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**Working Paper**

## Risk characteristics of covered bonds: Monitoring beyond ratings

ECB Working Paper, No. 2393

**Provided in Cooperation with:**

European Central Bank (ECB)

*Suggested Citation:* Grothe, Magdalena; Zeyer, Jana (2020) : Risk characteristics of covered bonds: Monitoring beyond ratings, ECB Working Paper, No. 2393, ISBN 978-92-899-4036-8, European Central Bank (ECB), Frankfurt a. M., <https://doi.org/10.2866/395233>

This Version is available at:

<https://hdl.handle.net/10419/229007>

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EUROPEAN CENTRAL BANK

EUROSYSTEM

## Working Paper Series

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Risk characteristics of covered bonds:  
monitoring beyond ratings

No 2393 / April 2020

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## **Abstract**

This paper proposes a set of indicators relevant for the risk characteristics of covered bonds, as based on granular publicly available transparency data. The indicators capture various aspects of cash flow risks related to the issuer, the cover pool and the payment structure. They offer unified risk metrics for the European covered bond universe, which ensures comparability across covered bonds issued by different issuers and rated by different credit rating agencies. The availability of granular risk indicators adds to the overall transparency of the market in the context of risk monitoring.

Keywords: covered bonds; risk monitoring; risk indicators;  
covered bond transparency data; credit ratings

JEL classification: G12; G24; G21; C30

## Non-technical summary

This paper analyses factors that influence the risk profile of covered bonds. Based on publicly available transparency data on individual covered bond programmes, we propose a set of granular risk indicators. They capture various aspects of cash flow risks, grouped into the following categories: (1) issuer risk, (2) overcollateralization, (3) cover pool risk, (4) mismatches between covered bond and cover pool cash flows, and (5) maturity type. The indicators are comparable across European covered bonds issued by different issuers and rated by different credit rating agencies and thus contribute to the overall transparency of the market.

The results of this paper illustrate that there is a significant heterogeneity of covered bond programmes with respect to various dimensions of their risk characteristics. For example, within the same rating class, we observe a significant variability of the proposed granular indicators, e.g. those informing on the risks in the cover pool like the share of cover pool assets in arrears or with very high loan-to-value ratios. Due to the nature of the covered bond as a financial product with double protection, the credit ratings of these instruments tend to be relatively high though, with 101 out of 198 bonds rated AAA. Consequently, some particular aspects of risk-related information available from the granular indicators, which could be of interest from the perspective of particular investor's risk preferences, may provide useful information and enable a better risk monitoring and comparability within the European covered bond market. The paper also offers a stylised example of an application of risk indicators for monitoring purposes.

The paper includes also a series of model-based robustness checks exploring to which extent the information content provided by the granular risk indicators may be already visible in the credit ratings. We employ a unilateral correlation analysis, turning further to a more systematic regression approach as well as the least absolute shrinkage and selection operator algorithm. In this way we identify those risk indicators, e.g. the issuer rating, that are likely to offer less of the new information in addition to the credit ratings.

Overall, the proposed risk indicators offer value added in terms of risk monitoring of the

European covered bond market, as compared to the information conveyed by the credit ratings only. While there is relatively little variability in the credit ratings of covered bonds, the proposed risk indicators offer comparable and relatively granular information on vulnerabilities embedded in these assets. The availability of such indicators, which are comparable across the European covered bond universe, adds to the transparency of the market in the context of risk monitoring.

# 1 Introduction

Covered bonds are an important source of market-based funding for European banks and an interesting financial product for investors. The covered bond market has been steadily growing over the past years, attracting new issuers and investors (see, for example European Covered Bond Council (2017), European Central Bank (2011b) and Packer, Stever, and Upper (2007)).<sup>1</sup> The key reason is that covered bonds include an additional layer of collateral, as compared to unsecured bank bonds, which offers investors a safer banking debt instrument and allows banks for cheaper refinancing in the debt market. At the same time, this specific feature of covered bonds adds a layer of complexity to the product, which may pose challenges with respect to the risk assessment. Based on new transparency data on individual covered bond programmes, this paper proposes a set of granular risk indicators, which can be uniformly computed and compared across issuers and credit rating agencies. The results illustrate that there is a significant heterogeneity of equally-rated covered bond programmes with respect to various dimensions of their granular risk characteristics. Consequently, some particular aspects of risk-related information available from the granular indicators, which could be of interest from the perspective of particular investor's risk preferences, may provide useful information and enable a better risk monitoring and comparability within the European covered bond universe, contributing to market transparency.

