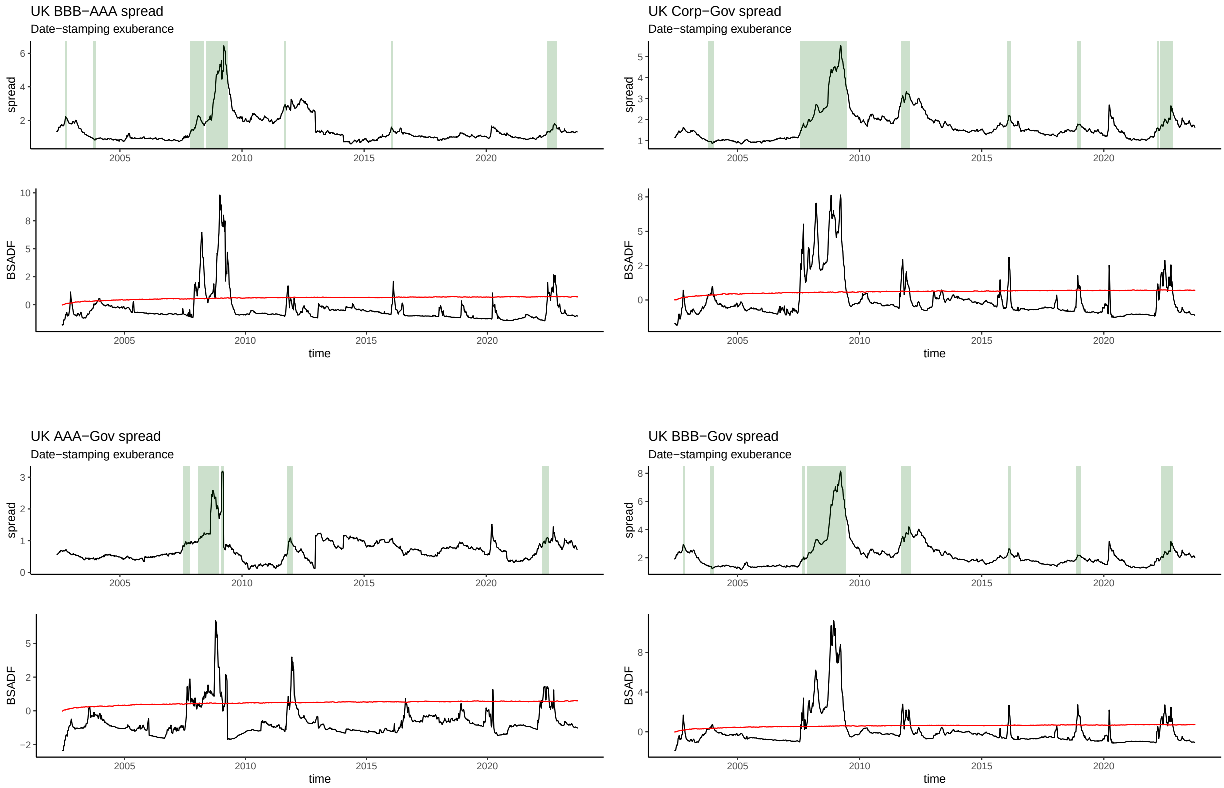
The picture displays the explosiveness date-stamping for each of the four spreads calculated. Each spread has its own grid. In the lower panel of each grid are the BSADF-test statistics (black line) and their corresponding critical values (red line) over the time horizon of the analysis. In the upper panel of each grid is the development of the spread shown. Every time the BSADF-test statistic crosses its critical values upwards, an explosive episode starts and every time it crosses the critical values downwards, an explosive episode ends. Explosive episodes that consist of at least three observations are highlighted in green in the upper panel.

