The Credit Spread Puzzle – Evidence from a Quasi-Natural Experiment*

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June 4, 2021

Abstract

Prior literature mostly finds bond yield spreads to be insufficiently explained by credit risk in structural models (the 'credit spread puzzle'). In contrast, several recent results consider credit spreads to consist of credit risk to a substantially larger extent (if not even entirely). We address this dissent in the literature using a different empirical methodology. We utilize the removal of sovereign guarantees for savings banks and state banks in Germany as a unique quasi-natural experiment allowing identification of the credit risk component. During a transition period of over ten years, bonds of the same issuer with and without credit risk could be directly compared. Interestingly, less than 20% of the yield spread is due to credit risk for these bonds.

Keywords: Credit spread puzzle, credit risk, sovereign guarantees, quasi-natural experiment.

JEL Classification: G12 (bond interest rates), G28 (government policy), G21 (banks).

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* We thank Nicole Branger, Jingzhi Huang, Robert Goldstein, Philipp Klein, Lars Norden, Judith Schneider, and the participants at the Midwest Finance Association Annual Meeting 2021 for valuable input and suggestions.

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I Introduction

There is an extensive literature on the ability of structural models to estimate credit risk and to explain observed bond yield spreads. A majority of the studies finds observed bond yield spreads to be insufficiently explained by these models (e.g. Eom et al., 2004; Chen et al., 2009; Huang and Huang, 2012; Huang et al., 2019). This finding is referred to as the 'credit spread puzzle'. A common approach in this strand of literature is to calibrate structural models to observed bond default rates, recovery rates, and the equity premium and compare yield spreads derived from these models to observed yield spreads. As Huang and Huang (2012) highlight, this refers to the question how credit risk *should* be priced. In contrast to this literature, recent results argue that the credit spread puzzle disappears when using different structural models. Feldhütter and Schaefer (2018) use a wide cross-section of default rates at different maturities and ratings and Du et al. (2019) include time-varying asset volatility and jumps.

It is an interesting observation that there is such a large dissent in a significant aspect of the finance literature, and new approaches to identification could lead to a better understanding of the puzzle. We suggest an empirical way of identification for the credit risk component in credit spreads by exploiting the removal of sovereign guarantees for savings banks and state banks in Germany as a unique quasi-natural experiment. These banks were protected by explicit sovereign guarantees until 2005. This also applied to debt securities issued by these banks. Following an investigation on uneven competition by the European Commission, the removal of the guarantees was accepted by the German government on April 11, 2002. The planned removal contained a transition period with the following characteristics: Bonds issued before July 19, 2001 remained guaranteed with no regards to the maturity. Later bond issues, up to July 18, 2005, with a maturity date until December 31, 2015 remained guaranteed whereas bond issues after July 18, 2005 were issued without sovereign guarantees.

From a methodological perspective, this situation allows for a near-ideal identification, in fact even reasonably close to hypothetical counterfactuals as mentioned in Culp et al. (2018), as from July 19, 2005 to December 31, 2015, there were bonds of the same issuers with and without credit risk traded on the same market allowing for a direct comparison. This situation is further well suited as the legal change affected a considerable share of European bond markets. The outstanding volume of the debt securities of these banks amounted to 506.7 billion Euro in 2005 and to 215.0 billion Euro in 2015. This accounts for around 4.8% of the outstanding volume of European debt securities amounting to 10.4 trillion Euros in 2005. The share in 2015 amounted to approximately 1.3% of 16.5 trillion Euros, respectively. In relation to the market for US debt securities, the volume compared to 2.4% in 2005 (25.3 trillion USD) and to 0.6% in 2015 (40.6 trillion USD) of the total outstanding principals.[1]

We exploit this quasi-natural experiment empirically by using an extensive dataset of monthly bond prices of German savings banks and state banks from 2005 to 2015 and compare yield spreads of guaranteed and non-guaranteed bonds from the same issuer. In addition to pairing the yield spreads of bonds by issuer, we conduct a matching to compare yields for bonds with very similar characteristics.