Covered bonds are debt instruments issued by banks and backed by collateral, a so-called cover pool, which is composed of private sector loans (usually residential and/or commercial mortgage loans) or public sector debt instruments (usually loans and/or debt securities). The issuer is responsible for the payments of the covered bond coupon and principal, while the cover pool becomes the source of payments only in the case of the issuer default. This structure implies a double-layered protection of covered bond cash

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<sup>1</sup>In the recent years the covered bond market also gained importance for monetary policy operations, where covered bonds were included in several purchase programmes of the Eurosystem (see European Central Bank (2009, 2011a, 2014, 2017a and 2017b), as well as Beirne et al. (2011)). For an overview of the role of the covered bond market, see also, e.g., Nicolaisen (2017), Oddenes and Fasseland (2014), Kleštinec (2013), as well as Vucetich and Watson (2013) for some cross-country statistics and the history of the market.

flows for an investor, as the payments are disrupted only when (1) the issuer defaults and (2) the cover pool resources are insufficient to make payments in a timely manner. Therefore, the analysis of risks related to this financial product needs to account for the credit quality of both, the issuer and the cover pool, also including the mismatches between the cash flows promised by the covered bond and those received from the cover pool. Based on newly available transparency data (see European Central Bank (2016)), such risk analysis is possible to conduct in a standardised way for a set of European covered bonds.<sup>2</sup>

Before the introduction of new data requirements, it was challenging to find timely and comparable information on various European covered bond programmes. Apart from the ratings of the credit rating agencies, more detailed information related to the credit quality of this financial product was either not available or not standardised. While the credit rating agencies have access to the loan-level information of the cover pool and are thus able to conduct particular stress tests and a very detailed risk analysis, the investors and other market participants can only rely on the aggregate indicators published by the credit rating agencies or the issuers.<sup>3</sup> At the same time, even the ratings of credit rating agencies do not offer a uniform platform for the comparative risk assessment of the covered bond universe, since the ratings are not fully comparable due to the differences in underlying methodologies (see, e.g., Moody's (2016), FitchRatings (2016a), Standard & Poor's (2015 and 2014), and DBRS (2017a), as well as FitchRatings (2018)).<sup>4</sup> Consequently, covered bonds with the same rating may still have various credit quality metrics of the cover pool, various levels of concentration in the pool, various levels of currency and asset-liability mismatches, which could all be relevant from the

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<sup>2</sup>A covered bond programme encompasses a series of covered bonds (of several or possibly even several tenths of ISINs), which are based on the same cover pool. The data on risk characteristics is thus available at the level of a covered bond programme. Throughout this paper, we use the expressions "covered bond" and the "covered bond programme" interchangeably, always meaning the programme.

<sup>3</sup>The availability of credit ratings for the risk assessment purposes is very useful, but there may be some caveats in the applied models and/or related to the information asymmetry, as shown in the past experiences, see, e.g., BIS (2008 or 2005).

<sup>4</sup>For example, some methodologies conduct the cover pool modelling under the assumption of an issuer default probability of 100%, while other methodologies model the cover pool quality under the occurrence of the issuer default (see, e.g., FitchRatings (2018) and Moody's (2016)).

perspective of individual risk preferences of particular investors (e.g., aversion to high concentration in the cover pool or to foreign currency exposures).<sup>5</sup>

While several covered bond legal frameworks make certain transparency requirements mandatory, as for example the case in Germany, France, Ireland, Luxembourg and the Netherlands, the required data coverage differs across countries. Moreover, some covered bond issuers publish covered bond and cover pool information on their websites, but not in a standardised manner. With respect to the information provided by the credit rating agencies, publishing standards differ substantially, for example with regard to the data granularity, definitions, formats and reference periods. To improve the data availability and increase transparency in the covered bond market, private sector initiatives were undertaken, in particular the covered bond label created by the European Covered Bond Council together with the European Mortgage Federation.<sup>6</sup> However, since not all covered bond programmes were represented in this initiative, it was only the introduction of the transparency requirements (see European Central Bank (2016)) which made a more detailed comparison of covered bond characteristics across the market possible.<sup>7</sup>