Figure 8: Japanese explosiveness over time



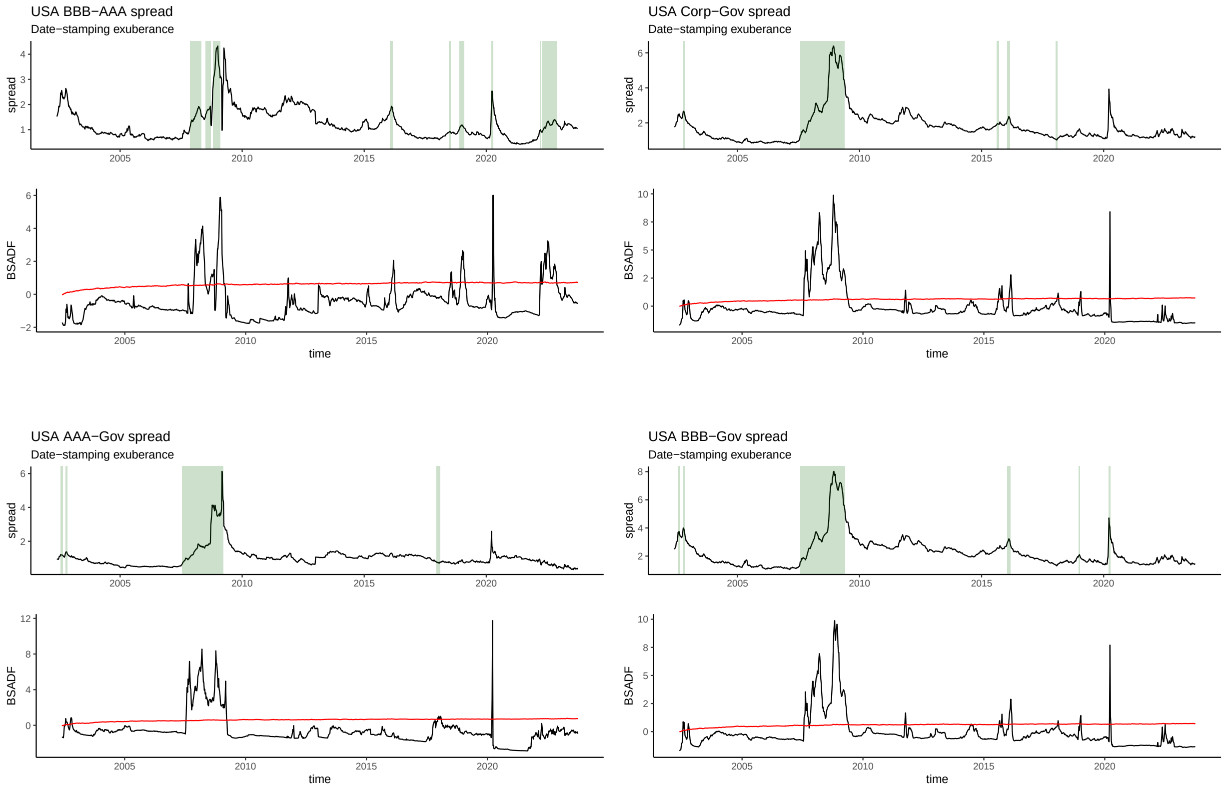
The picture displays the explosiveness date-stamping for each of the four spreads calculated. Each spread has its own grid. In the lower panel of each grid are the BSADF-test statistics (black line) and their corresponding critical values (red line) over the time horizon of the analysis. In the upper panel of each grid is the development of the spread shown. Every time the BSADF-test statistic crosses its critical values upwards, an explosive episode starts and every time it crosses the critical values downwards, an explosive episode ends. Explosive episodes that consist of at least three observations are highlighted in green in the upper panel.

Figure 9: UK explosiveness over time



The picture displays the explosiveness date-stamping for each of the four spreads calculated. Each spread has its own grid. In the lower panel of each grid are the BSADF-test statistics (black line) and their corresponding critical values (red line) over the time horizon of the analysis. In the upper panel of each grid is the development of the spread shown. Every time the BSADF-test statistic crosses its critical values upwards, an explosive episode starts and every time it crosses the critical values downwards, an explosive episode ends. Explosive episodes that consist of at least three observations are highlighted in green in the upper panel.

