Journal of Banking and Finance 70 (2016) 193–213

Contents lists available at ScienceDirect

Journal of Banking and Finance

journal homepage: www.elsevier.com/locate/jbf

Risk protection from risky collateral: Evidence from the euro bond market

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ARTICLE INFO

Article history:
Received 5 November 2014
Accepted 2 June 2016
Available online 24 June 2016

JEL classification:
G01
G12
G21
G32

Keywords:
Collateral
Secured debt
Covered bonds
Credit risk
Liquidity risk

ABSTRACT

This paper studies empirically how collateral protects the market value of defaultable bonds from changes in risk. We construct a measure of the risk protection from collateral, and estimate it under different economic conditions. Using yields from the euro bond market, we find that the risk protection from collateral is conditional, significantly stronger in both general and issuer-specific bad states. However, the collateral is risky, and a fall in the collateral value clearly lowers the risk protection. Consequently, the correlation between the bad state and the collateral value is crucial when assessing the risk reducing properties of collateral.

1. Introduction

Collateral insures against risk. It has an essential role in the current financial markets, above all sparked by the subprime-crisis and the euro sovereign debt crisis. In this paper we empirically study to what extent collateral protects the market value of defaultable bonds from changes in risk. We examine risk in *secured*, covered bonds compared to *unsecured*, senior bonds of the same issuer. To this end, we construct a novel measure of the risk protection from collateral, and estimate it under different economic conditions. Indeed, we find collateral to protect the market value of defaultable bonds, but there is considerable variation in the risk reduction under different economic conditions. The risk reduction varies both cross-sectionally and over time. Growing demand for collateral has forced market participants to adjust by broadening the range of assets accepted as collateral.[1] This paper empirically documents the properties of risky collateral.

We employ a new and extensive data set based on daily observations of individual bonds underlying the Markit iBoxx EUR Index. The sample covers the period 1999–2012, and includes bonds from 46 banks in 16 countries. Bond yields at a disaggregate, issuer level take full account of firm heterogeneity in credit risk as opposed to using yields of corporate bond indexes or average yields within rating grades. The sample contains several episodes of economic and financial distress with substantial changes in the risk levels. We observe yields on government bonds, agency bonds, and three classes of bank bonds: covered, senior, and subordinated bonds. We use the yields on these bond classes to identify the effect of collateral.

Credit risk is determined by the likelihood of default and the loss, given default. Fama and French (1993) find that the likelihood of default is one of three common risk factors in bond returns. Using a reduced-form model and assuming CDS spreads are a measure of credit risk only, Longstaff et al. (2005) find that this default component explains about 50% of the yield spreads between Aaa/Aa-rated bonds and Treasuries. For all rating categories, the majority of the corporate bond spread is due to default risk. In a parallel study based on structural credit risk models, Huang and Huang (2012) find that for investment-grade bonds, credit risk accounts for only a small fraction of the yield spread, typically around 20%.

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[1] As an example, in line with its statute, the Eurosystem provides credit to banks only on a collateralized basis. Assets that are pledged must be eligible, i.e. fulfil certain criteria. These criteria have been eased on several occasions. See www.ecb.europa.eu/paym/coll/html/index.en.html for more information.

http://dx.doi.org/10.1016/j.jbankfin.2016.06.001
0378-4266/

While collateral may have a small impact on the likelihood of default, it increases the recovery rate in case of default. Recovery rates on *defaulted* bonds are well studied in empirical literature, see Altman (2008) and Mora (2012) for a review of the literature. Risk reduction from collateral is also important for *defaultable* claims. For instance, financial market participants are governed by mark-to-market principles when it comes to valuation, accounting, and regulation. Falling market values of financial assets can lead to breaches of loan covenants, non-compliance with regulatory requirements, or require large cash outflows due to margin requirements. Such events can set off a negative spiral of financial distress, see e.g., Shleifer and Vishny (2011) and Brunnermeier (2009). We therefore find it relevant to study collaterals' influence on more risk factors than just credit risk. Particularly interesting in this respect is liquidity risk, as credit and liquidity risks are usually positively correlated, see Ericsson and Renault (2006) and Kalimipalli and Nayak (2012). Existing literature finds that the impact of credit and liquidity shocks on asset market values is stronger in bad economic times, see Acharya and Pedersen (2005) and Acharya et al. (2013). We disentangle credit and liquidity risk and study the risk protection from collateral conditional on adverse economic states.

The literature on disentangling of credit and liquidity risk can be divided into two strands. Our paper is related to the first strand which seeks to disentangle credit and liquidity effects by directly controlling for one of them. In its most constricted form, it involves comparing bonds with the same credit quality but with different liquidity, or vice versa. Warga (1992) uses the yield spread between off- and on-the-run US Treasury securities as a liquidity measure, while Longstaff (2004) uses the yield spread between securities issued by the US Treasury and the US agency Refcorp as a liquidity measure. Reinhart and Sack (2002) disentangle movements in Treasury, agency, swap, and senior corporate bond yields into several risk factors. Our paper is motivated by their approach, but it differs in that our attention is on how risk factors influence the pricing of the different bond *classes*. Thus, our attention is not on the absolute risk level *per se*, but on relative risk between secured and unsecured bonds. We estimate the yields' sensitivities, the factor loadings, to the risk factors. The factor loadings for covered bonds, compared to the loadings for the senior bonds, give us easy to interpret estimates of the risk reduction from collateral.

The second strand of literature uses proxies for credit quality and liquidity to explain the movements in yield spreads. We compare our empirical findings to two often-used proxies for credit and liquidity risk (rating and bid-ask spreads). These two proxies capture the development of relative risk as measured by our model. However, time and cross-sectional variables matter in measuring relative credit and liquidity risk, even after controlling for credit ratings or bid-ask spreads. Thus, credit rating is not a sufficient measure of relative credit risk, and bid-ask spreads are not a sufficient measure of relative liquidity risk.

Most of the literature on liquidity risk studies the unconditional effect of liquidity risk, that is, averaged over time, see e.g. Lin et al. (2011) and de Jong and Driessen (2012). However, Acharya and Pedersen (2005) find that liquidity risk may matter more in periods of illiquidity crises. Acharya et al. (2013) show that the response of corporate bond prices to liquidity shocks varies systematically between two regimes characterized as "normal" and "stress". We find that the risk protection from collateral is conditional on the economic conditions. The risk reduction is affected differently dependent on the risk being idiosyncratic or systematic in nature, or whether the risk is tied to the issuer or the collateral. As house loans are the typical collateral for covered bonds, we use house prices as proxy for the collateral value and find a significant reduction in risk protection from collateral against both credit and liquidity risk when house prices fall.

Our empirical study finds a resemblance in the pattern of relative liquidity risk and relative credit risk between covered and senior bonds. Ericsson and Renault (2006) develop a structural bond valuation model to simultaneously capture liquidity and credit risk. As default becomes more likely, the components of bond yield spreads attributable to illiquidity increase. Studying US corporate bond data, they find empirical support for their model's prediction. From a structural model that interacts liquidity and default risk, Chen et al. (2014) estimate that this interaction accounts for 25–40% of observed credit spreads, and up to 55% of the credit spread changes over the business cycle.

Our paper gives particular insight into covered bond risk. The view on covered bond risk is divergent. One strand of literature considers covered bonds to be without credit risk, see e.g., Kempf et al. (2012) who interpret the yield spread as a liquidity premium. Similar assumption is taken by Koziol and Sauerbier (2007) as they examine the effects of liquidity on bond prices. Another strand of literature finds credit risk as a determinant of covered bond yield spreads. Prokopczuk et al. (2013) show that not only liquidity, but also issuer-specific effects, especially the quality of the cover pool, are relevant drivers for yield spreads between covered bonds and German government bonds. They find that the yield spread between individual covered bonds is mainly driven by their relative liquidity and whether they are covered public-sector or mortgage loans. Studying the European covered bond market, Prokopczuk and Vonhoff (2012) show that country-specific differences exist and developments in the real estate market explain a major fraction of covered bond asset swap spreads during the financial crisis. The cited literature on covered bond risk studies the yield spread between covered bonds and governments bonds, or, covered bonds and interest rate swaps.

We are, to the best of our knowledge, the first to use the yield on senior and covered bonds to analyze the risk reduction from having collateral. Understanding the nature of collateral and related risks under varying economic states is relevant to investors, rating agencies, and regulators alike. Investors should consider the empirical findings when assessing the risk of secured investments or exposures, for example when performing stress tests. Policy makers should consider the findings in financial market regulations, for example in matters like collateral eligibility requirements and systemic risk. Just as an example, covered bonds within a given rating class are currently treated as a homogeneous debt class in many regulatory matters. Yet, the empirical findings in this paper show that risk sensitivities of covered bonds are clearly heterogeneous. To academics, evidence on the protection collateral offers to defaultable bonds can help explain investors' preferences for collateral. This insight can be used to further investigate the causes of secured financing.

2. Model construction

2.1. Bond market yields

The model is based on bond yields of five bond classes:

1. Yield on bonds issued by central **governments** (y_{gov}).
2. Yield on **agency bonds** (y_{agency}). Bonds issued by entities with a government guarantee.
3. Yield on **covered bonds** (y_{cov}) issued by banks. Bonds secured against specific assets or pools of assets.
4. Yield on **senior bonds** (y_{sen}) issued by banks. The bonds are unsecured and rank *pari-passu* with other senior debt.
5. Yield on **subordinated bonds** (y_{sub}) issued by banks. Unsecured debt with priority after senior debt.

The key difference between covered and senior bonds of the same issuer is that covered bonds are backed by collateral. If the collateral is insufficient to cover the claim of the covered bond holders in a default, their remaining claim on the bank ranks *pari-passu* with the claim of senior bond holders.[2]

2.2. Decomposition of bond yields in risk factors

Our model assumes that yields are influenced by three time-varying factors: The risk-free interest rate (R), the liquidity risk factor (L), and the credit risk factor (C).

In line with Reinhart and Sack (2002), the liquidity risk factor represents investors' preferences for liquidity rather than shifts in the amount of liquidity. The credit risk factor reflects changes in required compensation for bearing credit risk.

The yield spread between a risky bond and the risk-free interest rate is the *absolute* compensation for risk. We use the risk factors as building blocks in explaining the bond yields. In contrast to changes in the risk-free interest rate, changes in credit risk or liquidity risk do not affect yields equally. The sensitivities to these factors, for a given bond class, are the factor loadings. The higher the load, the more relevant the risk factor is in explaining the bond yield. As such, the factor loadings are *relative* measures of risk.

The bond yields are illustrated in Fig. 1. Formally, they can be expressed as the product between a matrix of factor loadings and a vector of the factors, i.e.,

$$\begin{pmatrix} y_{gov} \\ y_{agency} \\ y_{cov} \\ y_{sen} \\ y_{sub} \end{pmatrix} = \begin{pmatrix} 1 & \alpha_{gov} & \beta_{gov} \\ 1 & \alpha_{agency} & \beta_{agency} \\ 1 & \alpha_{cov} & \beta_{cov} \\ 1 & \alpha_{sen} & \beta_{sen} \\ 1 & \alpha_{sub} & \beta_{sub} \end{pmatrix} \cdot \begin{pmatrix} R \\ L \\ C \end{pmatrix}. \tag{1}$$

The factor loadings α show the corresponding bond yields' sensitivity to the liquidity risk factor. Similarly, the factor loadings β show the bond yields' sensitivity to the credit risk factor.

2.3. Restrictions on factor loadings

Government and agency bonds have no credit risk, hence $\beta_{gov} = \beta_{agency} = 0$.[3] Covered, senior, and subordinated bonds are exposed to credit risk. The credit risk factor, C, is bank specific. Changes in perceived credit quality of a bank affect all three bond classes issued by this bank, but the impact differs for the different classes. We place no restrictions on the relative size of the factor loadings for covered, senior, and subordinated bonds, but we normalize the factor loading for credit risk for subordinated bonds to 1, i.e., $\beta_{sub} = 1$. Hence, the factor loading for credit risk in covered bonds, β_{cov}, expresses the credit risk in covered bonds relative to the credit risk in subordinated bonds. Likewise, $\frac{\beta_{cov}}{\beta_{sen}}$ expresses the credit risk in covered bonds as a fraction of the credit risk in senior bonds. This ratio is the main objective of our study of credit risk protection from collateral.

Because there is no credit risk in government and agency bonds, we interpret any yield spread between these bonds as a liquidity premium, or more correctly an illiquidity premium. The factor loading for liquidity risk in government bonds is normalized to -1, i.e., $\alpha_{gov} = -1$. The risk-free interest rate R can therefore only be defined for an assumed level of liquidity. We define the risk-free interest rate as corresponding to the liquidity level of agency bonds, which is accomplished by imposing the restriction $\alpha_{agency} = 0$. The implication of these two restrictions ($\alpha_{gov} = -1$ and $\alpha_{agency} = 0$) is that the yield spread between agency and government bonds defines the size of the liquidity risk factor, L. The risk factor L is common for all bonds, i.e., a market-wide phenomenon, but with separate factor loadings for each bond class. The ratio $\frac{\alpha_{cov}}{\alpha_{sen}}$ is the main objective of our study of liquidity risk.