This paper proposes a set of risk indicators relevant for the risk profile of covered bonds. The indicators are grouped to the following categories: (a) issuer risk, (b) overcollateralization, (c) cover pool risk, (d) mismatches between the covered bond and the cover pool cash flows, and (e) maturity type. In particular, beyond the overall characteristics of the covered bond, our indicator set explores the detailed information on the timing, currencies and structure of covered bond and cover pool cash flows, as well as the char-

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<sup>5</sup>See also further literature illustrating the value of other variables for risk monitoring, in addition to credit ratings, e.g., Deku, Kara, and Marques-Ibanez (2019) or Grothe (2013), as well as some discussion on the credit rating industry in Bongaerts (2014).

<sup>6</sup>The "covered bond label", introduced in 2012, was designed in a cooperation of European covered bond issuers, investors and regulators. Covered bond issuers which want to use this label as a quality criterion for their programmes have to fulfil several requirements. For example, they have to publish a standardised Excel-Sheet (a so-called "Harmonised Transparency Template"), containing relevant covered bond and pool information on a quarterly basis. For details, see also <https://www.coveredbondlabel.com/>. As of end-2017, the European Covered Bond Council labelled 112 cover pools of 95 issuers across 16 jurisdictions, i.e. the coverage still not fully encompassing the whole universe of covered bond programmes. Moreover, the way to fill out the template is not fully standardised, which complicates the comparison across programmes.

<sup>7</sup>Also other institutions expressed the view that more harmonisation in the market is needed, see, e.g. European Banking Authority (2016).



acteristics of the cover pool in terms of distributions of arrears, loan-to-value ratios, countries, regions and asset types. In this way, our set of indicators offers an example of a broad information set which could be relevant for risk comparison of covered bonds across the whole European universe, which until now was not possible in this much detail.<sup>8</sup>

The results of this paper illustrate that there is a significant heterogeneity of covered bond programmes with respect to various dimensions of their risk characteristics. For example, within the same rating class, we observe a significant variability of the proposed granular indicators, e.g. those informing on the risks in the cover pool like the share of cover pool assets in arrears or with very high loan-to-value ratios. Due to the nature of the covered bond as a financial product with double protection, the credit ratings of these instruments tend to be relatively high though, with 101 out of 198 bonds rated AAA. Consequently, some particular aspects of risk-related information available from the granular indicators, which could be of interest from the perspective of particular investor's risk preferences, may provide useful information and enable a better risk monitoring and comparability within the European covered bond market.<sup>9</sup>

The paper includes also a series of model-based robustness checks exploring to which extent the information content provided by the granular risk indicators may be already visible in the credit ratings. We employ a unilateral correlation analysis, turning further to a more systematic regression approach as well as the least absolute shrinkage and selection operator algorithm. In this way we identify those risk indicators, e.g. the issuer rating, that are likely to offer less of the new information in addition to the credit ratings.

Overall, our results suggest that the transparency data contributes to a deeper under-

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<sup>8</sup>In the context of risk monitoring, the exact definition, selection and weighting of indicators needs, however, to be seen from the perspective of individual preferences. In this paper, we use a relatively broad set of simple indicators and abstract from detailed choices on how to weight them.

<sup>9</sup>This is in line with some findings, e.g. those showing that some characteristics of cover pool are relevant for pricing of covered bonds, even within the same credit rating segment (see Prokopczuk, Siewert, and Vonhoff (2013)). More generally, the fact that there is a pricing differentiation within the group of bonds with the same credit rating suggests that there are some further specific bond characteristics that could be important from the perspective of individual investors, e.g., specific features of the cover pool, potential for cash flow mismatches or secondary market liquidity.

standing of the risks related to the covered bonds, in particular allowing for an analysis of cover pool credit risk and cash flow aspects without the access to loan-level information. The risk indicators proposed in this paper allow for a comparison of bonds within the universe of one rating class. They can be selected in a way tailored to investor preferences, like for example aversion to high concentration risk or to high-LTV exposures. In result, investors could monitor the risks in a more detailed and systematic way, also being able to compare the indicator values across the European covered bond universe, contributing to market transparency.

The remainder of the paper is structured as follows. Section 2 describes the data. Section 3 introduces the granular risk indicators and illustrates new information provided in addition to the credit ratings, including also a stylised example of a risk monitoring application. Section 4 contains several model-based robustness checks and Section 5 concludes.