In our baseline analysis, we find an average spread difference due to credit risk of 16.3 basis points which corresponds to an overall proportion in the bond yield spreads of on average 18.3%. In further in-depth analyses, we first look at very close matches. In addition, we also provide one analysis for bonds issued with temporal proximity to the start of the transition period on July 18, 2005, as a discontinuity to compare bonds with very similar age. We find that the share of credit risk is even only at around 10% or below on average in these cases. When looking at different rating classes, the credit risk component for A-rated bonds accounts for 16.8% of the spread, while the explained percentage increases

[1] The outstanding volume of savings and state bank debt securities are available from the Deutsche Bundesbank. Numbers on the size of the European and US debt market are available from the European Central Bank and the Federal Reserve Bank of St. Louis.

up to 32.7% for BBB rated bonds. Interestingly, the size of these credit risk components is close to the values of around 30% for BBB rated bonds and around 20% for higher rated bonds as derived in Huang and Huang (2012). In contrast, we do not find a significant credit risk component for AA rated bonds.

Our work is closely related to the large literature discussing the size of the credit spread based on structural credit risk models. This refers to Eom et al. (2004), Chen et al. (2009), Huang and Huang (2012), and Huang et al. (2019), among other examples. In recent years, an increasing number of studies suggested structural models that are capable of matching the large credit spreads in debt markets. Important examples of this literature comprise Bhamra et al. (2009), Chen (2010), Feldhütter and Schaefer (2018), Du et al. (2019), Bai et al. (2020), and Kuehn et al. (2021). This provides evidence that credit risk and credit risk premia could explain large shares of empirical credit spreads. Interestingly, our results are in line with earlier work such as Huang and Huang (2012) that explain a lower share of the credit spread with credit risk. Berndt (2015) shows that the credit spread puzzle is not only limited to structural models but also appears in reduced-form models. Our paper is, further, also related to literature that studies the changes of credit spreads such as Collin-Dufresne et al. (2001), Nozawa (2017), or Elkamhi et al. (2021). Several results in this literature point towards the major importance of illiquidity and intermediary-based factors for credit spread changes (e.g., He et al., 2017, He et al., 2020). This is also found in the large literature on bond illiquidity and credit spreads (e.g., Longstaff et al., 2005, Bao et al., 2011, Dick-Nielsen et al., 2012, and Helwege et al., 2014). There is further some relation with literature that aims at decomposing the credit spread into individual parts such as Elton et al. (2001), Nozawa (2017), and Berndt et al. (2018).

From a methodological perspective, our study is particularly related to work using empirical approaches to understand the 'credit spread puzzle' and is less reliant on specific model assumptions such as Longstaff et al. (2005), Dick-Nielsen et al. (2012), Helwege et al. (2014), Berndt et al. (2018), and Culp et al. (2018). Our work is further part of a very small literature that assesses the credit spread puzzle for bond markets outside of the US, which is mainly done in Huang et al. (2019), where results are particularly close to ours.

The rest of this paper is organized as follows. Section II gives an overview of the institutional background and the main characteristics of the removal of sovereign guarantees. The data is presented in Section III. Section IV presents the identification approach. In Section V, we present the results. Finally, Section VI concludes.

II Institutional Background

The German banking system is structured in three sectors. It consists of commercial banks, cooperative banks, and public banks, the latter typically owned by the federal government, states or local authorities. Public banks mainly consist of savings banks and state banks. Savings banks operate independently from one another in regionally disjoint business regions. Their business model is characterized by accepting deposits and providing loans mostly for private and small to medium-sized commercial customers. As a complement to savings banks, state banks offer central clearing and provide liquidity. In addition, state banks function as house banks for the states they operate in and as commercial banks typically lending to medium-sized and larger firms (see Brunner et al., 2004). Taken as a group, public banks comprise 476 institutions out of a total number of around 2,344 banks in Germany at the end of 2005 and comprise 422 out of a total number of 1,960 banks at the end of 2015, respectively. They have a market share of 33.6% in the outstanding credit volume in 2005 and of 35.7% in 2015, respectively. The market share in deposits is 37.8% in 2005 and 31.5% in 2015.[2]

[2] The number of banks, credit volume and deposit volume for different sectors of the German banking system are available from the Deutsche Bundesbank.

For historical reasons, the public banking sector was protected by two explicit sovereign guarantees. The so-called maintenance obligation (*Anstaltslast*) referred to a guarantee to ensure the continuous operation of banks by capitalizing them and offsetting their losses if necessary. The guarantor's liability (*Gewährträgerhaftung*) affected the external relations to third parties and provided guarantees to all liabilities of public banks. As a result, the credit risk of the German state was applicable to public banks and to their financial liabilities. This arguably led to a comparative advantage through high ratings and low funding costs (see Körner and Schnabel, 2013). Following a complaint of commercial banks, the German government and the European Commission agreed on an abolition of state guarantees for public banks on April 11, 2002. The agreement included a so-called grandfathering clause. Newly issued liabilities in the period between July 19, 2001 and July 18, 2005 were guaranteed as long as they matured until December 31, 2015. Liabilities originated after July 18, 2005 were issued without any government guarantees. Liabilities issued before July 19, 2001 remained guaranteed beyond December 31, 2015.