To implement the model, we work in terms of deviations from the agency yield. Subtracting the agency yield and imposing our restrictions, the system of Eqs. (1) becomes

$$\begin{pmatrix} y_{gov} - y_{agency} \\ y_{cov} - y_{agency} \\ y_{sen} - y_{agency} \\ y_{sub} - y_{agency} \end{pmatrix} = \begin{pmatrix} -1 & 0 \\ \alpha_{cov} & \beta_{cov} \\ \alpha_{sen} & \beta_{sen} \\ \alpha_{sub} & 1 \end{pmatrix} \cdot \begin{pmatrix} L \\ C \end{pmatrix}. \tag{2}$$

2.4. A model for estimating relative credit risk

In Appendix B we show that

$$(y_{cov} - y_{agency}) = \frac{\beta_{cov}}{\beta_{sen}}(y_{sen} - y_{agency}) + \left(\alpha_{cov} - \frac{\beta_{cov}}{\beta_{sen}}\alpha_{sen}\right)(y_{agency} - y_{gov}). \tag{3}$$

If the ratio $\frac{\beta_{cov}}{\beta_{sen}}$ is less than one, collateral reduces credit risk.

The left-hand side of Eq. (3) is the compensation for both credit and liquidity risk in covered bonds. If there is no liquidity risk in neither covered nor senior bonds, then the risk compensation in covered bond yields is a fraction $\frac{\beta_{cov}}{\beta_{sen}}$ of the credit risk compensation in senior bond yields. However, the assumption of no liquidity risk does not hold, and is corrected in the second term on the right-hand side.

2.5. A model for estimating relative liquidity risk

In Appendix B we also show that

$$\begin{aligned}(y_{cov} - y_{agency}) &= \frac{\alpha_{cov}}{\alpha_{sen}}(y_{sen} - y_{agency}) + \left(\beta_{cov} - \frac{\alpha_{cov}}{\alpha_{sen}}\beta_{sen}\right)(y_{sub} - y_{agency}) \\ &\quad + \left(\frac{\alpha_{cov}}{\alpha_{sen}}\beta_{sen}\alpha_{sub} - \beta_{cov}\alpha_{sub}\right)(y_{agency} - y_{gov}).\end{aligned} \tag{4}$$

Collateral reduces liquidity risk if the ratio $\frac{\alpha_{cov}}{\alpha_{sen}}$ is less than one.

The benchmark liquidity risk model considers the development of four yield spreads. It estimates how covered bonds react to changes in the common liquidity risk factor - compared to how senior bonds react to the similar changes.

2.6. Risk indicators

There is evidence that changes in risk have a stronger impact on asset prices under adverse economic conditions, see Acharya and Pedersen (2005) and Acharya et al. (2013). We construct three indicators to interact with the benchmark risk models:

1. Market conditions indicator.
2. Idiosyncratic crisis indicator.
3. Collateral value indicator.

Fama and French (1989) find that corporate bond yields rise when economic conditions are weak. Based on this literature, we first construct a proxy for market conditions from the spread between the average yield on senior bonds and the yield on government bonds. If this yield spread, on a given date, is more than 10% lower than the average the previous six months, we categorize the

[2] Comprehensive information on covered bonds are found on the website of the European Covered Bond Council at www.ecbc.hypo.org.

[3] Both historical and recent events question the generality of this assumption. We return to this restriction when empirically testing the model.

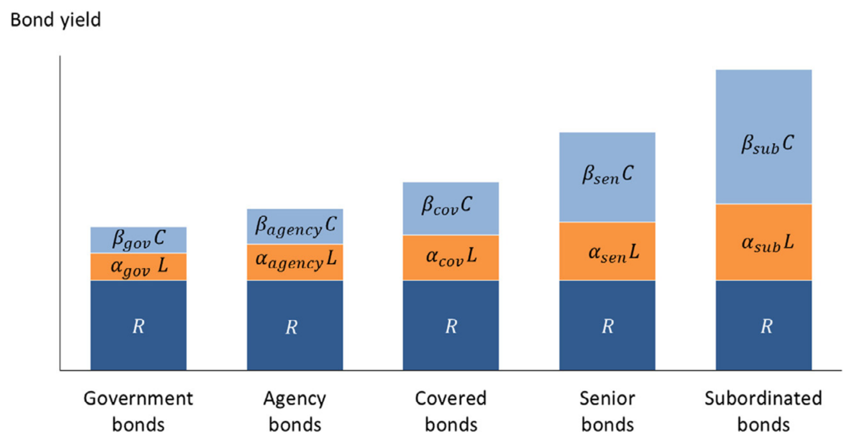

Fig. 1. Decomposed bond yields. Bond yields are influenced by three time-varying factors: The risk-free interest rate (R), liquidity risk (L), and credit risk (C). The factor loadings for liquidity risk (α) and credit risk (β) describe the importance of the risk factors. The figure is made for illustrative purposes; there are no restrictions on the absolute or relative size of the factor loadings in this general model.

market conditions as positive. Correspondingly, if the average yield spread is more than 10% higher than the average the previous six months the market conditions are negative. Anything in-between these levels is categorized as neutral market conditions. The daily, market conditions indicator applies to all banks. We run robustness tests where the $\pm$10% cut-off values are replaced by $\pm$5% and by $\pm$20%.

Second, we construct an indicator for idiosyncratic crises, representing a bad state for a given bond issuer. We define a bank to be in a state of crisis, if the yield spread between the bank's senior bonds and government bonds is more than 50% higher than the average spread for all banks. In robustness tests the 50% cut-off value is replaced by 25% and by 100%.

Third, the collateral in covered bonds is risky, being primarily housing loans conforming to legal eligibility criteria. The true value of the collateral is private information known only to the borrower. Because the majority of the cover pools consists of housing loans, the real estate market has a direct influence on cover pool value. We use quarterly changes in domestic house prices as a proxy for the development of the collateral value.

3. Data, descriptive analysis, and empirical strategy

We use the Eqs. (3) and (4) and run regressions (described in Section 3.4) to estimate the risk-reducing effect of having collateral. We find it convenient to first describe the data we use and present some descriptive statistics before we lay out the empirical strategy.

3.1. Bond data

In our empirical analysis, we use yields on German government bonds and bonds issued by the German agency Kreditanstalt für Wiederaufbau (KfW) as *government* and *agency* bond yields, respectively.[4] Monfort and Renne (2013), Favero et al. (2010) and Manganelli and Wolswijk (2009) show that there is a substantial degree of correlation among liquidity-driven spreads from different European countries. We therefore use the yields on German government bonds and KfW bonds as government and agency bond yields in all cases regardless of the nationality of the bank bonds being studied.

We use daily yield observations of bonds included in the Markit iBoxx EUR index family. The iBoxx indices track the movement of yields in several bond markets. The indices are compiled by a subsidiary of the financial information services company Markit.[5] The iBoxx EUR index family is widely used as a reference of the market development by financial market bodies (e.g., the European Central Bank and IMF), media (e.g., Financial Times) and as benchmarks by investors and asset managers. The index includes all bonds that fulfil the defined selection rules defined by Markit, i.e., the index is constructed by including given bonds – not given banks. The universe of bonds is reviewed monthly; those issues meeting the criteria described below at the end of the month are included in the index.

The bonds are fixed rate bonds whose cash flow can be determined in advance. Only bonds without call or conversion features are included in the sample. Further, only euro and legacy currency denominated bonds are included, but with no respect to the issuer's domicile, meaning that banks of all nationalities can be included in the sample as long as they have issued euro bonds. The bonds are rated investment grade by at least one of the three major rating agencies. The minimum amount outstanding for sovereign bonds is 2 billion euro, for agency and covered bonds 1 billion euro, and for corporate bonds 500 million euro. The yields are calculated from bid and ask quotes, not traded prices, which are provided by ten major financial institutions.[6] The data covers the period from the introduction of the euro as an accounting currency on 1 January 1999 to 31 January 2012. The sample represents a broad coverage of the investment grade fixed-income market for euro denominated bonds. This market segment includes bonds issued primarily by the largest western European banks. We collect the government bond yield and the agency bond yield and add observations of covered, senior, and subordinated bond yields for banks that have the three bond classes included in the index at the same time.

There is an insufficient number of observations of bank bonds across the entire maturity range to analyze how the risk protection depends on maturity. We therefore use data that is concentrated

[4] KfW is a German development bank supporting public policies. 80% of KfW's capital is held by the Federal Republic of Germany and 20% by the German federal states. KfW bonds have an explicit guarantee from the Federal Republic of Germany, written in a special law on the KfW. Due to the explicit and full debt guarantee, KfW bonds can default only if the German state itself defaults, equaling the credit risk of KfW to the credit risk of Germany. The agency is the fourth largest bond issuer in Europe, after the German, French, and Italian sovereigns. See e.g., Monfort and Renne (2013) for a discussion of German government and KfW bonds.

[5] Company website at www.markit.com.

[6] For more information on the index, see the Index Guide at www.markit.com/assets/en/docs/products/data/indices/bond-indices/iboxx-rules/benchmark/Markit%20iBoxx%20EUR_Benchmark%20Guide.pdf.

to the segment of the yield curve with most observations, as described below. The effect of a non-flat zero-coupon euro interest rate swap curve is eliminated using asset swap spreads.[7] However, asset swap spreads also exhibit a term structure. The yield spread between, for instance, a 1 year government bond asset swap spread and a 10 year agency bond asset swap spread, is influenced by the term structure of asset swap spreads at the time. We control for term structure risk by collecting yields of bonds that have similar remaining time to maturity.

Daily, the Markit indexes consist of on average 10 German government bonds (min. 2 and max. 18), spanning the entire maturity range. For KfW the Markit indexes consist of on average 4.4 bonds (min. 1 and max. 10), also spanning the entire maturity range. We collect government and agency bonds with expected remaining maturity of 3–5 years. Subsequently, we calculate the daily, unweighted average asset swap spread of the collected government and agency bonds.

Bonds issued by banks in the Markit indexes are categorized in three different classes. *Covered bonds* fulfils the criteria specified in UCITS 22.4 or similar directives, e.g., CAD III. In addition, other bonds with a structure affording an equivalent risk and credit profile, and considered by the market as covered bonds are included.[8] Unsecured bonds are classified into *senior* and *subordinated*, with the former having higher priority in a bank failure. Subordinated capital issued by financial institutions is further detailed into the respective tiers of subordination. In decreasing order of priority, subordinated bonds are classified as Lower Tier 2, Upper Tier 2, or Tier 1. The sample distribution of these classes of subordinated bonds is: Lower Tier 2 (70%), Upper Tier 2 (5%), and Tier 1 (24%).

We restrict the sample to banks that have same-day observations of covered, senior, and subordinated bonds. If there is more than one covered bond from the same bank included in the index at a given date, we collect the covered bond that has remaining time to maturity closest to four years. The same procedure goes for senior and subordinated bonds. We do not restrict the sample to bonds with remaining maturity of 3–5 years, as such a restriction would have reduced the sample substantially.

Bonds in the sample have a Markit iBoxx rating. This is the average *instrument* rating provided by Fitch Ratings, Moody's Investor Service, and Standard & Poor's. The rating is consolidated to the nearest rating grade, i.e., rating notches are not used. During the sample period, rating agencies typically rated subordinated debt one notch lower than the *issuer* rating. As of 30 June 2011, 73% of European financial institutions rated by Standard & Poor's had an issuer rating higher than BBB, indicating that the subordinated bond instrument rating was investment grade.

3.2. House prices

We use data on house prices from the Federal Reserve Bank of Dallas' international house price database at http://www.dallasfed.org/institute/houseprice/. The data set uses publicly available, national sources and includes quarterly data on nominal house prices. A brief overview of the sources and the methodology applied for selecting and homogenizing the data for comparability purposes can be found in Mack and Martinez-Garcia (2011). The data set does not contain data on house prices in Austria, Hungary, and Portugal.

3.3. Descriptive statistics

Table 1 summarizes the data on bond yields and shows that, gradually, more banks have same-day observations of covered, senior, and subordinated bonds. The increase has two explanations. First, over time more countries are included in the index, and second, over time more banks start issuing covered bonds. This feature of the data exposes the empirical results to a sample composition effect suggesting that for example country and year dummy variables can be picking up, respectively, time series and cross sectional variation in the data. For example, Spanish banks are represented in the sample over a longer time period than banks from other peripheral euro countries that can share several risk characteristics. To address this concern, we also form a sub-sample restricted to observations after 1 January 2007, concentrating the attention on the period where the majority of countries were included in the Markit index. Further, in the sub-sample, we exclude banks from countries with less than 500 observations, i.e., banks from Australia, Austria, Belgium, and Hungary. Table 2 shows the banks grouped by country, the number of observations in the sample and the sub-sample, and the distribution of the observations.

The bond yield spreads have varied substantially during the sample period, as shown in Fig. 2, indicating large shifts in risk. The period 1999–2007 was recognized by low and fairly stable bond yield spreads. During the financial crisis, both yield spreads and their volatility increased. After coming somewhat down, yield spreads once again increased during the euro sovereign debt crisis.

The figure also shows that yield spreads have a clear tendency to comove. Table 3 presents the correlation coefficients of the yield spreads in two sub-periods, 1 January 1999–31 December 2006, and 1 January 2007–31 January 2012. The correlations increased during the last and most volatile period, suggesting that relative factor loadings vary over time.