## 2 Data

The data on covered bonds is published by the credit rating agencies in compliance with the recently introduced transparency requirements (see European Central Bank (2016)).<sup>10</sup> Each agency publicly discloses data on all European covered bond programmes which it rates.<sup>11</sup> Published documents entail detailed information on programme characteristics, including the distribution of cash flows on the asset and liability sides (i.e., for the cover pool and the covered bond, also including currency distribution and interest rate characteristics). The data also contains detailed characteristics of the cover pool, including the distribution of loans with respect to their loan-to-value ratios, the share of assets in arrears, as well as asset distribution across countries and,

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<sup>10</sup>The data used in this paper is publicly available on the websites of four credit rating agencies. All numbers presented in this paper are based on own calculations.

<sup>11</sup>In case of non-disclosure, any delays in publication or the lack of compliance with the requirements, the ECB guideline states consequences as following (see European Central Bank (2016)): "If the criteria are not fulfilled for a particular covered bond programme, the Eurosystem may deem the public credit rating(s) related to the relevant covered bond programme not to meet the high credit standards of the ECAF. Thus, the relevant ECAI's public credit rating may not be used to establish the credit quality requirements for marketable assets issued under the specific covered bond programme."

within them, across regions. For the detailed list of the available information, see European Central Bank (2016, Section 2(b)). The data is published by four credit rating agencies, Moody's, Fitch, S&P and DBRS, on a quarterly basis and is available since end-November 2017 (first set for all covered bond programmes for Q3-2017).<sup>12</sup>

Rating agency	Number of bonds rated by each rating agency	Number of bonds rated exclusively by each rating agency	Number of bonds rated by both, Moody's and each other rating agency	Number of bonds rated by both, Fitch and each other rating agency
Moody's	138	84	*	27
Fitch	51	17	27	*
S&P	53	23	22	13
DBRS	24	3	19	8
Rating agency	Number of bonds rated by both, S&P and each other rating agency	Number of bonds rated by all, Moody's, Fitch and each other rating agency	Number of bonds rated by all, Fitch, S&P and each other rating agency	Number of bonds rated by all, Moody's, Fitch, S&P and DBRS
Moody's	22	*	6	*
Fitch	13	*	*	*
S&P	*	6	*	*
DBRS	5	7	3	2

Table 1: Overview of the data coverage across the credit rating agencies

NOTE: The names of credit rating agencies are displayed in the order corresponding to the number of bonds rated by each agency.

The data sample in this paper covers the programmes rated by Moody's, Fitch, S&P and DBRS published for Q3-2017. Out of all published programmes, we exclude the bonds with some rare features, like those where the currency of denomination or reporting is not euro, or those based on shipping, airplane or SME loans. Overall, 198 covered bond programmes are included in the analysis. Table 1 presents an overview of the number of covered bond programmes rated by agencies, while the definitions of main data characteristics are listed in Tables 2 - 4, as based on Moody's (2016), FitchRatings (2016a), Standard & Poor's (2015 and 2014), and DBRS (2017a).<sup>13</sup>

<sup>12</sup>Throughout the paper, the ordering of names of credit rating agencies corresponds to the number of bonds in our dataset rated by each agency. (see Table 1). Some credit rating agencies published also information going further back in time for some bonds (e.g., Fitch and DBRS), some others published the data for a broader set of covered bond programmes (e.g., Moody's, including non-European programmes).

<sup>13</sup>For further related details, see also Moody's (2017), FitchRatings (2017 and 2016b), Standard & Poor's (2017, 2016a and 2016b), DBRS (2015) as well as Commerzbank (2017).