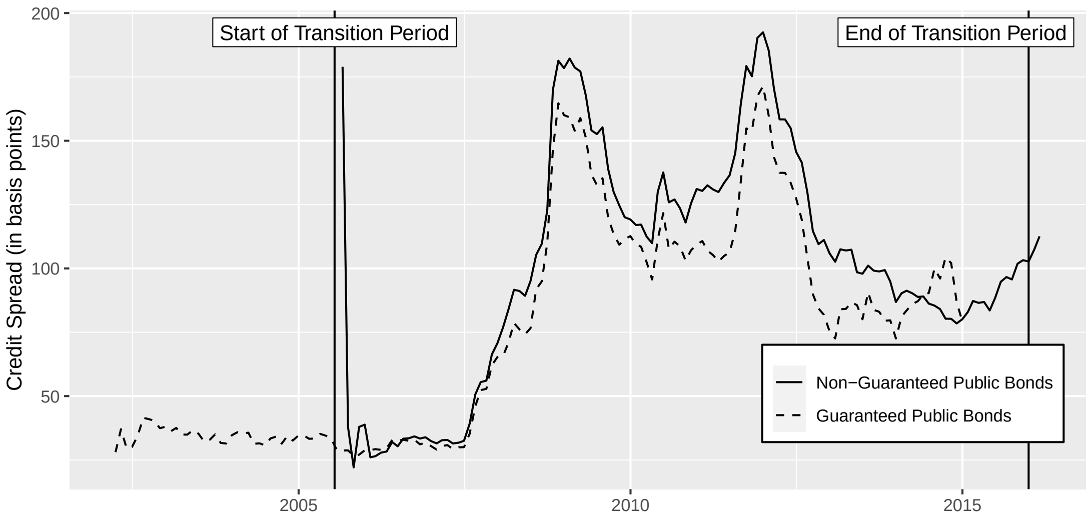

Figure 1: Evolution of Credit Spreads by Guarantee Characteristics

This figure displays the average credit spreads in basis points from 2002 to 2016 for savings bank and state bank bonds with and without explicit sovereign guarantees. All bonds included have a time to maturity of at least one year (see Section III). The essential events related to the gradual removal of sovereign guarantees are marked by vertical lines.

Figure 1 illustrates the average credit spreads for guaranteed and non-guaranteed bonds in the group of savings and state banks from 2002 to 2016.[3] Initially, the mean credit spreads of savings and state bank bonds remain on a similar level with a slowly declining tendency in the left part of the figure. The credit spread visibly decreases further after the start of the transition period with a small reversion in the years 2006 and in the first half of 2007. The first non-guaranteed savings bank and state bank bonds are introduced in the second half of 2005 and first trade at a fairly high discounts, subsequently moving to an average credit spread closely above the credit spread of the guaranteed bonds. The two time series start to diverge at the beginning of the financial crisis in 2007. From the second half of 2007 onwards, guaranteed bonds clearly display lower credit spreads relative to bonds without an explicit sovereign guarantee. The two time series display distinct peaks at the heights of the financial crisis and the European debt crisis. In the following, we make use of this setting to identify the extent of default risk in credit spreads of non-guaranteed bonds.

III Data

We create an extensive dataset of all bonds issued by German savings bank and state banks with Germany being the country of issuance for the period 2002 to 2015. We collect static bond characteristics from Thomson Reuters Eikon. The dataset is restricted to plain vanilla annually paying fixed-coupon bonds as the most common type of bond in Germany. We then collect monthly time series data for all available bonds from Thomson Reuters Datastream. We further obtain long-term issuer ratings from the three largest agencies Moody's, Fitch, and Standard & Poor's from Thomson Reuters Eikon.

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[3] The data for guaranteed savings and state bank bonds ends at the end of 2014 due to the removal of sovereign guarantees at the end of 2015. As we only include bonds with a minimum time to maturity of at least one year (see Section III), the last values of the time series are at the end of 2014. The data for non-guaranteed savings and state bank bonds begins in the second half of 2005 as formerly all savings and state bank bonds were guaranteed.