The Markit database includes both bid and ask prices on bonds from 1 January 2003, i.e., for 91% of the total observations in the sample. Fig. 3 shows the development of average bid-ask spreads by bond class. In the years 2003–2006 the bid-ask spread was substantially lower for covered bonds than for senior bonds, and for long periods even lower than the bid-ask spread for agency bonds. This relationship shifts after 2006, when the bid-ask spread increases for all bond classes. The covered bond bid-ask spread in this period is higher than for agency bonds and, at times, equally high as the senior bonds' bid-ask spread.

We use bond yields and house prices to calculate the risk indicators. The distribution of the market conditions indicator is (figures for the sub-sample in parenthesis): Negative market conditions 40% (45%), neutral market conditions 37% (31%), and positive market conditions 23% (24%). The percentage of observations categorized as an idiosyncratic, or issuer-specific, crisis-state is 8% for the sample and 9% for the sub-sample.

3.4. Empirical strategy

3.4.1. Estimation of credit risk

From Eq. (3) we formulate the *benchmark credit risk model* (Benchmark, credit risk model A) to estimate the relative factor loading for credit risk[9]:

[7] For all observations we calculate asset swap spreads using the information available in the database. See Appendix C for more on this calculation.

[8] The following bond types are included in the Markit iBoxx EUR Covered indexes: Austrian Pfandbriefe, Canadian, Hungarian, Italian, Portuguese, Scandinavian, Netherlands, Switzerland, UK, US, and New Zealand covered bonds, French Obligations Foncières, Obligations à l'Habitat, CRH and General Law Based Covered Bonds, German Pfandbriefe, Irish Asset Covered Securities, Luxembourg Lettres de Gage, Spanish Cedulas Hipotecarias, and Cedulas Territoreales.

[9] We use the risk factors $(y_{agency} - y_{gov})$ and $(y_{sub} - y_{agency})$ as regressors. An interesting extension, suggested by one of the referees, is to include also more fundamental factors such as equity market risk, credit market risk, and liquidity risk. Other macro factors could also be included.

Table 1
Descriptive statistics.

Year	Number of banking groups	Number of observations	$(y_{cov} - y_{agency})$		$(y_{sen} - y_{agency})$		$(y_{sub} - y_{agency})$		$(y_{agency} - y_{gov})$	
			Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.
1999	3	633	0.7	4.3	17.6	5.8	57.6	6.2	17.8	2.7
2000	4	955	14.2	10.5	28.1	5.4	69.0	11.3	22.3	6.7
2001	4	1044	14.6	10.8	28.7	9.1	72.2	17.2	18.7	4.0
2002	4	696	19.4	12.9	35.0	13.8	86.8	34.2	11.0	1.8
2003	4	720	18.0	10.1	36.6	22.3	103.8	63.9	7.5	1.1
2004	4	1032	7.6	5.1	19.8	5.3	48.3	18.3	7.7	1.1
2005	6	944	8.8	3.4	19.6	6.3	45.8	22.9	2.7	1.2
2006	10	2189	11.7	3.9	20.1	4.8	42.8	21.5	5.1	1.5
2007	13	2676	17.0	9.7	30.9	22.7	70.3	55.2	12.7	7.4
2008	22	4469	54.6	49.8	122.8	90.6	362.8	317.7	50.3	23.6
2009	34	5497	79.1	94.2	146.8	113.8	765.7	523.4	53.5	22.0
2010	37	7374	102.0	86.5	158.5	115.1	457.8	265.6	38.0	9.8
2011	33	7905	110.6	88.8	193.7	120.7	567.2	346.1	53.3	17.8
2012	32	704	164.2	114.6	268.7	115.0	820.5	380.6	71.7	6.7
Total	46	36,838	69.6	82.6	123.0	116.7	406.0	399.8	37.8	24.2

The table shows means and standard deviations of four yields spreads by year. The yields are averages of the daily observations in the data. The period covered is 1 January 1999 to 31 January 2012, i.e., 2012 only includes the month of January. Yield spreads are measured in basis points. The column “Number of observations” shows the total number of same-day observations for covered, senior, and subordinated bonds in a given year.

$$(y_{cov_{i,t}} - y_{agency_t}) = \varphi + \frac{\beta_{cov}}{\beta_{sen}}(y_{sen_{i,t}} - y_{agency_t}) + \gamma_1(y_{agency_t} - y_{gov_t}) + \varepsilon_{1it}, \tag{5}$$

where φ is a constant, $\gamma_1 = \alpha_{cov} - \frac{\beta_{cov}}{\beta_{sen}}\alpha_{sen}$, and ε_1 is the error term. The yield spreads on covered, senior, and subordinated bonds are from the same bank, denoted by subscript i. Government and agency bond yield spreads vary over time, but not across banks.

To account for any country and year effects, we extend the regression model in Eq. (5) by including dummy variables for country and year and interaction terms by running the regression (Benchmark II, credit risk model B)

$$\begin{aligned}(y_{cov_{i,t}} - y_{agency_t}) = {} & \alpha + \frac{\beta_{cov}}{\beta_{sen}}(y_{sen_{i,t}} - y_{agency_t}) + \gamma_1(y_{agency_t} - y_{gov_t}) \\ & + \sum_{j=1}^{n}\delta_{2j-1}D_j(y_{sen_{i,t}} - y_{agency_t}) \\ & + \sum_{j=1}^{n}\delta_{2j}D_j(y_{agency_t} - y_{gov_t}) \\ & + \sum_{j=1}^{n}\delta_{2n+j}D_j + \varepsilon_{1it}.\end{aligned} \tag{6}$$

where the Ds are dummy variables.[10]

We make two extensions of the regression model in Eq. (6). The first extension involves the three risk indicators discussed in Section 2.6 (market conditions, idiosyncratic crisis, and collateral value). We interact each of these three indicators with the spreads $(y_{sen_{i,t}} - y_{agency_t})$ and $(y_{agency_t} - y_{gov_t})$ (Indicators, credit risk model C). In the second extension we exploit the rating difference between a given bank's covered bonds and senior bonds (see Section 4.1 for details). We interact the rating difference with the spreads $(y_{sen_{i,t}} - y_{agency_t})$ and $(y_{agency_t} - y_{gov_t})$ (Indicators, credit risk model D).

3.4.2. Estimation of liquidity risk

From Eq. (4) we formulate the *benchmark liquidity risk model* (Benchmark, liquidity risk model A) to estimate the relative factor loading for liquidity risk:

$$\begin{aligned}(y_{cov_{i,t}} - y_{agency_t}) = {} & \varphi + \frac{\alpha_{cov}}{\alpha_{sen}}(y_{sen_{i,t}} - y_{agency_t}) + \gamma_2(y_{sub_{i,t}} - y_{agency_t}) \\ & + \gamma_3(y_{agency_t} - y_{gov_t}) + \varepsilon_{2it},\end{aligned} \tag{7}$$

where $\gamma_2 = \beta_{cov} - \frac{\alpha_{cov}}{\alpha_{sen}}\beta_{sen}$, $\gamma_3 = \frac{\alpha_{cov}}{\alpha_{sen}}\beta_{sen}\alpha_{sub} - \beta_{cov}\alpha_{sub}$, and ε_2 is the error term.

Also for the liquidity risk model we use dummy variables to account for any country and year effects and extend the liquidity risk model in Eq. (7) as follows (Benchmark II, liquidity risk model B):

$$\begin{aligned}(y_{cov_{i,t}} - y_{agency_t}) \\ = {} & \varphi + \frac{\alpha_{cov}}{\alpha_{sen}}(y_{sen_{i,t}} - y_{agency_t}) + \gamma_2(y_{sub_{i,t}} - y_{agency_t}) \\ & + \gamma_3(y_{agency_t} - y_{gov_t}) + \sum_{j=1}^{n}\delta_{3j-2}D_j(y_{sen_{i,t}} - y_{agency_t}) \\ & + \sum_{j=1}^{n}\delta_{3j-1}D_j(y_{sub_{i,t}} - y_{agency_t}) + \sum_{j=1}^{n}\delta_{3j}D_j(y_{agency_t} - y_{gov_t}) \\ & + \sum_{j=1}^{n}\delta_{3n+j}D_j + \varepsilon_{1it}.\end{aligned} \tag{8}$$

We further extend the regression model in Eq. (8) by interacting the aforementioned bid-ask spreads with the three yield spreads $(y_{sen_{i,t}} - y_{agency_t})$,$(y_{sub_{i,t}} - y_{agency_t})$, and $(y_{agency_t} - y_{gov_t})$ (Bid-aks spread, liquidity risk model C).

3.4.3. Panel data regressions

We use a panel regression model, for a cross section of 46 banks. Note that the benchmark risk models (5) and (7) do not include a bank specific constant term. Therefore, the panel structure will be absorbed into the residual. The panel is unbalanced, and the data exhibit autocorrelation and heteroskedasticity as well as cross-sectional dependencies. The error across bonds from different banks are correlated due to common shocks in a given time period (contemporaneous correlation) and the error variance differs across banks due to characteristics unique to the bank (panel heteroskedasticity). Ignoring the correlation of regression disturbances over time and between banks can lead to biased statistical inference. We address AR(1)-type autocorrelation via a two-step Prais–Winsten FGLS procedure, where the autocorrelation coefficients are panel specific. We calculate panel-corrected standard error estimates where the disturbances are assumed to be heteroskedastic and contemporaneously correlated across banks.

[10] Note that n is the sum of the number of different countries and the number of different years, subtracted two (the base country and base year).

Table 2
Overview of banks in the sample and the sub-sample. The table shows the banks in the sample and the sub-sample. The sample consists of banks with same-day observations of covered, senior, and subordinated bonds. The observation numbers in the table refer to the number of such same-day observations. The bars show how the observations are distributed over time. 2012 includes only the month of January. The sub-sample is restricted to observations after 1 January 2007. Further, the sub-sample excludes banks from countries with less than 500 observations, i.e., banks from Australia, Austria, Belgium, and Hungary.

Banking group	Sample	Sub-sample	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
ANZ	22	0														
Australia	*22*	*0*														
Raiffeisen Bank	22	0														
Austria	*22*	*0*														
Dexia	359	0														
Belgium	*359*	*0*														
Danske Bank	961	961														
Denmark	*961*	*961*														
BNP	961	961														
BPCE	407	407														
Caisse d'Epargne	1,702	825														
Credit Agricole	749	749														
Credit Mutuel	1,151	1,151														
Societe Generale	919	919														
France	*5,889*	*5,012*														
BayernLB	935	935														
Commerzbank	2,454	1,298														
Deutsche Bank	1,470	666														
Deutsche Postbank	253	253														
HSH Nordbank	230	230														
HVB	2,651	660														
Germany	*7,993*	*4,042*														
OTP Bank	282	0														
Hungary	*282*	*0*														
Allied Irish Banks	255	255														
Bank of Ireland	255	255														
Ireland	*510*	*510*														
Banca Intesa	432	432														
Banca Monte dei Paschi di Siena	388	388														
Banco Popolare	301	301														
UniCredit	643	643														
Italy	*1,764*	*1,764*														
ABN Amro	2,445	872														
ING	790	790														
SNS Bank	301	301														
Netherlands	*3,536*	*1,963*														
Banco Comercial Portugues	300	300														
Banco Espirito Santo	451	451														
Portugal	*751*	*751*														
BBVA	1,470	1,298														
Bancaja	231	231														
Banco Sabadell	279	279														
Banesto	215	215														
Caja Madrid	617	617														
Santander	1,511	1,298														
Spain	*4,323*	*3,938*														
Handelsbanken	853	853														
Nordea	688	688														
SEB	688	688														
Sweden	*2,229*	*2,229*														
Credit Suisse	279	279														
UBS	578	578														
Switzerland	*857*	*857*														
Bank of Scotland	2,175	1298														
Barclays	578	578														
HSBC	1,317	1,298														
Lloyds	473	473														
Nationwide	1,172	917														
Royal Bank of Scotland	410	410														
United Kingdom	*6,125*	*4,974*														
Bank of America	1,215	1,215														
United States	*1,215*	*1,215*														
Number of observations	36,838	28,216	633	955	1,044	696	720	1,032	944	2,189	2,676	4,469	5,497	7,374	7,905	704
Number of banking groups	46	42	3	4	4	4	4	4	6	10	13	22	34	37	33	32

4. Results

4.1. How collateral reduces credit risk in defaultable bonds

How does a change in the underlying credit risk factor influence yields on secured bonds compared to unsecured ones of the same issuer? And, does this relationship exhibit variation under different economic conditions? As a starting point, we run the benchmark credit risk model (5) on the total sample. The results are shown in column A of Table 4. The "global" credit risk in covered bonds, relative to the credit risk in senior bonds, is estimated to 0.28. The interpretation of the estimated coefficient is that, on average,