Name	Definition	Data availability
<b>Covered Bond Rating</b>	Rating published by the credit rating agency. For the sake of comparability, the rating is transformed to a linear numerical scale. For covered bonds rated by several credit rating agencies, we use the average credit rating. Unit: notches. <sup>a</sup>	Moody's, S&P, DBRS
<b>Issuer Risk</b>	Long-term default rating of the issuer on unsecured bonds. If data is not available, we use other measures of the counterparty risk assessment, as provided by the credit rating agencies. The counterparty risk assessment provides a probability of default assessment on a bank's operating obligations, such as payment obligations associated with covered bonds (and certain other secured transactions), derivatives, letters of credit, third-party guarantees, servicing and trustee obligations and other similar obligations that arise from a bank in performing its essential operating functions. For the sake of comparability, the rating is transformed to a linear numerical scale. Unit: notches.	Moody's, S&P, DBRS
<b>Leeway</b>	The number of rating notches by which an issuer rating can be lowered before the covered bonds may face a downgrade. Unit: notches.	Moody's, S&P
<b>Main Collateral Asset Type</b>	Type of the assets with the largest share in the cover pool (e.g., residential, commercial, public sector). Unit: EUR (nominal value of the assets) or (of cover pool assets), depending on the credit rating agency.	Moody's, S&P, DBRS
<b>Cover Pool Asset Distribution</b>	Distribution of the cover pool assets among asset types (e.g., residential, commercial, public sector assets), countries and regions. Unit: EUR (nominal value of the assets) or (of cover pool assets), depending on the credit rating agency.	Moody's, S&P, DBRS
<b>Overcollateralization</b>	Overcollateralisation compares the value of cover pool assets to the value of covered bonds, on nominal or net present value basis, depending on the credit rating agency and the issuer. Committed overcollateralization is the overcollateralization that the issuer is required to maintain, either based on the covered bond legal framework or the contractual obligation. Unit: % (of covered bonds).	Moody's, S&P, DBRS
<b>Asset-Liability Profile</b>	The principal cash flows of the cover pool assets and covered bonds, divided into maturity buckets. For most bonds (those rated by Moody's and Fitch), the maturity buckets are: 0-1Y, 1-2Y, 2-3Y, 3-4Y, 4-5Y, 5-10Y and >10Y. <sup>b</sup> Unit: EUR (nominal value of the assets) or % (of covered bonds or cover pool assets, respectively), depending on the credit rating agency.	Moody's, S&P, DBRS

**Table 2: Overview of data available from the transparency templates (1/3)**

NOTE: The table presents an overview of the data available from the transparency templates published by the credit rating agencies. The column "Data source" indicates whether given information is available for several credit rating agencies or is specific for one agency. The names of credit rating agencies are displayed by the number of bonds rated by each agency (see Table 1).

<sup>a</sup>The choice of a linear scale is motivated by its simplicity and traceability. The resulting transformation can be easily compared and aggregated across the credit rating agencies. At the same time, this transformation may have some drawbacks in case there are non-linear effects, for example between the investment- and non-investment grade classes. See also Annex A, Table A-1 for an overview and mapping of rating scales.

<sup>b</sup>The maturity buckets for principal cash flows of under 10 years in the case of DBRS are: 0-5Y, 5-8Y, 8-10Y.

Name	Definition	Data availability
<b>Weighted Average Life</b>	Weighted average life (in years) of the assets or covered bonds, calculated by multiplying principal payments by the period in which they are received/paid and dividing the result by the total amount of principal. Timing of principal payments is normally based on scheduled payments. Unit: years.	Moody's, S&P, DBRS
<b>Interest Rate Distribution</b>	Nominal value of the cover bond liabilities and cover pool assets with the fixed and floating rate. Unit: EUR (nominal value of the assets) or % (of covered bonds or cover pool assets, respectively), depending on the credit rating agency.	Moody's, S&P, DBRS
<b>Currency Distribution</b>	Nominal value of the cover bond liabilities and cover pool assets denominated in various currencies. Unit: EUR (nominal value of the assets) or % (of covered bonds or cover pool assets, respectively), depending on the credit rating agency.	Moody's, S&P, DBRS
<b>LTV Distribution</b>	Distribution of cover pool assets according to their loan-to-value ratio. For most bonds (those rated by Moody's, Fitch and S&P), the LTV buckets are: 0-40%, 40%-50%, 50%-60%, 60%-70%, 70%-80%, 80%-90%, 90%-100%, >100%. Unit: EUR (nominal value of the assets) or % (of cover pool assets), depending on the credit rating agency.	Moody's, S&P, DBRS
<b>Arrears</b>	Cover pool assets in arrears. For most bonds (those rated by Moody's, Fitch and S&P), the buckets for the length of arrears are: less than 3 months, 3-6 months, 6 months or more. <sup>a</sup> Unit: EUR (nominal value of the assets) or % (of cover pool assets), depending on the credit rating agency.	Moody's, S&P, DBRS
<b>Collateral Score (Moody's-specific)</b>	The collateral score measures the credit quality of the cover pool and determines the amount of the cover pool written off as a result of asset credit deterioration following a CB anchor event. The higher the credit quality of the cover pool, the lower the collateral score. Unit: %.	Moody's
<b>Cover Pool Losses (Moody's-specific)</b>	Assumption of the Moody's Expected Loss Model. The sum of collateral risk (i.e., Collateral Score post-haircut) and market risk. The loss following a CB anchor event will primarily depend on (1) the value of the cover pool in relation to the outstanding covered bonds; and potentially (2) any additional unsecured claim against the issuer or any outstanding claim against swap counterparties. In assessing the value of the cover pool, our considerations include (1) the credit quality of the cover pool; (2) the refinancing risk if funds need to be raised against the cover pool; and (3) any interest-rate and currency risk to which the cover pool is exposed. Unit: %.	Moody's