In terms of data filtering, we eliminate observations with double entries, delete bonds with missing values in relevant variables (e.g. coupon or issue size) and as a common practice, we exclude bonds with very short and very long maturities (less than one year and above 30 years). We only include observations when there are actual market prices and remove observations that contain only prices determined by Thomson Reuters. We further remove bond observations that do not have a rating. If more than one rating is available for a certain point in time, we follow regulatory standards and apply the second-best rating.

We distinguish between bonds with and without credit risk based on the date of issue. Savings and state bank bonds issued before July 18, 2005 with a maturity until December 31, 2015 are subject to sovereign guarantees and are, therefore, considered as free of credit risk. Other public bank bonds without guarantees are considered to have the respective credit risk of the issuer. Our methodological setup simultaneously requires observations of both groups. Requiring a time to maturity of at least one year, we analyze the time period from July 18, 2005 to December 31, 2014.

Our final sample comprises 104,764 monthly observations of 3,795 bonds in total from 137 issuers. 13,255 bond observations stem from 130 savings banks and 91,509 from seven state banks. With respect to rating categories, our sample includes 1,179 bond observations with an issuer rating of AA, 89,149 of A, 14,436 of BBB. 23,125 observations belong to the non-credit risk treatment group and 81,639 belong to the credit risk control group.

IV Empirical Methods

Our main variable of interest is the credit spread of bonds measured over a presumably risk-free benchmark in basis points (bps). We use the spread over benchmark provided by Thomson Reuters Datastream. It is calculated as the bond yield minus the yield of an equivalent government benchmark bond chosen by currency, size, maturity, and coupon. We winsorize outliers in credit spreads at the 0.1% and the 99.9% level.

Our methodology exploits the simultaneous existence of bonds from public banks with and without credit risk traded on the same market. This approach is similar to the identification strategy used in Dick-Nielsen et al. (2012) who compare bonds with the same credit risk but different liquidity. Over the transition period from 2005 to 2015, it is possible to employ a similar strategy to identify the credit risk component by comparing bonds with similar characteristics of which one is free of credit risk. The credit spread of a non-guaranteed bond minus the credit spread of a sufficiently similar guaranteed bond is our proxy for credit risk. It is obviously essential for this analysis to pair guaranteed and non-guaranteed bonds with very similar bond characteristics.

We only pair bond observations from the same issuer. In this way the treatment and control observation do not differ in common firm-specific characteristics such as leverage (e.g., Collin-Dufresne et al., 2001) or informational opaqueness (e.g., Dick-Nielsen et al., 2012). The point in time of the price data of the matches is allowed to deviate by 14 days. As we match bonds at nearly the same time, the states of the business cycle, equity markets and debt markets are reasonably identical (e.g., Collin-Dufresne et al., 2001; Ericsson and Renault, 2006).

With regards to the issue size, the time to maturity, and the annual fixed coupon rate, we apply a matching procedure using a Mahalanobis metric matching (MM). The issue size, as used in Longstaff et al. (2005) and Houweling et al. (2005), serves as a proxy for a bond's liquidity. The coupon rate and the time to maturity ensure that we compare bonds with similar cash flows and in this way also a similar duration and convexity. There is no different taxation between both groups of bonds. Other bond characteristics do not deviate to the best of our knowledge, as all these bonds are plain vanilla fixed-coupon bonds without any exotic or derivative features.[4]

In addition to matching bond characteristics, we include one further analysis, where we compare bonds that were issued with particular temporal proximity to the beginning of the transition period. The bond age is a common proxy for liquidity risk in the credit spread literature (e.g., Houweling et al., 2005; Dick-Nielsen et al., 2012). We, therefore, conduct two analyses only including bonds issued from 2004 to 2006 and even only including bonds issued in 2005 itself, the year, new issues started to be issued without sovereign guarantees.

The Mahalanobis metric is a common choice as it accounts for the difference in variances and correlations between variables by using a covariance matrix C. This can be formalized as

$$d_{MM}(i,j) = (X_i - X_j)' \, C^{-1} \, (X_i - X_j) \,, \tag{IV.1}$$

where X_i and X_j are vectors of k characteristic variables, i be a bond from the treatment group, and j a bond from the control group, respectively. For any given observation i from 29,535 observations with no credit risk, we choose the observation j from the observations subject to credit risk associated with the smallest Mahalanobis distance d_{MM}.