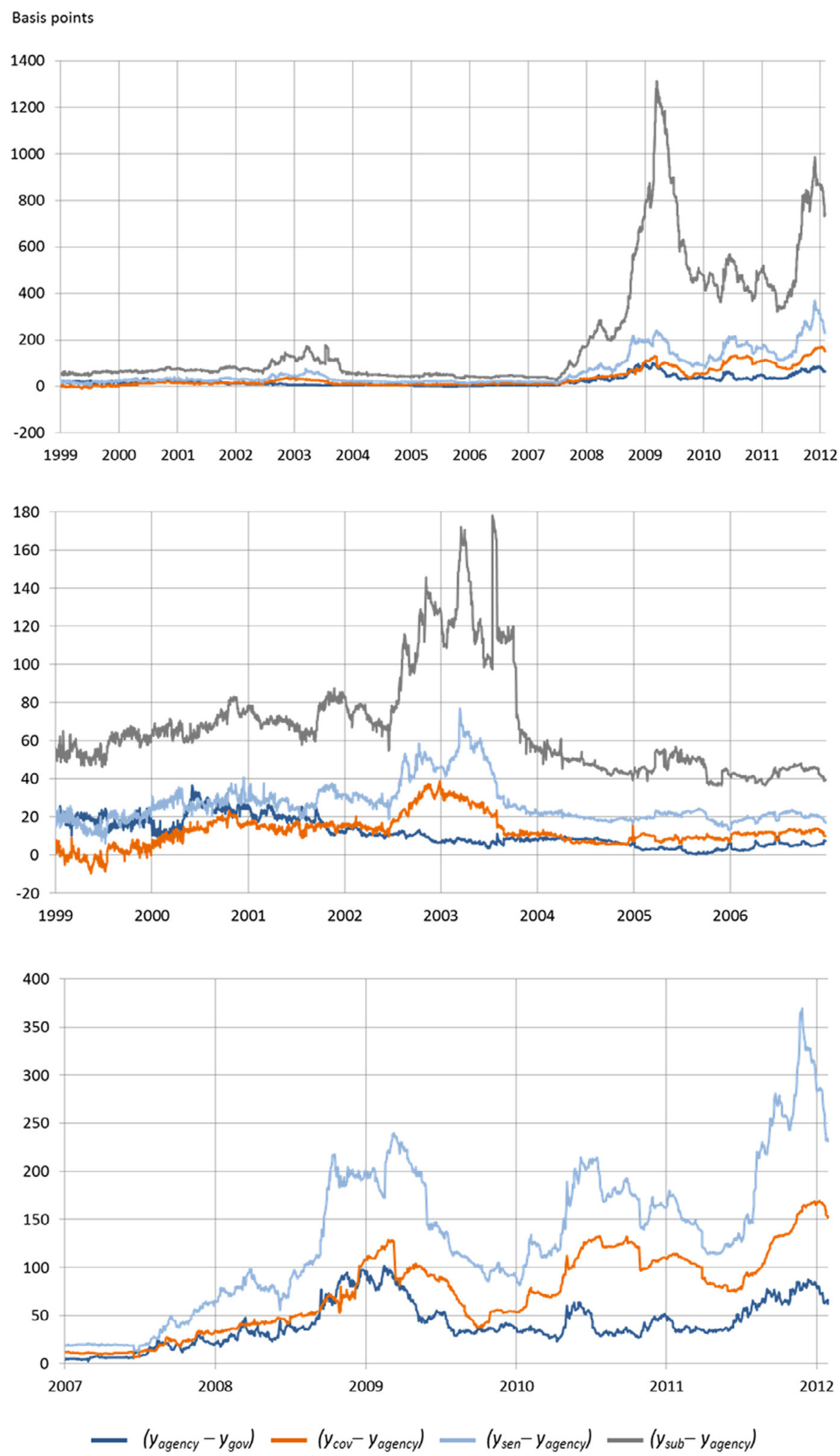

Fig. 2. Bond yield spreads. The figure shows the time series of four bond yields compared to the yield on bonds issued KfW (y_{agency}). The bond yields are: German government bonds (y_{gov}), covered bonds (y_{cov}), senior bonds (y_{sen}), and subordinated bonds (y_{sub}). The bond yields are averages of the daily observations in the sample. The top panel covers the full sample period of 1 January 1999–31 January 2012, and shows the increase in yields spreads from 2007. To better show the development in the first, relatively calm period, the middle panel covers the period 1 January 1999–31 December 2006. The bottom panel covers the period 1 January 2007–31 January 2012 and excludes the subordinated bond yield spread to better show the development of the remaining yield spreads.

based on all banks over the full sample period, credit risk has an influence on covered bond yields that is 28% of the influence on senior bond yields (see the interpretation of $\frac{\beta_{cov}}{\beta_{sen}}$ in Section 2.4). Alternatively, the influence of credit risk is 72% lower, a significant difference in risk. However, it also means that there is credit risk in covered bonds.

Table 3
Correlation coefficients.

	$(y_{cov} - y_{agency})$	$(y_{sen} - y_{agency})$	$(y_{sub} - y_{agency})$	$(y_{agency} - y_{gov})$
1 January 1999 to 31 December 2006				
$(y_{cov} - y_{agency})$	1.00			
$(y_{sen} - y_{agency})$	0.31	1.00		
$(y_{sub} - y_{agency})$	0.07	0.73	1.00	
$(y_{agency} - y_{gov})$	0.05	0.14	0.21	1.00
1 January 2007 to 31 January 2012				
$(y_{cov} - y_{agency})$	1.00			
$(y_{sen} - y_{agency})$	0.78	1.00		
$(y_{sub} - y_{agency})$	0.31	0.46	1.00	
$(y_{agency} - y_{gov})$	0.28	0.49	0.52	1.00

The table shows correlation coefficients for four yield spreads in the data set. The top panel is correlation coefficients for daily observations in the period 1 January 1999 to 31 December 2006 with 8213 observations. The bottom panel covers the period 1 January 2007 to 31 January 2012 with 28,625 observations.

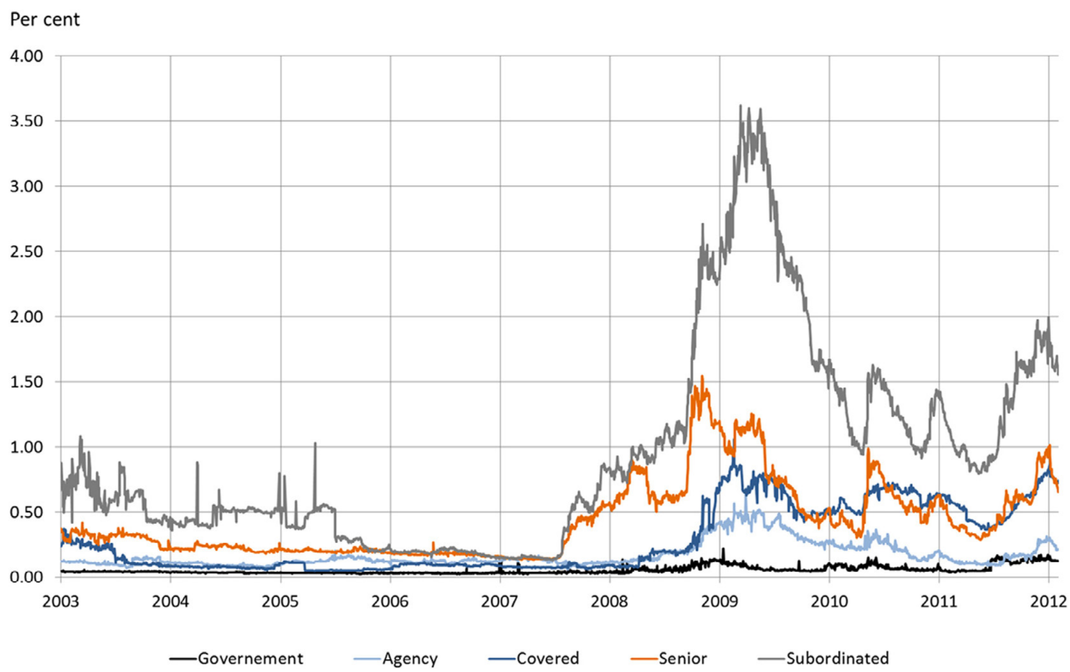

Fig. 3. Bond bid-ask spreads. The figure shows the time series of bid-ask spreads for five bond classes: German government bonds, KfW German agency bonds, covered bonds, senior bonds, and subordinated bonds. The bid-ask spread of a bond class is the average of the bid-ask spreads on individual bonds in the sample. The bid-ask spreads are spanning the time period 1 January 2003 to 31 January 2012.

Economic and institutional features can influence the relative factor loading for credit risk. We expand the benchmark credit risk model by interacting the right-hand side variables with country and year dummy variables and we also include the dummy variables in isolation. The country variable can pick up local differences in the covered bond legislation (like overcollateralization and regulatory supervision) or differences in bank financing patterns including the use of covered bonds. The year variable can reflect the general macroeconomic or financial conditions, the development of international bank regulations (like bail-in of senior bonds), or the increase in bank capital requirements. The list of influencing features is not exhaustive.

Fig. 4 presents the relative credit risk in covered bonds by country, and shows considerable variation. The banks with the highest covered bond credit risk are found in Portugal (0.77), Ireland (0.51), Italy (0.44), United Kingdom (0.31), and United States (0.29).[11] Higher relative credit risk means lower risk protection from collateral. The estimated differences in relative credit risk to German covered bonds (0.15) are economically and statistically significant. These countries were at the heart of either the subprime crisis (US) or the euro sovereign debt crisis. There is a substantial higher relative credit risk in covered bond from peripheral euro countries compared to core-euro countries like Germany, Netherlands, Belgium, Austria, and France. The outlier in this respect is Spanish covered bonds with a relative credit risk in line with many of the core-euro countries. Besides potential differences in the covered bond framework, this result indicates that collateral has not reduced risk well during crises.

By studying the variation in relative factor loading over time, we find evidence that collateral indeed has reduced risk during stressed periods. Fig. 5 shows the estimated relative credit risk in covered bonds by year. The most striking results are the low values 2006–2009. The last three of these years cover the subprime crisis, sparked by the meltdown in the US mortgage markets. The estimates show that covered bonds reacted much less than senior bonds to the increase in the credit risk level. The years 2006–2008 even have negative estimated values.

[11] In this context we disregard Australian and Hungarian banks that have a limited number of observations.

Table 4
Relative credit risk using the full sample.

	Obs.	A Benchmark	B Benchmark II	C Indicators	D Rating
Relative credit risk		0.28***	0.15***	0.17***	0.37***
		(0.007)	(0.026)	(0.028)	(0.071)
γ_1		0.32***	−0.53***	−0.60***	−0.58***
		(0.018)	(0.040)	(0.045)	(0.177)
Interaction effects with $(y_{sen_i} - y_{agency})$					
Neutral sentiment (base)	13,621			–	
Negative sentiment	14,899			−0.03***	
				(0.004)	
Positive sentiment	8318			0.02***	
				(0.005)	
Interaction effects with $(y_{sen_i} - y_{agency})$					
No crisis (base)	34,007			–	
Idiosyncratic crisis	2831			−0.12***	
				(0.006)	
Interaction effects with $(y_{sen_i} - y_{agency})$					
House prices	35,783			−1.57***	
				(0.185)	
Interaction effects with $(y_{sen_i} - y_{agency})$					
Identical rating (base)	2412				–
One rating grade difference	22,494				−0.22***
					(0.066)
Two rating grades difference	11,932				−0.32***
					(0.064)
Interaction effects between country and $(y_{sen_i} - y_{agency})$					
Germany (base)	7993		–	–	–
Australia	22		0.11	−0.08	0.04
			(0.086)	(0.106)	(0.087)
Austria	22		−0.21***	(empty)	−0.17***
			(0.030)		(0.030)
Belgium	359		0.11	0.06	0.04
			(0.069)	(0.074)	(0.069)
Denmark	961		−0.02**	−0.12***	0.02
			(0.011)	(0.013)	(0.010)
France	5889		0.09***	0.05***	0.05***
			(0.006)	(0.006)	(0.0060)
Hungary	282		0.25**	(empty)	0.07
			(0.117)		(0.120)
Ireland	510		0.36***	0.23***	0.36***
			(0.035)	(0.026)	(0.030)
Italy	1764		0.29***	0.33***	0.31***
			(0.014)	(0.012)	(0.013)
Netherlands	3536		0.04***	−0.00	−0.00
			(0.008)	(0.008)	(0.011)
Portugal	751		0.62***	(empty)	0.53***
			(0.023)		(0.020)
Spain	4323		0.10***	0.18***	0.12***
			(0.009)	(0.009)	(0.009)
Sweden	2229		0.03**	−0.10***	−0.01
			(0.012)	(0.009)	(0.011)
Switzerland	857		−0.09***	−0.15***	−0.10***
			(0.016)	(0.011)	(0.014)
United Kingdom	6125		0.16***	0.17***	0.11***
			(0.007)	(0.007)	(0.007)
United States	1215		0.14***	0.18***	0.19***
			(0.017)	(0.016)	(0.017)
Interaction effects between yearand $(y_{sen_i} - y_{agency})$					
1999 (base)	633		–	–	–
2000	955		−0.06	−0.05	−0.09**
			(0.034)	(0.036)	(0.036)
2001	1044		−0.08***	−0.09***	−0.09***
			(0.031)	(0.033)	(0.033)
2002	696		0.10**	0.11***	0.10**
			(0.042)	(0.043)	(0.044)
2003	720		0.04	0.10**	0.12***
			(0.039)	(0.041)	(0.040)
2004	1032		0.28***	0.28***	0.21***
			(0.069)	(0.070)	(0.068)
2005	944		0.12	0.24**	0.08
			(0.091)	(0.100)	(0.955)