**Table 3: Overview of data available from the transparency templates (2/3)**

NOTE: The table presents an overview of the data available from the transparency templates published by the credit rating agencies. The column "Data source" indicates whether given information is available for several credit rating agencies or is specific for one agency. The names of credit rating agencies are displayed by the number of bonds rated by each agency (see Table 1).

<sup>a</sup>Additionally, Fitch and S&P offer also buckets for 1-2 months and 2-3 months. Moody's offers also a second option to define the buckets for arrears, as follows: less than 2 months, 2-6 months, 6 months or more. This option is reported for 118 out of 144 programmes. To align the data across all credit rating agencies, we use the threshold of 3 months, corresponding also to the Basel Committee on Banking Supervision's definition of non-performing exposures (see also Basel Committee on Banking Supervision (2017)).

Name	Definition	Data availability
Timely Payment Indicator (Moody's-specific)	Moody's Timely Payment Indicator. It reflects the probability that payments on the covered bond will be made in a timely fashion following a covered bond anchor event (e.g., a default of the issuer) and follows a 6-element scale that ranges from "Very High" to "Very Improbable". Unit: descriptive scale.	Moody's
Payment Continuity Uplift (Fitch-specific)	Fitch's Payment Continuity Uplift. It reflects the uplift related to the probability that payments on the covered bond will be made in a timely fashion following a covered bond anchor event (e.g., a default of the issuer). Unit: notches.	Fitch
Target Credit Enhancement (S&P-specific)	S&P's Target Credit Enhancement. It reflects the probability that payments on the covered bond will be made in a timely fashion. Unit: units.	S&P
Cover Pool Credit Assessment (DBRS-specific)	DBRS's Cover Pool Credit Assessment. It reflects the uplift related to the probability that payments on the covered bond will be made in a timely fashion following a covered bond anchor event (e.g., a default of the issuer). Unit: notches.	DBRS
Maturity type	"Hard bullet" is a covered bond repayable in full on a single scheduled maturity date. "Soft bullet" is a covered bond where the initial scheduled maturity date may be extended to a later scheduled maturity date, usually not exceeding 2 years post the maturity date, unless it qualifies as a pass through. "Pass through" is a covered bond that moves to a pass through structure after a trigger event, e.g. an issuer default or an issuer's failure to conduct a mandatory amortisation test, including where the bond has a scheduled maturity date set to fall after the last maturing cover pool asset. "Mixed" is where covered bonds of different maturity types are issued. Unit: descriptive.	Moody's, Fitch, DBRS, S&P,

Table 4: Overview of data available from the transparency templates (3/3)

NOTE: The table presents an overview of the data available from the transparency templates published by the credit rating agencies. The column "Data source" indicates whether given information is available for several credit rating agencies or is specific for one agency. The names of credit rating agencies are displayed by the number of bonds rated by each agency (see Table 1).

### **3 Risk indicators**

This section introduces granular risk indicators and presents the results of monitoring. It shows their summary statistics and distributions for the European covered bond universe. In a more detailed approach, we illustrate the variability of indicators within one rating class, showing how much additional information they provide on the various aspects of potential vulnerabilities. The section concludes with a stylised example of an application of risk indicators for monitoring purposes.