Besides a baseline matching model (1) that uses the coupon, issue size, and maturity without distance limitations (named caliper in matching analysis), we calculate a second matching to generate even closer matches. Model (2) sets a range for the caliper of 0.5 standard deviations for each variable. Treatment and control observation for coupon, issue size, and maturity should not deviate more than this value in order to achieve more accurate pairings.

[4] Appendices A.1, A.2, and A.3 provide detailed variable definitions, summary statistics of and correlations between the variables of our matching setup, respectively. The authors are happy to provide any further checks of robustness. Dick-Nielsen et al. (2012) control for maturity and issuer name.

V Results

Table 1 presents the means of continuous bond characteristics and the credit spreads of the treatment and control groups. It further displays the difference between these averages. We perform t-tests on the differences in means to test for statistical significance. Before the matching, some considerable differences between the treatment and control groups exist in all variables. These numbers are presented in the left part of the table. The average issue size is higher for guaranteed bond observations, whereas the average maturity is lower. These differences make a lot of sense, because issuers had a clear incentive to issue larger volumes with maturity dates before the end of the transition period before the transition period started. The average coupons are economically almost equal in size, although they are statistically different, too.

We conduct the first matching step pairing observations with observations from the same issuer with similar characteristics in terms of Mahalanobis distance to make bond characteristics more comparable. This is displayed in model (1) in the center of the table. The differences of the maturity and the issue size become smaller in economic terms. The differences for the coupon remain small. The total difference in issue size decreases but the issue size remains notably smaller for the control group of non-guaranteed bonds compared to the treatment group. This could, therefore, result in a potentially larger credit spread for the control group due to more liquidity risk and therefore to a potentially overestimated spread difference.

We tighten matching requirements in model (2) by further setting a range of 0.5 standard deviations for coupon, issue size, and maturity. While the t-tests remain significant, the differences are economically small with values of less than 0.1 percentage points for the coupon, around one percent for the maturity and less than 0.5 percent for the issue size.[5]

[5] The results even remain qualitatively unchanged when requiring the issue size to be matched exactly, which is possible because there are typical sizes, the issuers tend to repeatedly use. These results are available from the authors upon request.

Table 1: Matching Results

This table reports the matching results as means of the characteristic variables and of the credit spread (in bps) before and after matching for the groups of guaranteed and non-guaranteed bond observations, respectively. For the credit spread, the shares in the overall spreads are indicated in italics. Mahalanobis metric matching is applied to two models with respect to different matching requirements in characteristic variables. Model (1) does not impose any limitations. Model (2) sets a range for the matching caliper of the coupon, the issue size, and the maturity of 0.5 standard deviations. The number of observations paired with the unique number of control observations is stated below. The differences between groups are stated together with the corresponding t-values of two-tailed tests. In the matched samples of models (1) and (2), the table reports results of a pairwise t-test. Significance levels are indicated by *** $p < 0.01$, ** $p < 0.05$ and * $p < 0.1$.

				After Matching					
	Before Matching			(1)			(2)		
Variable	Guar.	Non-Guar.	Diff. (t-val.)	Guar.	Non-Guar.	Diff. (t-val.)	Guar.	Non-Guar.	Diff. (t-val.)
Coupon	0.035	0.035	0.000*** (3.738)	0.035	0.034	0.001*** (26.283)	0.034	0.034	0.000*** (3.906)
Maturity	3.600	3.963	-0.363*** (-23.245)	3.591	3.362	0.229*** (31.429)	3.237	3.215	0.022*** (4.961)
Issue Size	18.299	17.341	0.958*** (124.136)	18.320	17.986	0.334*** (58.343)	18.137	18.063	0.074*** (22.401)
Credit Spread	70.119	117.951	-47.832*** (-120.565)	72.828	89.133	-16.305*** (-52.953)	79.875	90.440	-10.565*** (-35.798)
Share			*0.406*			*0.183*			*0.117*
N	23,125	81,639		21,268	7,380		13,502	6,329	

For the credit spread, we obtain significantly negative differences between treatment and control groups. The credit spread of guaranteed bonds is smaller than the spread of non-guaranteed bonds reflecting the lower level of credit risk due to sovereign guarantees. Our baseline model (1) yields a difference in credit spreads of -16.3 bps. In terms of the overall credit spread this accounts for 18.3% on average. This implies that 81.7% are explained by other factors.

Model (2) uses a stricter matching methodology. The credit spread component is smaller but still significant. Model (2) estimates the spread difference to amount to -10.6 bps which in turn makes up roughly 11.7% of the overall spread. The results of both models are in favor of a large extent of the unexplained credit spread component.