Table 4 (*continued*)

	Obs.	A Benchmark	B Benchmark II	C Indicators	D Rating
2006	2189		−0.18*	−0.19*	−0.18*
			(0.091)	(0.105)	(0.098)
2007	2676		−0.16***	−0.05	−0.10***
			(0.036)	(0.035)	(0.038)
2008	4469		−0.23***	−0.18***	−0.17***
			(0.028)	(0.029)	(0.029)
2009	5497		−0.14***	−0.18***	−0.07**
			(0.028)	(0.029)	(0.029)
2010	7374		−0.12***	0.17**	−0.02
			(0.029)	(0.031)	(0.034)
2011	7905		−0.02***	0.07**	−0.04
			(0.036)	(0.029)	(0.030)
2012	704		−0.01	0.09***	0.05
			(0.034)	(0.033)	(0.035)
Country dummies		No	Yes	Yes	Yes
Year dummies		No	Yes	Yes	Yes
Sentiment dummies		No	No	Yes	No
Idiosyncratic crisis dummy		No	No	Yes	No
House prices interaction		No	No	Yes	No
Rating dummies		No	No	No	Yes
Obs.		36,838	36,838	35,783	36,838
R^2		0.45	0.78	0.89	0.77

This table presents the results from the regressions of the unrestricted benchmark credit risk model (column A) and three extensions of the model (columns B–D) using the total sample. In the three latter regressions we include dummy variables (D) for country and for year. The dummy variables are interacted with both right-hand side variables:

$$(y_{cov_{i,t}} - y_{agency_t}) = \alpha + \frac{\beta_{cov}}{\beta_{sen}}(y_{sen_{i,t}} - y_{agency_t}) + \gamma_1(y_{agency_t} - y_{gov_t}) + \sum_{j=1}^{n}\delta_{2j-1}D_j(y_{sen_{i,t}} - y_{agency_t}) + \sum_{j=1}^{n}\delta_{2j}D_j(y_{agency_t} - y_{gov_t}) + \sum_{j=1}^{n}\delta_{2n+j}D_j + \varepsilon_{1it}.$$

For each country and for each year we report the estimated coefficient for the interaction term between the dummy variable and the spread $(y_{sen} - y_{agency})$. The base values for the country and year dummy variables are Germany and 1999. Column C also contains estimated coefficients for the interaction term between three risk indicators and the spread $(y_{sen_i} - y_{agency})$. Column D also contains estimated coefficients for the interaction term between rating differences and the spread $(y_{sen_i} - y_{agency})$. Note that the estimated coefficients for the intercept, the dummy variables, and the interaction effects between the dummy variables and the spread $(y_{agency} - y_{gov})$ are not reported, but can be obtained from the authors upon request. The number of daily observations is reported as well as how the observations are distributed between the categories when variables are added. The statistics are based on a Prais–Winsten regression assuming first-order autocorrelation in disturbance terms. The numbers in parentheses are panel-corrected standard errors that are heteroskedasticity and autocorrelation robust between panels. Significance at the 10%, 5%, and 1% level is indicated by *, **, and ***, respectively.

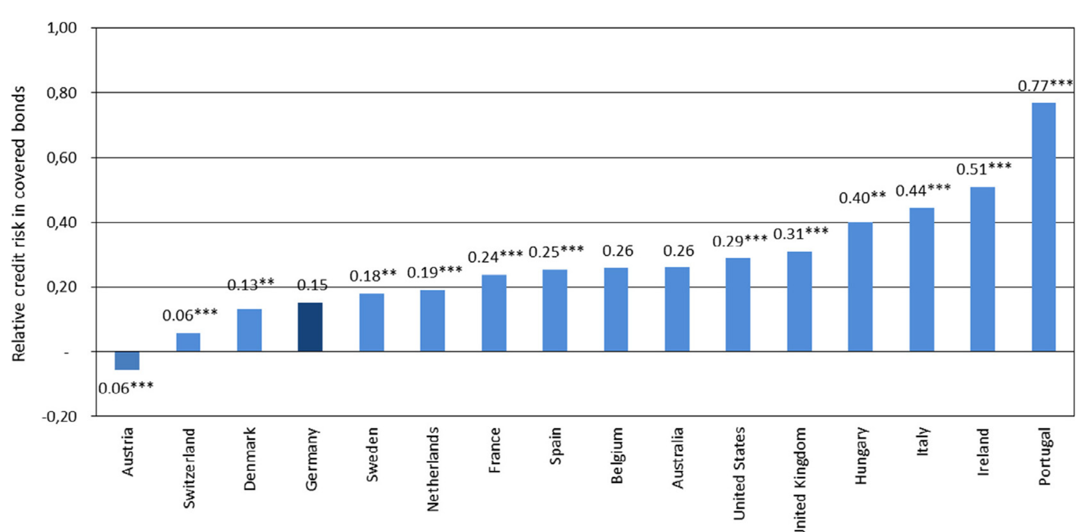

Fig. 4. Credit risk in covered bonds by country. The figure shows the estimated relative credit risk in covered bonds. The banks are grouped according to their country. We control for time series variation. Germany is used as base country and the estimate of relative credit risk in covered bonds at 0.15 is significant at the 1%-level. For the other countries, significance at the 10%, 5%, and 1% level is indicated by *, **, and ***, respectively. The significance level refers to the difference to the German level. For example, relative credit risk in covered bonds issued by French banks is estimated to be 0.09 percentage point higher than the German level (significant at the 1% level). Adding this interaction effect to the base value, we find a relative credit risk of covered bonds issued by French banks of 0.24. The statistics are based on a Prais–Winsten regression assuming first-order autocorrelation in disturbance terms. The estimation results are given in column B of Table 4.

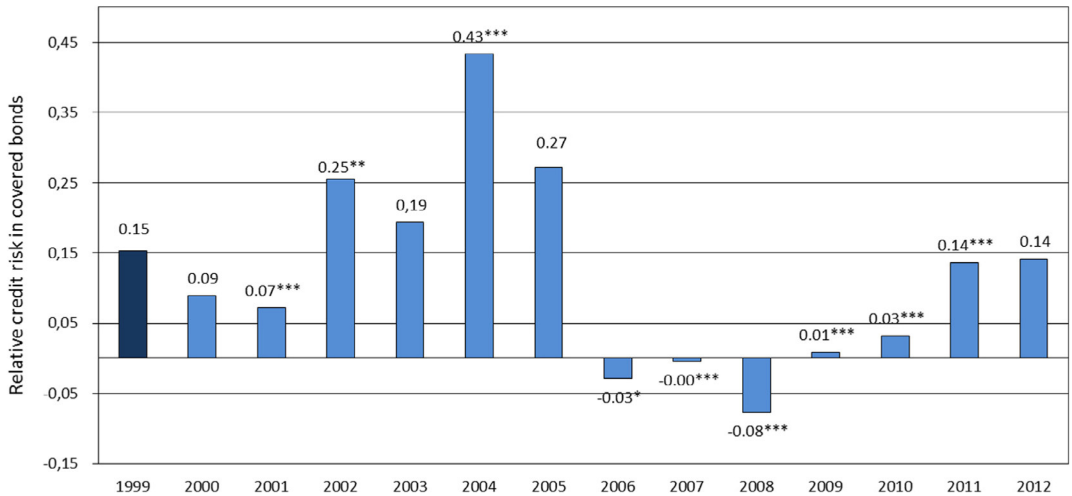

Fig. 5. Credit risk in covered bonds by year. The figure shows the estimated relative credit risk in covered bonds. We control for cross sectional variation. 1999 is used as base year and the estimate of 0.15 is significant at the 1%-level. For the remainder of the years, significance at the 10%, 5%, and 1% level is indicated by *, **, and ***, respectively. The bars are the sum of the base value and the estimated interaction effect with the respective years' dummy variable. The significance level refers to the difference to the 1999 level. The statistics are based on a Prais–Winsten regression assuming first-order autocorrelation in disturbance terms. The estimation results are given in column B of Table 4.

To control for the possible sample composition bias described in the data section, we redo the regressions using the sub-sample. Results are reported in columns A and B of Table 5. Most of the results are in line with our findings made using the full sample.

We use the subsample to further refinene the year and country analysis. The estimation is done using the same approach as in Eq. (6), but we now interact an indicator for year and country with the two yield spreads. The results are shown in Fig. 6.[12] The relative credit risk in the US peaked in 2009, as the subprime crisis abated. Spanish, Portuguese, and Irish levels increased 2010–2012, as the euro sovereign debt crisis evolved. The increase in the latter period is not as pronounced for covered bonds issued by banks from the core-euro area. In this respect, Spain is less of an outlier as previously noted.

Summing up the results so far, the relative credit risk was, on average, lower during the subprime crisis and higher during the euro sovereign debt crisis. US covered bonds showed an increase in credit risk during the subprime crisis, and covered bonds issued by banks from countries worst hit by the euro sovereign debt crisis had a higher relative credit risk than core-euro countries. It looks like collateral offers protection in some adverse economic states, but, in others it does not.

To study the variation in the risk protection under different economic conditions, we run the benchmark credit risk model with interaction terms between the right-hand side variables and our three risk indicators (country and year dummy variables and interaction terms with the dummy variables are still included). Results are found in column C of Table 4 using the full sample and Table 5 using the sub-sample.

When the risk indicator signals negative market conditions, the credit risk in covered bonds is 0.03 percentage points lower than under neutral market conditions. The result indicates that covered bonds, on average, offer some extra protection during a negative market development. In a positive market we find an increase in relative credit risk.

When the issuer is in a state of crisis, recognized by considerable higher senior bond yield spread than other banks, we find a significant lower relative credit risk in the covered bonds. The relative credit risk of covered bonds during an issuer crisis is estimated to be 0.12 percentage points lower than of covered bonds during a no-crisis state. Thus, covered bonds offer a substantial, protection from idiosyncratic crises. The estimated effects are identical using the sub-sample.

Finally, the relative credit risk in covered bonds *increases* in periods with falling house prices. The interpretation of the estimated coefficient of -1.6 is that a reduction in house prices of 10% increases relative credit risk with 0.16.

To sum up the results, covered bonds offer a moderate protection against the general market conditions, and a strong protection against an idiosyncratic crisis. However, if these negative states are paired with falling house prices, a proxy for collateral value, the credit risk in secured bonds instead can increase compared to unsecured bonds.

The influence of the house prices is illustrated by the development of the housing markets in US, Spain, and Germany, as shown in Fig. 7. Leading up to the subprime crisis, US experienced falling house prices starting 2007. In contrast, European housing markets had not yet started to fall. In this period we find relative credit risk in covered bonds to be high in the US and low in Europe. Similar, the euro sovereign debt crisis was recognized by the distressed property markets that evolved in the GIIPS countries, and we find higher credit risk in European covered bonds, and highest in the peripheral countries. Taken together, these findings fit the estimated pattern of a negative covariation between the property prices and the credit risk in covered bonds. Generalized, collateral offers risk protection, as long as the risk is not coupled to falling collateral value.

To examine if the results are sensitive to the calibration of the indicators, we redo the regression using alternative indicator values. We calibrate the market conditions indicator using both $\pm 5\%$ and $\pm 20\%$ as cut-off levels (compared to the original $\pm 10\%$), and the idiosyncratic crisis indicator using both 25% and 100% as cut-off levels (compared to the original 50%). The estimated interaction effects show the same pattern regardless of calibration, thus, supporting the main findings.

Our measure of relative risk is based on the covariation of bond market yields, i.e., utilizing the information content in market prices. An alternative method is to compare proxies for the credit risk of secured bonds to similar proxies for unsecured bonds. As

[12] Detailed results are not reported in the paper, but can be obtained from the authors upon request.

Table 5
Relative credit risk using the sub-sample.