Figure 10: US explosiveness over time



The picture displays the explosiveness date-stamping for each of the four spreads calculated. Each spread has its own grid. In the lower panel of each grid are the BSADF-test statistics (black line) and their corresponding critical values (red line) over the time horizon of the analysis. In the upper panel of each grid is the development of the spread shown. Every time the BSADF-test statistic crosses its critical values upwards, an explosive episode starts and every time it crosses the critical values downwards, an explosive episode ends. Explosive episodes that consist of at least three observations are highlighted in green in the upper panel.

C Date-stamping results

Table 7: Date-stamping of Corp-Gov spreads' explosiveness

Region	Start	End	Duration	Signal
Australia				
	2007-08-31	2007-09-21	3	positive
	2007-10-26	2009-05-15	81	positive
	2011-11-25	2012-02-03	10	positive
	2013-01-18	2013-03-01	6	negative
	2020-03-27	2020-05-08	6	positive
	2022-04-08	2022-12-30	38	positive
Canada				
	2002-10-11	2002-11-08	4	positive
	2004-01-02	2004-03-05	9	negative
	2007-07-13	2009-05-22	97	positive
	2011-09-23	2011-10-28	5	positive
	2015-08-14	2016-04-01	33	positive
	2017-12-22	2018-02-09	7	negative
	2018-12-07	2019-01-25	7	positive
	2020-03-20	2020-04-17	4	positive
	2022-07-01	2022-09-16	11	positive
	2022-09-23	2022-12-30	14	positive
Euro Area				
	2007-08-03	2009-05-08	92	positive
	2010-01-29	2010-02-26	4	negative
	2010-04-23	2010-05-14	3	negative
	2020-03-20	2020-04-09	3	positive
	2022-06-17	2022-07-08	3	positive
	2022-10-14	2022-11-04	3	positive
Japan				
	2007-11-23	2009-07-10	85	positive
	2010-02-19	2010-06-25	18	negative
	2011-06-10	2011-07-01	3	positive
	2016-02-19	2016-09-02	28	positive
	2018-12-28	2019-10-25	43	positive
UK				
	2003-10-17	2003-11-07	3	negative
	2003-11-21	2004-01-09	7	negative
	2007-07-27	2009-06-19	99	positive
	2011-09-09	2011-10-28	7	positive
	2011-11-04	2012-01-20	11	positive
	2016-01-22	2016-03-11	7	positive
	2018-11-23	2019-01-18	8	positive
	2022-03-11	2022-04-01	3	positive
	2022-04-22	2022-08-12	16	positive
	2022-08-19	2022-10-28	10	positive
USA				
	2002-10-11	2002-11-01	3	positive
	2007-07-27	2009-05-22	95	positive
	2015-08-14	2015-09-18	5	positive
	2016-01-22	2016-03-04	6	positive
	2018-01-12	2018-02-09	4	negative

This table provides the BSADF-test results for the corporate government bond spreads. In the first column are the country/region names and in columns two and three are the estimated start and end dates of explosiveness displayed. Column four shows the number of explosive observations for each period and the last column illustrates whether it is a positive or negative explosive phase. Tests are run at the 5% nominal significance level with critical values obtained from wild bootstrapping with $10,000$ bootstrap repetitions.