Table 2: Matching Results over Ratings

This table shows the matching results as means of credit spreads (in bps) per rating class. The shares in the overall spreads are indicated in italics. Mahalanobis metric matching is applied in two models with respect to different matching requirements for characteristic variables. Model (1) does not impose any limitations. Model (2) sets a range for the matching caliper of the coupon, the issue size, and the maturity of 0.5 standard deviations. The number of observations paired with the unique number of control observations is stated below. The differences between groups are stated together with the corresponding t-values of two-tailed tests. In the matched samples of models (1) and (2), the table reports results of a pairwise t-test. Significance levels are indicated by *** $p < 0.01$, ** $p < 0.05$ and * $p < 0.1$.

				After Matching					
	Before Matching			(1)			(2)		
Rating	Guar.	Non-Guar.	Diff. (t-val.)	Guar.	Non-Guar.	Diff. (t-val.)	Guar.	Non-Guar.	Diff. (t-val.)
AA	45.160	90.103	-44.943***	51.875	45.623	6.252***	59.785	54.922	4.863***
			(-18.834)			(5.552)			(2.627)
			0.499			*-0.137*			*-0.089*
N	535	644		376	113		143	76	
A	67.982	111.226	-43.244***	70.397	84.566	-14.169***	79.030	88.325	-9.295***
			(-105.369)			(-45.286)			(-31.420)
			0.389			*0.168*			*0.105*
N	21,368	67,781		19,670	6,852		12,938	6,020	
BBB	118.408	153.804	-35.396***	118.408	176.036	-57.628***	112.654	167.520	-54.866***
			(-26.981)			(-42.742)			(-27.778)
			0.230			*0.327*			*0.328*
N	1,222	13,214		1,122	427		421	237	

In addition, we estimate the average credit spread differences for varying issuer rating classes in Table 2. Surprisingly, the difference of the credit spreads is positive in model (1) and model (2). While the number of observation is comparably small, this indicates that credit risk appears to not be the primary concern for the prices of these AA-rated bonds. In contrast, credit risk proxied by the removal of sovereign guarantees is clearly reflected in lower-rated bonds. The share of credit risk varies from 16.8% (-14.2 bps) for A-rated bond observations to 32.7% (-57.6 bps) for a BBB rating estimated by model (1) and from 10.5% (-9.3 bps) to 32.8% (-54.9 bps) by model (2). Hence, the share of credit risk in the spreads strongly increases in magnitude with lower rating classes.

We further calculate the differences in credit spreads for individual years in Table 3. The proportion in the overall spread varies considerably over the years. The difference is particularly high in the second half of 2005. Some of the first non-guaranteed bonds were traded at fairly high discounts leading to an average credit spread of non-guaranteed bonds of 40.4 bps in model (1). In contrast, the remaining guaranteed bonds were initially traded at fairly high prices leading to a credit spread of 18.1 bps for the guaranteed bonds. This indicates that it was initially apparently unattractive for investors to invest in bonds without guarantees while most of the available bonds of savings and state banks still contain these guarantees. The difference is insignificant in model (2).

Abstracting from the immediate introduction phase, the credit risk component varies between values of around 10% before the financial and European debt crisis to values around 20% during the heights of the crisis years using model (1) which corresponds to a difference in credit spreads of up to -38.2 bps. The share of the credit risk component returns to lower levels in 2013 and is insignificant in 2014. For model (2), the credit risk component is not significant in 2006 but rises up to 16.5% (-26.8 bps) in 2009. It is interesting to notice that the credit risk component is substantially larger during the financial crisis and European debt crisis. Nevertheless, even in times of crises the share of the credit risk component does not exceed 22% of the overall credit spread.

Table 3: Matching Results over Time

This table shows the matching results as means of credit spreads (in bps) per year from 2005 to 2014. The shares in the overall spreads are indicated in italics. Mahalanobis metric matching is applied in two models with respect to different matching requirements for characteristic variables. Model (1) does not impose any limitations. Model (2) sets a range for the matching caliper of the coupon, the issue size, and the maturity of 0.5 standard deviations. The number of observations paired with the unique number of control observations is stated below. The differences between groups are stated together with the corresponding t-values of two-tailed tests. In the matched samples of models (1) and (2), the table reports results of a pairwise t-test. Significance levels are indicated by *** $p < 0.01$, ** $p < 0.05$ and * $p < 0.1$.