	Obs.	A Benchmark	B Benchmark II	C Indicators	D Rating
Relative credit risk		0.24***	0.02	0.13***	0.12***
		(0.007)	(0.028)	(0.024)	(0.034)
γ_1		0.18***	−0.01	0.08	0.31***
		(0.019)	(0.089)	(0.092)	(0.111)
Interaction effects with $(y_{sen_i} - y_{agency})$					
Neutral sentiment (base)	8824			–	
Negative sentiment	12,522			−0.03***	
				(0.004)	
Positive sentiment	6870			0.01***	
				(0.005)	
Interaction effects with $(y_{sen_i} - y_{agency})$					
No crisis (base)	25,572			–	
Idiosyncratic crisis	2644			−0.12***	
				(0.006)	
Interaction effects with $(y_{sen_i} - y_{agency})$					
House prices	27,465			−1.59***	
				(0.19)	
Interaction effects with $(y_{sen_i} - y_{agency})$					
Identical rating (base)	539				–
One rating grade difference	17,182				0.01
					(0.018)
Two rating grades difference	10,495				−0.12***
					(0.019)
Interaction effects between countryand $(y_{sen_i} - y_{agency})$					
Germany (base)	4042		–	–	–
Denmark	961		−0.05***	−0.12***	−0.04***
			(0.010)	(0.013)	(0.010)
France	5012		0.06***	0.04***	0.03***
			(0.006)	(0.007)	(0.006)
Ireland	510		0.26***	0.23***	0.29***
			(0.026)	(0.026)	(0.026)
Italy	1764		0.24***	0.33***	0.28***
			(0.011)	(0.012)	(0.012)
Netherlands	1963		0.01	−0.00	−0.02**
			(0.010)	(0.010)	(0.010)
Portugal	751		0.53***	(empty)	0.47***
			(0.015)		(0.015)
Spain	3938		0.10***	0.17***	0.12***
			(0.008)	(0.009)	(0.008)
Sweden	2229		−0.01	−0.10***	−0.04***
			(0.010)	(0.009)	(0.011)
Switzerland	857		−0.15***	−0.15***	−0.15***
			(0.011)	(0.011)	(0.011)
United Kingdom	4974		0.10***	0.17***	0.06***
			(0.006)	(0.008)	(0.007)
United States	1215		0.10***	0.17***	0.06***
			(0.016)	(0.016)	(0.017)
Interaction effects between yearand $(y_{sen_i} - y_{agency})$					
2007 (base)	2593		–	–	–
2008	4322		−0.06**	−0.15***	−0.07***
			(0.029)	(0.025)	(0.029)
2009	5446		−0.05	−0.14***	−0.05*
			(0.029)	(0.025)	(0.029)
2010	7290		0.095***	0.20***	0.09***
			(0.031)	(0.026)	(0.030)
2011	7905		0.16***	0.10***	0.13***
			(0.029)	(0.024)	(0.029)
2012	660		0.16***	0.12***	0.15***
			(0.035)	(0.029)	(0.035)
Country dummies		No	Yes	Yes	Yes
Year dummies		No	Yes	Yes	Yes
Sentiment dummies		No	No	Yes	No
Idiosyncratic crisis dummy		No	No	Yes	No
House prices interaction		No	No	Yes	No
Rating dummies		No	No	No	Yes

(*continued on next page*)

Table 5 (*continued*)

	Obs.	A Benchmark	B Benchmark II	C Indicators	D Rating
Obs.		28,216	28,216	27,465	28,216
R^2		0.57	0.86	0.88	0.86

This table presents the results from the regressions of the unrestricted benchmark credit risk model (column A) and three extensions of the model (columns B–D) using the sub-sample. In the three latter regressions we include dummy variables (D) for country and for year. The dummy variables are interacted with both right-hand side variables:

$$(y_{cov_{i,t}} - y_{agency_t}) = \alpha + \frac{\beta_{cov}}{\beta_{sen}}(y_{sen_{i,t}} - y_{agency_t}) + \gamma_1(y_{agency_t} - y_{gov_t}) + \sum_{j=1}^{n}\delta_{2j-1}D_j(y_{sen_{i,t}} - y_{agency_t}) + \sum_{j=1}^{n}\delta_{2j}D_j(y_{agency_t} - y_{gov_t}) + \sum_{j=1}^{n}\delta_{2n+j}D_j + \varepsilon_{1it}.$$

For each country and for each year we report the estimated coefficient for the interaction term between the dummy variable and the spread ($y_{sen} - y_{agency}$). The base values for the country and year dummy variables are Germany and 2007. Column C also contains estimated coefficients for the interaction term between three risk indicators and the spread ($y_{sen_i} - y_{agency}$). Column D also contains estimated coefficients for the interaction term between rating differences and the spread ($y_{sen_i} - y_{agency}$). Note that the estimated coefficients for the intercept, the dummy variables, and the interaction term between the dummy variables and the spread ($y_{agency} - y_{gov}$) are not reported, but can be obtained from the authors upon request. The number of daily observations is reported as well as how the observations are distributed between the categories when variables are added. The statistics are based on a Prais–Winsten regression assuming first-order autocorrelation in disturbance terms. The numbers in parentheses are panel-corrected standard errors that are heteroskedasticity and autocorrelation robust between panels. Significance at the 10%, 5%, and 1% level is indicated by *, **, and ***, respectively.

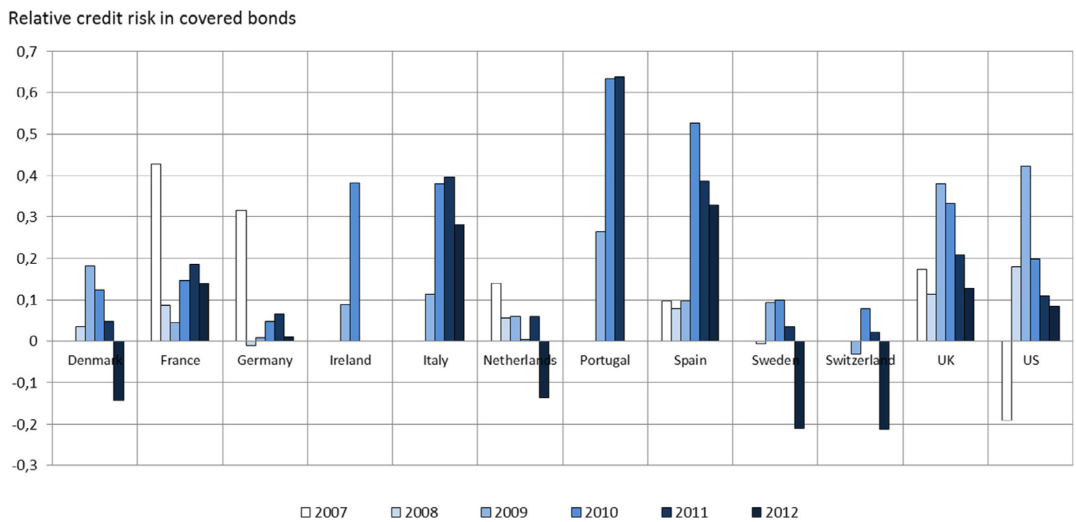

Fig. 6. Credit risk in covered bonds by country and year. The figure shows the estimated credit risk in covered bonds compared to senior bonds using the sub-sample.

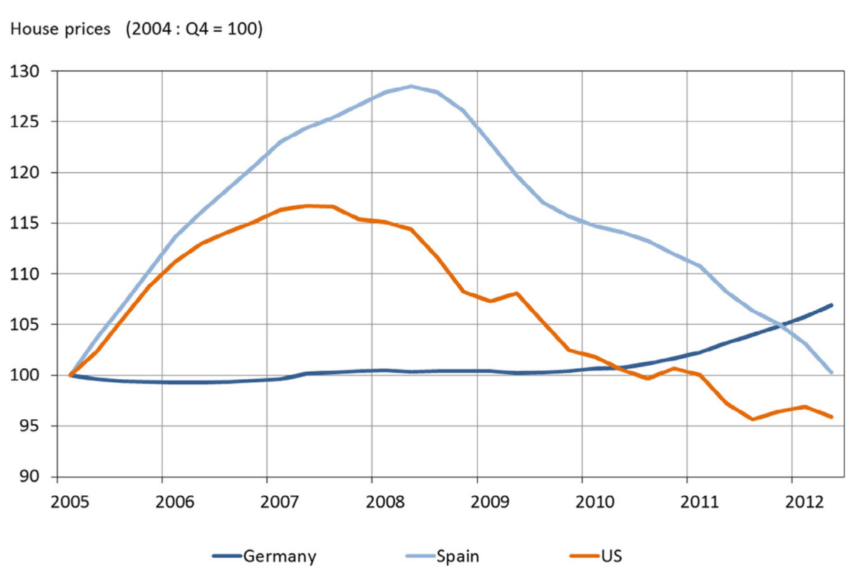

Fig. 7. Development in house prices. The figure shows the time series of house prices in the US, Germany, and Spain. The series are indexed at value 100 at end of fourth quarter 2004. Data is taken from Federal Reserve Bank of Dallas' international house price database.

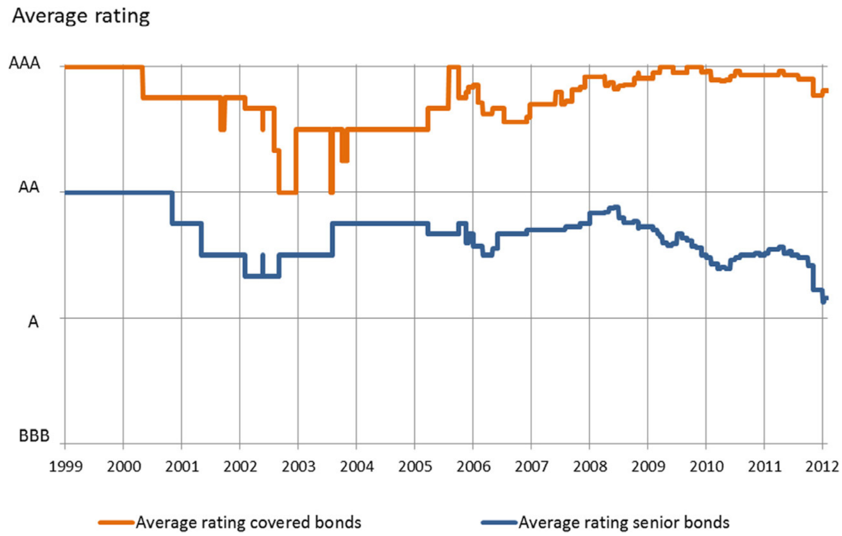

Fig. 8. Average credit ratings on covered bonds and senior bonds. The figure shows the time series of the average Markit iBoxx ratings of covered bonds and senior bonds in the sample. The Markit iBoxx rating is the average of the ratings from Fitch Ratings, Moody's Investor Service, and Standard Poor's. The average ratings are calculated for the time period 1 January 1999 to 31 January 2012.

a final exercise, we therefore compare the market's assessment of relative credit risk (the empirical factor loadings) to the credit rating agencies' assessment (the difference between the rating of a covered bond and a senior bond issued by the same bank). Does a larger rating difference for pairs of covered and senior bonds correspond to a lower empirical relative credit risk?

Fig. 8 shows the development of the average bond rating for, respectively, covered bonds and senior bonds in the sample. The observed rating difference for pairs of covered and senior bonds is either none, one, or two rating grades. At the start of the sample period, with fewer observations than later, the average difference is one rating class. In the period 2002–2006 this difference narrows, before it increases again. The increase is primarily due to the reduced ratings of senior bonds following the financial crisis, the sovereign debt crisis, and the intensified discussions on bail-in regulations.

We find that the credit ratings capture the empirical relative factor loadings for credit risk.[13] As reported in column D of Table 4, the relative credit risk in covered bonds is estimated to 0.37 when the rating of the same-issuer covered and senior bond is identical. When the rating difference is one rating grade the estimated value decreases to 0.15, and when there are two rating grades between the covered and the senior bond, the value is estimated to 0.05. Results of this regression run on the sub-sample are reported in column D of Table 5. The sub-sample has a limited number of observations with identical rating on covered and senior bonds. However, we find an economically and statistically significant lower relative credit risk when there are two rating grades between the bond classes.

Interestingly, the year and country variables matter in determining the empirical factor loadings, even after including credit ratings. Evidently, credit rating is not a sufficient measure for relative credit risk. This finding is line with John et al. (2003) that document that secured debt has higher yield than unsecured debt, after controlling for credit rating.

[13] A cautionary note, rating up- and downgrades are not always triggered by changes in credit quality. Changes in the rating agency's methodology can lead to technical changes in the bond rating. We have not addressed this issue. We also disregard the question of potential causality between yield spreads and ratings.

4.2. How collateral reduces liquidity risk in defaultable bonds

The estimated cross-sectional and time series variation in relative liquidity risk resemble the pattern found for relative credit risk.

Running the benchmark liquidity risk model (7) using the total sample, the liquidity risk in covered bonds is estimated to 0.25 of the liquidity risk in senior bonds. The results are shown in column A of Table 6. As for the analysis of credit risk, we expand the benchmark liquidity risk model by including dummy variables for country and year and also by interacting the right-hand side variables with the dummy variables. The results are presented in column B of Table 6. In addition, Table 7 shows the results using the sub-sample. We note that the interaction terms both between country and year and the senior spread (over agency) behave much in the same way as the interaction terms we found when analyzing credit risk.

Liquidity is a concept that is difficult to quantify, see Helwege et al. (2014) and Houweling et al. (2005). The bid-ask spread is a much used proxy, primarily in the stock market where data is widely available. To check the correspondence of relative liquidity risk as measured by the empirical factor loadings and the bid-ask spreads, we add interaction terms between the right-hand side variables and the bid-ask spread for the individual covered and senior bonds. Results are found in column C of Table 6. The estimated interaction effects show that higher covered bond bid-ask spreads are related to higher relative liquidity risk in covered bonds as measured by the benchmark liquidity risk model. Likewise, lower senior bond bid-ask spreads are associated with higher, estimated, relative liquidity risk. The interpretation of the estimated coefficients is that an increase in the difference between the covered bond's bid and ask *price* of 1 per cent increases, *ceteris paribus*, the relative liquidity risk in covered bonds with 0.03 percentage points. A decrease in the difference between the senior bond's bid and ask *price* of 1 per cent increases the relative liquidity risk in covered bonds with 0.03 percentage points. We get similar results using the sub-sample (see column C of Table 7). The year and country variables matter in determining the empirical factor loadings for liquidity risk, even after including bid-ask spread. Consequently, empirical factor loading for liquidity risk contains more information than bid-ask spreads. Liquidity risk influences asset prices in different ways. The liquidity risk premium

Table 6
Relative liquidity risk using the full sample.