Table 8: Date-stamping of BBB-AAA spreads' explosiveness

Region	Start	End	Duration	Signal
Australia				
	2007-08-31	2007-09-21	3	positive
	2007-11-02	2008-05-09	27	positive
	2009-03-06	2009-06-05	13	positive
	2020-03-20	2020-08-21	22	positive
	2020-10-02	2020-11-13	6	positive
Canada				
	2007-12-07	2008-05-23	24	positive
	2008-10-31	2009-02-27	17	positive
	2011-10-07	2011-10-28	3	positive
	2017-11-03	2018-03-29	21	negative
	2018-06-29	2018-07-20	3	positive
	2020-03-20	2020-04-17	4	positive
	2022-07-29	2022-08-26	4	positive
	2022-09-30	2022-12-23	12	positive
Euro Area				
	2007-06-01	2007-07-06	5	negative
	2007-11-30	2008-05-30	26	positive
	2008-07-04	2008-09-19	11	positive
	2008-10-10	2009-05-08	30	positive
	2011-09-09	2011-10-14	5	positive
	2018-05-25	2018-06-15	3	positive
	2018-06-22	2018-07-27	5	positive
	2018-08-03	2018-09-14	6	positive
	2018-10-05	2019-01-18	15	positive
	2020-03-20	2020-05-01	6	positive
	2022-05-13	2022-06-03	3	positive
	2022-06-10	2023-01-13	31	positive
Japan				
	2002-08-09	2002-08-30	3	positive
	2005-04-29	2005-06-03	5	positive
	2008-04-04	2008-07-18	15	positive
	2008-11-28	2009-09-18	42	positive
	2011-06-03	2011-07-01	4	positive
	2016-11-04	2017-01-27	12	positive
UK				
	2002-10-04	2002-11-01	4	positive
	2003-11-28	2004-01-02	5	negative
	2007-11-23	2008-06-06	28	positive
	2008-07-04	2009-05-29	47	positive
	2011-09-23	2011-10-21	4	positive
	2016-02-05	2016-03-04	4	positive
	2022-07-01	2022-08-12	6	positive
	2022-08-19	2022-11-25	14	positive
USA				
	2007-11-16	2008-05-02	24	positive
	2008-07-04	2008-09-19	11	positive
	2008-10-17	2009-02-06	16	positive
	2016-01-22	2016-03-04	6	positive
	2018-06-22	2018-07-20	4	positive
	2018-11-23	2019-02-01	10	positive
	2020-03-20	2020-04-17	4	positive
	2022-03-11	2022-04-01	3	positive
	2022-04-22	2022-11-18	30	positive

This table provides the BSADF-test results for the BBB-AAA corporate bond spreads. In the first column are the country/region names and in columns two and three are the estimated start and end dates of explosiveness displayed. Column four shows the number of explosive observations for each period and the last column illustrates whether it is a positive or negative explosive phase. Tests are run at the 5% nominal significance level with critical values obtained from wild bootstrapping with $10,000$ bootstrap repetitions.

D Robustness checks

GSADF-results

The GSADF-statistics of the AAA Corp-Gov and BBB Corp-Gov are as follows:

Table 9: GSADF-test results

	GSADF-statistic	**GSADF critical values** 90%	95%	99%
Australia				
AAA-Gov	***8.35	2.63	2.95	3.79
BBB-Gov	***8.54	2.78	3.19	3.96
Canada				
AAA-Gov	***5.73	2.75	3.12	4.03
BBB-Gov	***8.54	2.78	3.19	3.96
Euro Area				
AAA-Gov	**4.16	2.86	3.27	4.21
BBB-Gov	***9.62	2.71	3.09	3.92
Japan				
AA-Gov	**3.30	2.60	2.93	3.63
BBB-Gov	***7.93	3.23	3.72	5.03
UK				
AAA-Gov	***6.70	3.06	3.52	4.72
BBB-Gov	***11.22	2.73	3.10	4.07
USA				
AAA-Gov	***11.75	3.13	3.60	4.98
BBB-Gov	***9.88	2.82	3.22	4.14

This table provides the GSADF-test results for the weekly benchmark analysis. In the first column are the analysed spreads. The second column provides the calculated GSADF-test statistic and the remaining three columns show the bootstrapped critical values for the 90%, 95% and 99% quantile estimated with 10,000 replications. The significance levels 10%, 5%, and 1% are illustrated by *, **, and ***. All results are round to two decimals.