				After Matching					
	Before Matching			(1)			(2)		
Year	Guar.	Non-Guar.	Diff. (t-val.)	Guar.	Non-Guar.	Diff. (t-val.)	Guar.	Non-Guar.	Diff. (t-val.)
2005	20.007	52.052	-32.045***	18.148	40.378	-22.230***	14.611	14.415	0.196
			(-3.299)			(-9.239)			(0.082)
			0.616			*0.551*			*-0.014*
N	2,304	126		1,432	105		285	73	
2006	27.239	29.101	-1.862***	26.386	29.245	-2.859***	26.789	26.716	0.073
			(-3.317)			(-6.764)			(0.124)
			0.064			*0.098*			*-0.003*
N	5,238	1,363		4,804	759		2,355	604	
2007	37.936	45.204	-7.268***	38.544	41.916	-3.372***	38.831	40.330	-1.499***
			(-14.499)			(-11.123)			(-4.168)
			0.161			*0.080*			*0.037*
N	4,395	3,051		4,083	1,071		2,888	942	
2008	100.470	124.923	-24.453***	100.962	129.202	-28.240***	104.612	124.089	-19.477***
			(-20.110)			(-34.786)			(-22.936)
			0.196			*0.219*			*0.157*
N	3,392	3,816		3,282	999		2,296	847	
2009	137.535	157.950	-20.415***	137.266	175.498	-38.232***	135.423	162.196	-26.773***
			(-20.736)			(-36.456)			(-26.007)
			0.129			*0.218*			*0.165*
N	2,530	7,946		2,467	1,214		1,869	1,097	

(Table continued.)

2010	103.930	125.325	-21.395***	102.940	126.988	-24.048***	99.777	112.523	-12.746***
			(-28.444)			(-25.749)			(-13.504)
			0.171			*0.189*			*0.113*
N	1,982	10,870		1,944	1,157		1,439	1,012	
2011	126.401	155.078	-28.677***	126.321	150.874	-24.553***	126.220	142.040	-15.820***
			(-27.821)			(-23.384)			(-15.277)
			0.185			*0.163*			*0.111*
N	1,491	12,205		1,489	968		1,097	823	
2012	119.200	142.039	-22.839***	119.205	134.257	-15.052***	116.534	125.583	-9.049***
			(-15.994)			(-11.857)			(-7.780)
			0.161			*0.112*			*0.072*
N	914	11,453		913	599		664	503	
2013	81.906	99.945	-18.039***	81.932	88.769	-6.837***	72.835	75.903	-3.068***
			(-9.129)			(-4.559)			(-2.619)
			0.180			*0.077*			*0.040*
N	592	12,846		581	400		426	332	
2014	88.318	86.167	2.151	88.490	86.319	2.171	78.186	82.015	-3.829**
			(0.947)			(0.972)			(-2.208)
			-0.025			*-0.025*			*0.047*
N	287	17,963		273	222		203	174	

Besides the issue size, another possible measure of liquidity for bonds is the bond age. As a check of robustness and as described in Section IV, we also control for differences in the bond age. We do so by only including bonds which were issued close to the start of the transition period. In one step, this is done excluding all bonds issued before the year 2004 and after the year 2006. In another step, we even limit the sample to bonds issued within the year 2005. The respective results using the matching procedures of models (1) and (2) are presented in Appendix A.4. For bonds issued between 2004 and 2006, indicated by spread shares of 19.8% (-18.1 bps) and 8.4% (-6.7 bps), respectively, the results remain qualitatively unchanged. Indicated by spread shares of 11.8% (-9.8 bps) in model (1) and of 6.4% (-4.7 bps) in model (2), the credit risk component is smaller when only looking at bonds issued in 2005.

Overall, on average only 20% or less of the credit spread results from credit risk in our sample. This supports the existence of non-credit risk components that determine most of the credit spread.

VI Conclusion

Extensive prior research has looked at the extent of credit risk in bond yield spreads mainly finding credit spreads to be insufficiently explained by credit risk. Yet, works such as Feldhütter and Schaefer (2018) and Du et al. (2019) show that structural models of credit default can generate credit spreads that are in the magnitude of empirically observed credit spreads. It is an interesting aspect that there remains such a large dissent in a significant issue of the finance literature.

The removal of sovereign guarantees for savings banks and state banks in Germany in 2005 generated a situation where bonds of these banks became subject to credit risk instead of previously being credit risk-free. The implemented transition phase, including a grandfathering agreement, allows for a direct comparison between bonds with and without credit risk of the same issuer and with similar characteristics.