	Obs.	A Benchmark	B Benchmark II	C Bid-ask spread
Relative liquidity risk		0.25***	0.13***	0.34***
		(0.007)	(0.026)	(0.039)
γ_1		0.03***	0.06**	−0.04***
		(0.001)	(0.025)	(0.015)
γ_2		0.22***	−0.50***	−1.12***
		(0.018)	(0.041)	(0.239)
Interaction effects with $(y_{sen_i} - y_{agency})$				
Covered bond bid-ask	33,509			0.03***
				(0.007)
Senior bond bid-ask	33,509			−0.03***
				(0.003)
Interaction effects between countryand $(y_{sen_i} - y_{agency})$				
Germany (base)	7993		–	–
Australia	22		0.21**	−0.01
			(0.090)	(0.122)
Austria	22		−0.26***	−0.28***
			(0.029)	(0.028)
Belgium	359		−0.03	0.04
			(0.071)	(0.075)
Denmark	961		−0.08***	−0.07***
			(0.011)	(0.01)
France	5889		0.07***	0.06***
			(0.007)	(0.007)
Hungary	282		−0.19**	−0.17***
			(0.081)	(0.066)
Ireland	510		0.34***	0.40***
			(0.038)	(0.028)
Italy	1764		0.26***	0.25***
			(0.015)	(0.015)
Netherlands	3536		−0.00	−0.09***
			(0.009)	(0.009)
Portugal	751		0.45***	0.37***
			(0.028)	(0.023)
Spain	4323		0.09***	0.2***
			(0.009)	(0.01)
Sweden	2229		−0.01	−0.06***
			(0.011)	(0.009)
Switzerland	857		−0.16***	−0.18***
			(0.019)	(0.015)
United Kingdom	6125		0.12***	0.11***
			(0.007)	(0.007)
United States	1215		0.01	−0.06***
			(0.019)	(0.018)
Interaction effects between yearand $(y_{sen_i} - y_{agency})$				
1999 (base)	633		–	–
2000	955		−0.05	(empty)
			(0.034)	
2001	1044		−0.07**	(empty)
			(0.031)	
2002	696		0.06	(empty)
			(0.047)	
2003	720		0.10**	–
			(0.045)	
2004	1032		0.23***	−0.04
			(0.072)	(0.087)
2005	944		0.14	−0.04
			(0.100)	(0.106)
2006	2189		−0.19*	−0.55***
			(0.102)	(0.121)
2007	2676		−0.18***	−0.35***
			(0.037)	(0.048)
2008	4469		−0.21***	−0.37***
			(0.027)	(0.040)
2009	5497		−0.13***	−0.34***
			(0.027)	(0.040)
2010	7374		−0.00	−0.14***
			(0.037)	(0.042)
2011	7905		0.05*	−0.15***
			(0.029)	(0.041)

Table 6 (*continued*)

	Obs.	A Benchmark	B Benchmark II	C Bid-ask spread
2012	704		0.06* (0.033)	−0.10** (0.044)
Country dummies		No	Yes	Yes
Year dummies		No	Yes	Yes
Bid-ask spread interaction		No	No	Yes
Obs.		36,838	36,838	33,509
R^2		0.51	0.90	0.96

This table presents the results from the regressions of the unrestricted benchmark liquidity risk model (column A) and two extensions of the model (columns B and C) using the total sample. In the two latter regressions we include dummy variables (D) for country and year. The dummy variables are interacted with the three right-hand side variables as given by the equation.

$$(y_{cov_{i,t}} - y_{agency_t}) = \varphi + \frac{\alpha_{cov}}{\alpha_{sen}}(y_{sen_{i,t}} - y_{agency_t}) + \gamma_2(y_{sub_{i,t}} - y_{agency_t}) + \gamma_3(y_{agency_t} - y_{gov_t}) + \sum_{j=1}^{n}\delta_{3j-2}D_j(y_{sen_{i,t}} - y_{agency_t}) + \sum_{j=1}^{n}\delta_{3j-1}D_j(y_{sub_{i,t}} - y_{agency_t}) + \sum_{j=1}^{n}\delta_{3j}D_j(y_{agency_t} - y_{gov_t}) + \sum_{j=1}^{n}\delta_{3n+j}D_j + \varepsilon_{1it}.$$

For each country and for each year we report the estimated coefficient for the interaction term between the dummy variable and the spread $(y_{sen_i} - y_{agency})$. The base values for the country and year dummy variables are Germany and 1999. In column C we also present estimated coefficients for the interaction term between bid-ask spreads and the spread $(y_{sen_i} - y_{agency})$. Note that the estimated coefficients for the intercept, the dummy variables, and the interaction terms between the dummy variables and the spreads $(y_{sub_i} - y_{agency})$ and $(y_{agency} - y_{gov})$ are not reported, but can be obtained from the authors upon request. The number of daily observations is reported as well as how the observations are distributed between the categories when dummy variables are employed. The statistics are based on a Prais–Winsten regression assuming first-order autocorrelation in disturbance terms. The numbers in parentheses are panel-corrected standard errors that are heteroskedasticity and autocorrelation robust between panels. Significance at the 10%, 5%, and 1% level is indicated by *, **, and ***, respectively.

Table 7
Relative liquidity risk using the sub-sample.

	Obs.	A Benchmark	B Benchmark II	C Bid-ask spread	D CBPP
Relative liquidity risk		0.22*** (0.006)	−0.05 (0.031)	−0.01 (0.031)	−0.05 (0.031)
γ_2		0.02*** (0.001)	0.08*** (0.013)	0.09*** (0.011)	0.09*** (0.013)
γ_3		0.13*** (0.018)	−0.1 (0.096)	−0.07 (0.092)	−0.09 (0.096)
Interaction effects with $(y_{sen_i} - y_{agency})$					
Covered bond bid-ask	28,216			0.02*** (0.005)	
Senior bond bid-ask	28,216			−0.03*** (0.002)	
Interaction effects with $(y_{sen_i} - y_{agency})$					
CBPP in-active (base)	18,592				–
CBPP active	9624				−0.02*** (0.005)
Interaction terms between countryand $(y_{sen_i} - y_{agency})$					
Germany (base)	4042		–	– –	
Denmark	961		−0.10*** (0.01)	−0.08*** (0.010)	−0.10*** (0.01)
France	5012		0.07*** (0.006)	0.05*** (0.006)	0.07*** (0.006)
Ireland	510		0.31*** (0.029)	0.38*** (0.024)	0.30*** (0.029)
Italy	1764		0.25*** (0.011)	0.24*** (0.012)	0.25*** (0.011)
Netherlands	1963		−0.00 (0.011)	−0.13*** (0.010)	−0.01 (0.011)
Portugal	751		0.43*** (0.02)	0.37*** (0.019)	0.41*** (0.02)
Spain	3938		0.10*** (0.008)	0.21*** (0.009)	0.10*** (0.008)
Sweden	2229		−0.04*** (0.01)	−0.06*** (0.009)	−0.04*** (0.01)
Switzerland	857		−0.18***	−0.21***	−0.18***

(*continued on next page*)

Table 7 (*continued*)

	Obs.	A Benchmark	B Benchmark II	C Bid-ask spread	D CBPP
			(0.012)	(0.012)	(0.011)
United Kingdom	4974		0.09***	0.09***	0.09***
			(0.006)	(0.006)	(0.006)
United States	1215		0.00	−0.07***	0.00
			(0.016)	(0.016)	(0.016)
Interaction terms between country and $(y_{sen_i} - y_{agency})$					
2007 (base)	2593		–		–
2008	4322		0.01	−0.00	0.01
			(0.031)	(0.032)	(0.031)
2009	5446		0.02	−0.01	0.03
			(0.032)	(0.032)	(0.032)
2010	7290		0.21***	0.24***	0.22***
			(0.033)	(0.032)	(0.033)
2011	7905		0.25***	0.23***	0.26***
			(0.032)	(0.032)	(0.032)
2012	660		0.25***	0.28***	0.28***
			(0.036)	(0.036)	(0.036)
Country dummies		No	Yes	Yes	Yes
Year dummies		No	Yes	Yes	Yes
Bid-ask spread interaction		No	No	Yes	No
CBPP dummy		No	No	No	Yes
Obs.		28,216	28,216	28,216	28,216
R^2		0.58	0.88	0.96	0.88

This table presents the results (using the sub-sample) from the regressions of the unrestricted benchmark liquidity risk model (column A) and three extensions of the model (columns B, C, and D). For the regression results reported in columns B and C, we include dummy variables for country and year. The dummy variables are interacted with the three right-hand side variables as given by the equation.

$$(y_{cov_{i,t}} - y_{agency_t}) = \varphi + \frac{\alpha_{cov}}{\alpha_{sen}}(y_{sen_{i,t}} - y_{agency_t}) + \gamma_2(y_{sub_{i,t}} - y_{agency_t}) + \gamma_3(y_{agency_t} - y_{gov_t}) + \sum_{j=1}^{n}\delta_{3j-2}D_j(y_{sen_{i,t}} - y_{agency_t}) + \sum_{j=1}^{n}\delta_{3j-1}D_j(y_{sub_{i,t}} - y_{agency_t}) + \sum_{j=1}^{n}\delta_{3j}D_j(y_{agency_t} - y_{gov_t}) + \sum_{j=1}^{n}\delta_{3n+j}D_j + \varepsilon_{1it}.$$

For each country and for each year we report the estimated coefficient for the interaction term between the dummy variable and the spread $(y_{sen_i} - y_{agency})$. The base values for the country and year dummy variables are Germany and 2007. In column C we also present estimated coefficients for the interaction term between bid-ask spreads and the spread $(y_{sen_i} - y_{agency})$. Column D also contains the estimated coefficient for the interaction term between and indicator function for the periods where the Eurosystem Covered Bond Purchase Programme (CBPP) is active and the spread $(y_{sen_i} - y_{agency})$. Note that the estimated coefficients for the intercept, the dummy variables, and the interaction terms between the dummy variables and the spreads $(y_{sub_i} - y_{agency})$ and $(y_{agency} - y_{gov})$ are not reported, but can be obtained from the authors upon request. The number of daily observations is reported as well as how the observations are distributed between the categories when dummy variables are employed. The statistics are based on a Prais–Winsten regression assuming first-order autocorrelation in disturbance terms. The numbers in parentheses are panel-corrected standard errors that are heteroskedasticity and autocorrelation robust between panels. Significance at the 10%, 5%, and 1% level is indicated by *, **, and ***, respectively.

includes a compensation for higher transactions costs, but can also include a premium for the risk that bonds will become less liquid in the future. Bid-ask spreads only capture the former effect.

The model can be used to evaluate recent events in the financial markets. Steps were taken to improve liquidity in the covered bond market during the euro sovereign debt crisis. The first Eurosystem Covered Bond Purchase Programme (CBPP1) was announced on 7 May 2009. Under CBPP1 the Eurosystem made outright purchases of covered bonds of 60 billion euro to the end of June 2010. The second programme (CBPP2) was launched 6 October 2011 and involved covered bond purchases of 40 billion euro until the end of October 2012.

Beirne et al. (2011) present empirical evidence that during the period of CBPP1, covered bond market liquidity improved, moving closer to pre-crisis levels. They focus on the outstanding amount of covered and senior bank bonds and show that CBPP1 did stimulate a revival of the covered bond market. However, this revival appears to have been driven by banks substituting the issuance of senior bonds with that of covered bonds, rather than reviving the bank bond market as a whole.

We expand the benchmark liquidity risk model with a dummy variable that is one in periods where the CBPP was in effect, and zero otherwise. We run the regression using the sub-sample, i.e., we study the period from two year and four months prior to the announcement of CBPP1 to the end of the sample at 31 January 2012 when CBPP2 was still in effect. During this period, CBPP was active for one third of the observations. We include interaction terms with the country and year dummy variables. The results are presented in column D of Table 7. We find the relative liquidity risk in covered bonds to be 0.02 percentage points lower in periods where the CBPP was in effect. A possible explanation for this small effect is that the CBPP had positive spillover effects to the senior bond market. This result modifies the finding of Beirne et al. (2011) that the senior bond market was negatively influenced based on the development of outstanding volume.

4.3. Robustness

We conduct robustness checks on two methodological aspects of the analysis: The selection of subordinated bonds and the selection of bond maturities.

First, the yield on subordinated bonds is required for the estimation of relative liquidity risk. As described in the data section, we use yields on subordinated bonds regardless of the bonds belonging to the sub-classes Lower Tier 2, Upper Tier 2, or Tier 1. The sub-classes rank differently in order of priority, and this feature can influence bond prices. We redo the regressions on relative liquidity risk using subordinated bonds of only the Lower Tier 2-category. The estimated relative liquidity risk in covered bonds, without controlling for year and country effects, are then found to be higher, 0.35 compared to the original 0.25. The other empirical findings are unchanged. Overall, the results are robust to the selection of subordinated bonds.