Date-stamping results

The explosive episodes in both the AAA Corp-Gov and BBB Corp-Gov spreads are date-stamped as follows:

Table 10: Date-stamping of AAA Corp-Gov spreads' explosiveness

Region	Start	End	Duration	Signal
Australia				
	2007-08-31	2007-09-21	3	positive
	2007-10-26	2008-08-08	41	positive
	2008-08-22	2008-09-12	3	positive
	2008-09-19	2009-04-03	28	positive
	2011-11-25	2012-03-02	14	positive
	2020-07-17	2021-07-09	51	negative
	2021-09-17	2021-10-22	5	negative
	2022-05-20	2023-01-20	35	positive
Canada				
	2005-11-25	2006-01-06	6	positive
	2007-07-27	2009-05-01	92	positive
	2016-01-22	2016-04-15	12	positive
	2020-03-27	2020-04-17	3	positive
Euro Area				
	2003-09-19	2003-10-10	3	positive
	2007-11-23	2008-01-11	7	positive
	2008-02-01	2008-02-22	3	positive
	2008-04-04	2008-11-07	31	positive
Japan				
	2008-03-07	2008-04-11	5	positive
	2008-09-26	2008-10-17	3	positive
	2008-11-21	2009-01-02	6	positive
	2011-10-14	2011-11-04	3	positive
	2016-02-19	2016-09-02	28	positive
	2019-08-09	2019-09-13	5	positive
	2019-09-20	2019-11-08	7	positive
	2020-04-24	2020-07-31	14	positive
UK				
	2007-08-03	2007-11-09	14	positive
	2008-03-20	2009-01-23	44	positive
	2009-02-27	2009-04-03	5	positive
	2011-11-11	2012-01-27	11	positive
	2022-04-22	2022-07-29	14	positive
USA				
	2002-07-26	2002-08-30	5	positive
	2002-10-04	2002-11-01	4	positive
	2007-07-20	2009-03-27	88	positive
	2017-12-15	2018-02-09	8	negative

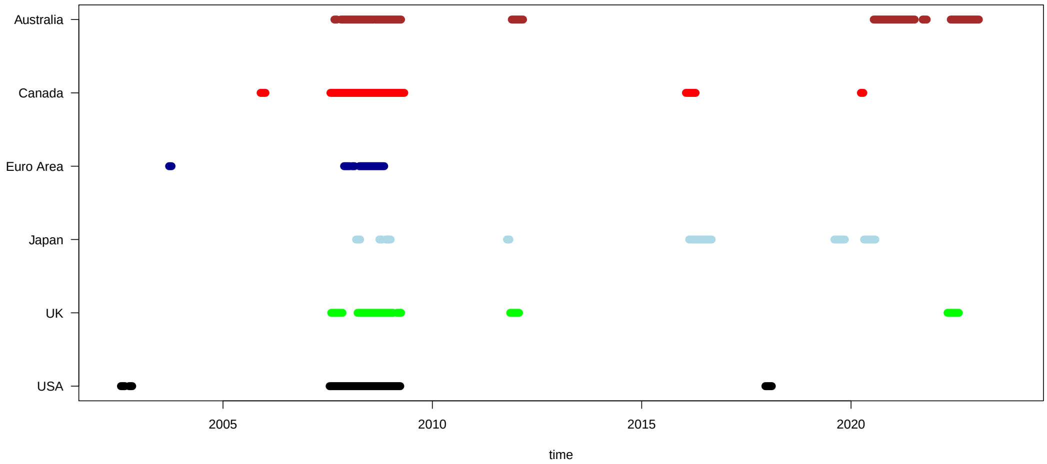
This table provides the BSADF-test results for the AAA corporate government bond spreads. In the first column are the country/region names and in columns two and three are the estimated start and end dates of explosiveness displayed. Column four shows the number of explosive observations for each period and the last column illustrates whether it is a positive or negative explosive phase. Tests are run at the 5% nominal significance level with critical values obtained from wild bootstrapping with $10,000$ bootstrap repetitions.