We exploit this policy change as a quasi-natural experiment in order to identify the extent of credit risk in bond yield spreads empirically without any specific parametric model, thereby asking the question of what extent of the credit spread should be considered to be related to credit risk. Building on an extensive dataset of monthly German bond price data from 2005 to 2015, we find a difference in spreads of guaranteed and non-guaranteed bonds of on average 16.3 basis points. In our sample, these 16.3 basis points account for 18.3% of the average total credit spread leaving 81.7% (72.8 basis points) unexplained. This proportion is well in line with theoretically derived credit related spreads in literature such as in Huang and Huang (2012) and Huang et al. (2019). Our results building on a unique new approach, therefore, support positions in favor of a substantial non-credit risk component.

A Appendix

A.1 Variable Definitions

This table presents definitions of all variables used in our matching approach. All variables are from Thomson Reuters.

Type	Variable	Description
Bond Characteristics	Coupon	Annual fixed coupon rate
	Issuer Name	Unique name for the issuing bank
	Maturity	Remaining time until principal repayment (years)
Liquidity	Issue Size	Amount issued as the number of bonds issued multiplied by the face value (log)
Dependent Variable	Cedit Spread	Yield difference to a government benchmark calculated by Thomson Reuters

A.2 Summary Statistics

This table reports summary statistics of the continuous variables included in our matching approach. The credit spread is winsorized at the 0.1% and 99.9% level for the full sample which is divided into sub-samples afterwards. The "Min." and "Max." of the credit spread are the winsorization levels in all three subsamples except for the maximum credit spread of the guaranteed bonds.

Variable	Unit	Mean	Std. Dev.	Min.	Max.
		Full Sample			
Coupon	decimals	0.035	0.011	0.003	0.080
Issue Size	log(euro)	17.553	1.402	8.700	21.129
Maturity	years	3.883	2.274	1.000	24.308
Credit Spread	bps	107.393	57.433	-52.271	403.827
		Guaranteed			
Coupon	decimals	0.035	0.009	0.010	0.060
Issue Size	log(euro)	18.299	0.896	10.597	20.436
Maturity	years	3.600	2.015	1.000	10.447
Credit Spread	bps	70.119	53.202	-52.271	391.900
		Non-Guaranteed			
Coupon	decimals	0.035	0.011	0.003	0.080
Issue Size	log(euro)	17.341	1.446	8.700	21.129
Maturity	years	3.963	2.336	1.000	24.308
Credit Spread	bps	117.951	54.094	-52.271	403.827

A.3 Correlations

This table shows correlations between the continuous variables included in our matching approach.

Variable	Coupon	Issue Size	Maturity	Credit Spread
Coupon	1.000	-	-	-
Issue Size	0.010	1.000	-	-
Maturity	0.155	0.053	1.000	-
Credit Spread	0.195	-0.151	0.064	1.000

A.4 Matching Results Discontinuity Bond Age

This table shows the matching results as means of credit spreads (in bps) for an analysis only including bonds issued between 2004 and 2006 and an analysis only including bonds issued in 2005 itself. The shares in the overall spreads are indicated in italics. Mahalanobis metric matching is applied in two models with respect to different matching requirements in characteristic variables. Model (1) does not impose any limitations. Model (2) sets a range for the matching caliper of the coupon, the issue size, and the maturity of 0.5 standard deviations. The number of observations paired with the unique number of control observations is stated below. The differences between groups are stated together with the corresponding t-values of two-tailed tests. In the matched samples of models (1) and (2), the table reports results of a pairwise t-test. Significance levels are indicated by *** $p < 0.01$, ** $p < 0.05$ and * $p < 0.1$.

				After Matching					
	Before Matching			(1)			(2)		
Issue Year	Guar.	Non-Guar.	Diff. (t-val.)	Guar.	Non-Guar.	Diff. (t-val.)	Guar.	Non-Guar.	Diff. (t-val.)
2004-2006	72.122	101.652	-29.530***	73.249	91.289	-18.040***	73.691	80.433	-6.742***
			(-39.745)			(-45.502)			(-21.008)
			0.291			*0.198*			*0.084*
N	14,621	11,509		13,135	3,820		7,757	3,020	
2005	73.375	97.471	-24.096***	73.092	82.867	-9.775***	68.635	73.297	-4.662***
			(-19.532)			(-20.136)			(-7.940)
			0.247			*0.118*			*0.064*
N	7,798	4,206		6,804	1,786		3 104	1 151	

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