Second, the benchmark risk models are constructed for bond yields that are similar in time to maturity. As described in the data section, the empirical tests have attention on the part of the yield curve with most observations, and the process of collection observations is outlined. Using asset swap spreads the potential bias is narrowed down to the term structure of asset swap spreads. As a robustness test, we redo the regressions limiting both the remaining life of the covered, senior, and subordinated bonds included (2–6 years and 3–5 years) and the absolute difference in time to maturity (2 years and 1 year) on a given day. The results remain highly significant and, generally, of the same magnitude. The relative credit risk of covered bonds during an issuer-specific crisis was originally estimated to be 0.12 percentage points lower than during a no-crisis state. In the robustness tests the estimated value drops to the interval 0.02–0.07. Overall, we find the procedure of collecting observations to be robust to any significant influence of term structure.

5. Concluding remarks

Collateral reduces risk in case of default. In this paper we have shown, based on data from the covered bond market, that collateral reduces risk in defaultable bonds, i.e., bonds that have not defaulted. We found a considerable cross-sectional and time variation in the risk reduction from having collateral. We have presented a parsimonious model that distinguishes between credit risk and liquidity risk. Collateral protects against both types of risks. We have found the risk reduction to be particularly strong when there is an issuer-specific crisis. The value of collateral is risky, and we have shown that a fall in the collateral value clearly lowers the risk protection. With collateral, you protect your claim against risk, but you also take on the risk that your risk protection will change.

Appendix A. Covered bonds

Covered bonds are issued by financial institutions, and are an essential source of financing for many banks' mortgage lending and public sector lending.

Traditionally, bank borrowing in European countries was done by *unsecured* debt instruments with equal priority in bankruptcy. Deposits, senior bonds, and interbank borrowing are examples of unsecured borrowing that rank *pari passu*. Deposits can be covered by deposit insurance, but this guarantee is provided by a third party. Fig. 9 illustrates a traditional bank balance sheet with unsecured debt instruments. Bond market financing is usually done issuing senior bonds and different types of subordinated bonds, with the latter class having a lower priority in the case of default.

German and Danish banks were exceptions to this financing structure. These banks have a long history of long term, *secured* borrowing, in the form of covered bonds, known as "Pfandbriefe" in Germany and "Realkreditobligationer" in Denmark. Today, more than 30 European countries have introduced legislation to support covered bond issuance. Outside Europe, four countries (Australia, Canada, New Zealand, and South Korea) have active covered bond markets and numerous countries have enacted or are working on covered bond legislation (US, Japan, Mexico, Chile, Brazil, India, Morocco, and UAE).

Covered bonds offer the investor a dual recourse, both to a defined part of the bank's loan portfolio (the cover pool) as well as a claim on the bank. Established asset classes for this purpose include mortgages and other retail client loans, and public sector loans. However, other types of loans as well as financial instruments can be eligible as collateral depending on local legal frameworks. Fig. 10 illustrates a bank balance sheet including covered bonds. In this case, banks issue three types of bonds; covered, senior, and subordinated.

The method used to ring-fence the cover pool varies. In most jurisdictions, the legislation either excludes the cover pool from the insolvency estate of the bank, or provides covered bondholders with a preferred claim within the insolvency estate itself. In some jurisdictions a specialist bank principle applies, meaning the cover pool is transferred to a special purpose entity, which in turn issues covered bonds. A consequence of the specialist bank principle is that the covered bonds and senior/subordinated bonds of a bank group are issued by different legal entities.

During the recent years of market turmoil, covered bonds have played a crucial role in providing wholesale debt financing to banks. Covered bonds are also favored by regulators, with a special

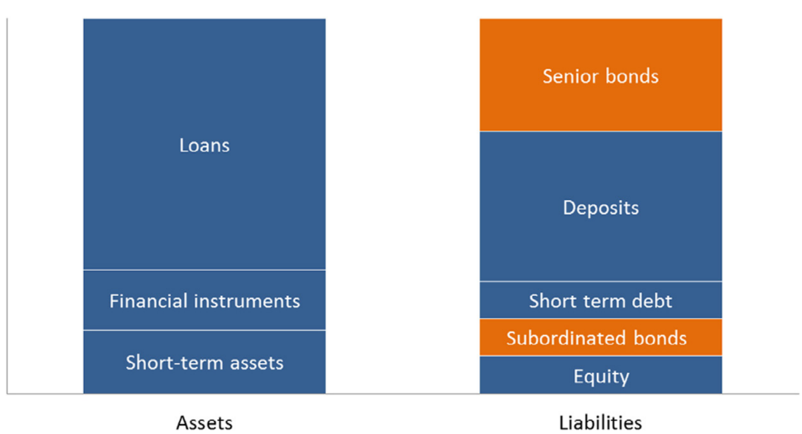

Fig. 9. The balance sheet of a bank. The figure shows a high-level balance sheet for a traditional bank on a consolidated basis. This bank do not issue covered bonds. Consequently, there are no bondholders with a claim on specific assets. In the case of insolvency the bondholders receive payments from the insolvency assets according to their rank in order of priority.

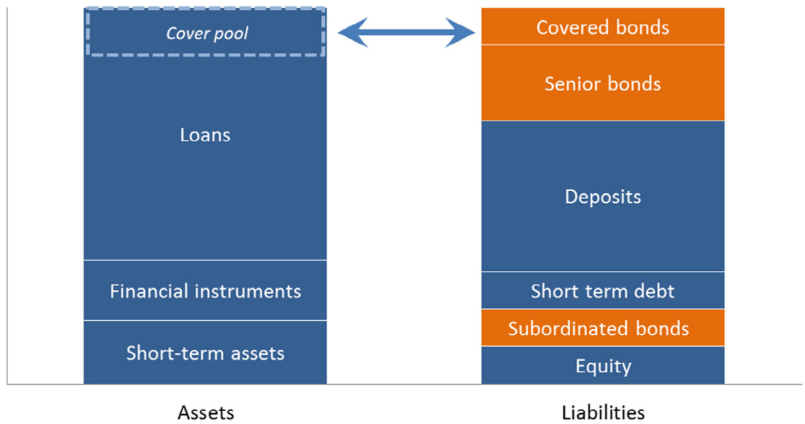

Fig. 10. The balance sheet of a bank issuing covered bonds. Secured bond financing requires the bank to ring-fence assets as collateral for the covered bond investors. If the issuer defaults on its outstanding covered bonds, the bond investors may take possession and if necessary sell the loans in the cover pool to cover their claims before other, unsecured lenders are repaid.

role in regulatory matters, like capital adequacy regulations, liquidity regulations, and central bank financing operations. The issuance of covered bonds has increased substantially, while the issuance of senior bonds by banks has fallen. With over 2.7 trillion euro outstanding at the end of 2011, covered bonds play an important role in the European capital markets. The value of European mortgage covered bonds outstanding is around a third of the EU's residential mortgage market. However, the relevance of covered bonds for the residential mortgage market differs from country to country.

Strict legal and supervisory frameworks, asset segregation, and a dynamic cover pool maintaining the quality of the collateral are all essential characteristics to ensure bondholders' protection to credit losses. These characteristics reduce credit risk in covered bonds compared to senior bonds. The internationalization of formerly domestic covered bond markets began more than 15 years ago with the introduction of a new benchmark product attracting international institutional investors and providing the necessary liquidity. Market liquidity is further strengthened from large outstanding issues, the jumbo market.

Appendix B. Models for credit risk and liquidity risk

The yield spreads are functions of the factors for liquidity risk, L, and credit risk, C:

$$(y_{gov} - y_{agency}) = -L \tag{9}$$

$$(y_{cov} - y_{agency}) = \alpha_{cov} L + \beta_{cov} C \tag{10}$$

$$(y_{sen} - y_{agency}) = \alpha_{sen} L + \beta_{sen} C \tag{11}$$

$$(y_{sub} - y_{agency}) = \alpha_{sub} L + C. \tag{12}$$

By rearranging Eqs. (9) and (12), we can express the liquidity risk and credit risk factors as

$$L = (y_{agency} - y_{gov}) \tag{13}$$

$$C = (y_{sub} - y_{agency}) - \alpha_{sub}(y_{agency} - y_{gov}). \tag{14}$$

Next, plugging (13) and (14) in (10), we get

$$\begin{aligned}(y_{cov} - y_{agency}) = {} & (\alpha_{cov} - \alpha_{sub}\beta_{cov})(y_{agency} - y_{gov}) \\ & + \beta_{cov}(y_{sub} - y_{agency}).\end{aligned} \tag{15}$$

Likewise, plugging (13) and (14) in (11), we get

$$\begin{aligned}(y_{sen} - y_{agency}) = {} & (\alpha_{sen} - \alpha_{sub}\beta_{sen})(y_{agency} - y_{gov}) \\ & + \beta_{sen}(y_{sub} - y_{agency}).\end{aligned} \tag{16}$$

Rearranging this equation, we get

$$\begin{aligned}&(y_{sub} - y_{agency}) \\ &= \frac{1}{\beta_{sen}}[(y_{sen} - y_{agency}) - (\alpha_{sen} - \alpha_{sub}\beta_{sen})(y_{agency} - y_{gov})].\end{aligned} \tag{17}$$

Finally, plugging (17) in (15) and collecting terms, we get

$$\begin{aligned}&(y_{cov} - y_{agency}) \\ &= \frac{\beta_{cov}}{\beta_{sen}}(y_{sen} - y_{agency}) + \left(\alpha_{cov} - \frac{\beta_{cov}}{\beta_{sen}}\alpha_{sen}\right)(y_{agency} - y_{gov}).\end{aligned} \tag{18}$$

We follow an analogous approach to estimate the relative factor loading for liquidity risk, $\frac{\alpha_{cov}}{\alpha_{sen}}$. Rearranging Eqs. (11) and (12), we express the liquidity risk and credit risk factors as

$$L = \frac{1}{\alpha_{sen}}[(y_{sen} - y_{agency}) - \beta_{sen} C] \tag{19}$$

and

$$C = (y_{sub} - y_{agency}) - \alpha_{sub}(y_{agency} - y_{gov}). \tag{20}$$

Next, plugging (20) in (19), we get

$$\begin{aligned}L = {} & \frac{1}{\alpha_{sen}}[(y_{sen} - y_{agency}) - \beta_{sen}[(y_{sub} - y_{agency}) \\ & - \alpha_{sub}(y_{agency} - y_{gov})]].\end{aligned} \tag{21}$$

Finally, plugging (20) and (21) in (10) and collecting terms, we get

$$\begin{aligned}&(y_{cov} - y_{agency}) \\ &= \frac{\alpha_{cov}}{\alpha_{sen}}(y_{sen} - y_{agency}) + \left(\beta_{cov} - \frac{\alpha_{cov}}{\alpha_{sen}}\beta_{sen}\right)(y_{sub} - y_{agency}) \\ &\quad + \left(\frac{\alpha_{cov}}{\alpha_{sen}}\beta_{sen}\alpha_{sub} - \beta_{cov}\alpha_{sub}\right)(y_{agency} - y_{gov}).\end{aligned} \tag{22}$$

Appendix C. A technical note on asset swap spreads

All yields are converted to a spread over the zero-coupon euro interest rate curve by calculating the asset swap spread. An asset swap is a position that combines a fixed rate bond with a fixed-to-floating interest rate swap. Agency and corporate bonds are generally quoted with their asset swap spread.

Markit includes asset swap spreads in their database for some bonds from 2 May 2006 and for all bonds from 1 August 2009.

Based on the information in the database on bond price, accrued interest, coupon, coupon frequency, maturity date etc., we calculate asset swap spreads for all observations. Given the present value of fixed and floating rate payments, the asset swap spread (ASW) is calculated as follows:

$$ASW = \frac{PV_{fixed} - DP}{PV_{floating}}$$

where DP is the bond's market price (dirty price),

$$PV_{fixed} = \sum_{t=1}^{T} C_t \times DF_t^{fixed} + Principal_T \times DF_T^{fixed},$$

and

$$PV_{floating} = \sum_{t=1}^{T} \frac{L_t}{360} \times DF_t^{floating},$$

where C_t is the coupon payment and L_t is the number of days between floating rate payments. Here

$$DF_n^{fixed} = \frac{1}{(Swap_n + 1)^{L_n^{fixed}/360}}$$

and

$$DF_n^{floating} = \frac{1}{(Swap_n + 1)^{L_n^{floating}/360}},$$

where $Swap_n$ is the zero-coupon euro swap curve rate at the next coupon payment date and L_n is the number of days between next coupon payment date and calculation day.

This definition of asset swap spreads is generally called the *par* asset swap spread. We divide the par asset swap spread by the bond's bid price to obtain what is generally called the *true* asset swap spread.

To calculate the zero-coupon euro swap curve, we use Libor rates up to 11 months (overnight, 1 week, 2 weeks, 1 month rate, and so on). Starting from 12 months, we use ICAP rates (1 year, 2 years, 3 years rates, and so on).

Calculating the asset swap margin based on the available information in the Markit database implies potential minor calculation errors. We do not adjust our calculations for settlement days. Ex-coupon periods and short or long first coupon periods can also lead to minor calculation errors. However, comparing our calculations of asset swap spreads to the ones provided by Markit, we find the deviations to be insignificant.

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