Table 11: Date-stamping of BBB Corp-Gov spreads' explosiveness

Region	Start	End	Duration	Signal
Australia				
	2007-08-17	2007-09-28	6	positive
	2007-10-05	2008-06-06	35	positive
	2008-09-19	2009-07-10	42	positive
	2020-03-20	2020-06-05	11	positive
	2022-04-08	2022-12-30	38	positive
Canada				
	2007-07-06	2009-06-05	100	positive
	2011-09-23	2011-11-04	6	positive
	2015-08-14	2016-03-24	32	positive
	2017-02-17	2017-03-31	6	negative
	2017-04-07	2017-05-19	6	negative
	2017-10-06	2018-04-06	26	negative
	2020-03-20	2020-04-24	5	positive
	2022-07-22	2022-08-26	5	positive
	2022-09-30	2022-12-02	9	positive
Euro Area				
	2007-09-07	2007-10-05	4	positive
	2007-11-16	2009-05-15	78	positive
	2020-03-20	2020-04-09	3	positive
	2022-06-17	2022-07-22	5	positive
	2022-09-30	2022-11-11	6	positive
Japan				
	2002-08-02	2002-10-04	9	positive
	2008-02-01	2008-08-15	28	positive
	2008-08-29	2009-09-18	55	positive
	2011-06-03	2011-07-01	4	positive
	2015-10-02	2015-10-30	4	positive
	2016-02-19	2016-08-26	27	positive
	2016-09-30	2016-10-21	3	positive
	2016-10-28	2017-02-03	14	positive
UK				
	2002-10-04	2002-11-08	5	positive
	2003-11-14	2004-01-09	8	negative
	2007-08-17	2007-09-28	6	positive
	2007-11-02	2009-06-05	83	positive
	2011-09-16	2011-10-28	6	positive
	2011-11-04	2012-02-03	13	positive
	2016-01-29	2016-03-11	6	positive
	2018-11-16	2019-01-25	10	positive
	2022-04-29	2022-06-03	5	positive
	2022-06-10	2022-08-12	9	positive
	2022-08-19	2022-10-28	10	positive
USA				
	2002-07-26	2002-08-23	4	positive
	2002-10-11	2002-11-01	3	positive
	2007-07-27	2007-10-12	11	positive
	2007-10-19	2009-05-29	84	positive
	2016-01-15	2016-03-04	7	positive
	2018-12-21	2019-01-11	3	positive
	2020-03-13	2020-04-09	4	positive

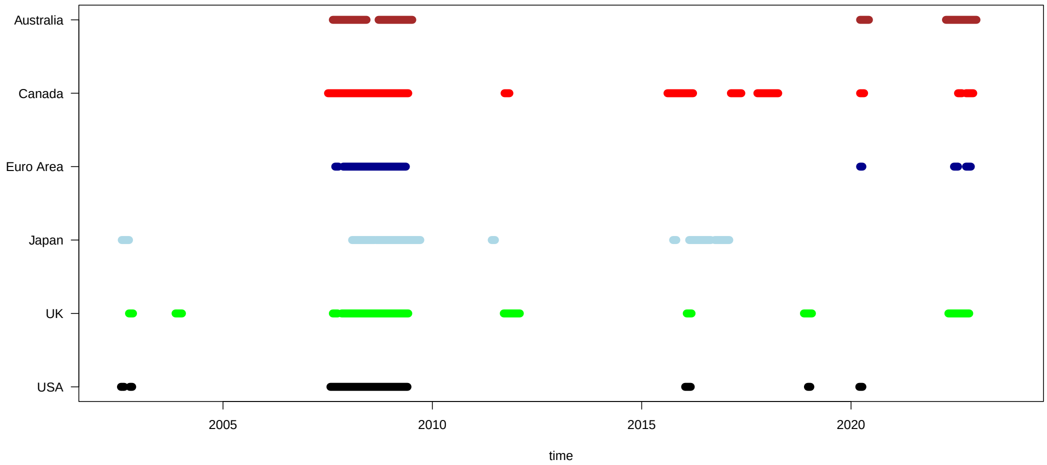
This table provides the BSADF-test results for the BBB corporate government bond spreads. In the first column are the country/region names and in columns two and three are the estimated start and end dates of explosiveness displayed. Column four shows the number of explosive observations for each period and the last column illustrates whether it is a positive or negative explosive phase. Tests are run at the 5% nominal significance level with critical values obtained from wild bootstrapping with $10,000$ bootstrap repetitions.

Figure 11: Visual overview of AAA Corp-Gov explosive periods



The plot displays the explosive episodes of the AAA-Gov spreads for each of the six analysed countries. Colourful bars illustrate explosive episodes. Each country gets its own colour.

Figure 12: Visual overview of BBB Corp-Gov explosive periods



The plot displays the explosive episodes of the BBB-Gov spreads for each of the six analysed countries. Colourful bars illustrate explosive episodes. Each country gets its own colour.

Co-explosiveness results

Table 12: Co-explosiveness test results between AAA Corp-Gov and BBB Corp-Gov spreads within countries - KPSS-based analysis

		Full Sample		**GFC**		**Euro Debt**		**General Trouble**		**COVID-19**	
y_t	x_{t-i}	$\hat{i}$	p	$\hat{i}$	p	$\hat{i}$	p	$\hat{i}$	p	$\hat{i}$	p
Australia AAA-Gov	Australia BBB-Gov	-9	0.00	-13	0.00	-6	*0.00*	23	*0.00*	-1	0.18
Australia BBB-Gov	Australia AAA-Gov	9	0.00	14	0.17	4	*0.00*	26	*0.00*	1	0.31
Canada AAA-Gov	Canada BBB-Gov	-3	0.00	-2	0.82	26	*0.04*	-26	0.14	-14	0.10
Canada BBB-Gov	Canada AAA-Gov	3	0.00	2	0.24	0	*0.00*	26	0.12	20	0.00
Euro Area AAA-Gov	Euro Area BBB-Gov	-15	0.00	-5	0.02	26	*0.00*	26	*0.00*	0	*0.02*
Euro Area BBB-Gov	Euro Area AAA-Gov	15	0.00	5	0.00	-26	*0.05*	26	*0.00*	1	*0.01*
Japan AA-Gov	Japan BBB-Gov	-26	0.00	-14	0.00	-12	0.00	26	0.00	18	*0.38*
Japan BBB-Gov	Japan AA-Gov	13	0.00	14	0.01	-9	0.52	26	0.00	-26	*0.16*
UK AAA-Gov	UK BBB-Gov	-6	0.00	-9	0.33	-26	0.00	-2	*0.00*	0	0.04
UK BBB-Gov	UK AAA-Gov	6	0.00	9	0.00	3	0.00	11	*0.22*	0	0.04
USA AAA-Gov	USA BBB-Gov	-1	0.00	-2	0.18	26	*0.14*	26	0.00	25	*0.00*
USA BBB-Gov	USA AAA-Gov	1	0.00	2	0.01	-26	*0.12*	26	0.00	26	*0.10*

This table displays the co-explosiveness testing results for the BBB-Gov and AAA-Gov spreads within countries. The analysis is run based on a KPSS-test. The full sample results as well as the results for the four subsamples GFC, Euro Debt, General Trouble and COVID-19 are provided. In the first two columns are the dependent (y_t) and explanatory variables (x_{t-i}). Than, for both the full sample and the four subsamples, the estimated lead/lag parameter ($\hat{i}$) and the p-values are shown. The critical values are calculated using a wild bootstrap procedure with $5,000$ replications. p-values larger 5% are in green and larger 2.5% but smaller/equal to 5% are written in blue. Be aware that numbers are round to two decimals. Therefore, a 0.051 would be displayed as 0.05 and is highlighted in green. Situations where at least one of the two time series under consideration is not explosive are written in italics.

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