#### **3.1 Indicator definitions**

Based on the transparency data, we develop a set of risk indicators, grouped into the following categories: (1) issuer risk, (2) overcollateralization, (3) cover pool risk, (4) mismatches between the covered bond and the cover pool cash flows, and (5) maturity type. The indicators are based on the data which is comparable across all data providers (four credit rating agencies) and all issuers. In this way, the risk indicators constitute a uniform platform for a comparison of covered bonds across the whole European market with respect to the set of important characteristics.

##### **3.1.1 Issuer risk**

Issuer risk is captured by the rating ascribed by the credit rating agency, as defined in Tables 2 - 4. For completeness, we also consider the sovereign rating of the issuer's country, but we use this variable, along with some country dummies, only for the robustness purposes, as it is highly correlated with the issuer rating.<sup>14</sup>

##### **3.1.2 Overcollateralisation**

Overcollateralisation compares the value of cover pool assets to the value of covered bonds. We use the following indicators:

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<sup>14</sup>The issuer rating incorporates the macroeconomic risk of the country where the issuer is located, as well as, at least to some extent, the sovereign risk (see also Moody's (2017)). See also Table B-1 in Annex B for the correlation between the issuer and sovereign ratings.

- **Overcollateralization (OC)** - Nominal overcollateralization, defined as:

$$OC = 100 * \left( \frac{CP}{CB} - 1 \right), \quad (1)$$

where  $CP$  denotes the nominal value of the cover pool and  $CB$  denotes the nominal value of the covered bond, and

- **Committed Overcollateralization (OC)** - The overcollateralization which the issuer is required to maintain, either based on the covered bond legal framework or the contractual obligation.

### 3.1.3 Cover pool risk

The cover pool risk is captured by several indicators characterising the asset pool:

- **Arrears** - The share of the cover pool assets which have been in arrears for at least 3 months,

- **High LTV loans (Very high LTV loans)** - The share of the cover pool assets with the loan-to-value ratio exceeding 80% (and 100%, respectively),

- **Commercial assets** - The share of commercial loans in the cover pool,

- **Regional concentration** - The largest share of the cover pool assets concentrated in one region, while regions are defined within countries,

- **Macroeconomic risk (MR)** - Macroeconomic risk relevant for the cover pool, defined as:

$$MR = \sum_{c=1}^C \frac{CP_c}{CP} * R_c, \quad (2)$$

where  $CP_c$  denotes the nominal value of the cover pool assets in country  $c$ ,  $R_c$  denotes the sovereign rating of country  $c$  and  $C$  denotes the number of all countries relevant for the cover pool, and

- **Real estate risk (RR)** - Real estate risk relevant for the cover pool, defined as the share of residential loans in the cover pool originated in a country where the residential



real estate sector was identified as vulnerable by the European Systemic Risk Board (see European Systemic Risk Board (2016a and 2016b)).

$$RR = \sum_{i=1}^C \frac{CP_i * R_i}{CP}, \quad (3)$$

where  $CP_i$  denotes the nominal value of the cover pool assets in country  $i$ ,  $C$  denotes the number of all countries relevant for the cover pool,  $R_i$  equals 1 if country  $i$  received a warning related to the vulnerabilities in the residential real estate sector from the European Systemic Risk Board in 2016 and 0 otherwise.

For the purpose of comparison of the data availability, we also use the indicators provided by the credit rating agencies, i.e. collateral score, cover pool losses and the timely payment indicator by Moody's, payment continuity uplift by Fitch, target credit enhancement by S&P and cover pool credit assessment by DBRS, which summarise the credit rating agency's assessment about the credit quality of the cover pool (all as defined in Tables 3-4).

### 3.1.4 Mismatches between the covered bond and the cover pool cash flows

Cash flow mismatches are captured by the following indicators:

- **Asset-liability mismatch** ( $ALM_T$ ) - Mismatch between the cash flows on the asset and liability sides, defined as:

$$ALM_T = \max\left(\frac{\sum_{t=1}^T CB_t - \sum_{t=1}^T CP_t}{CB}; 0\right), \quad (4)$$

where  $CB_t$  ( $CP_t$ ) denotes the nominal value of the cover bond liabilities (cover pool assets) scheduled for payment in year  $t$ , and  $T$  denotes the number of years for which the mismatch is computed. We consider the asset-liability mismatches for 3 and 5 years. We use in the charts, if not specified otherwise, the asset-liability mismatch for a 5-year horizon, which corresponds to a typical maturity of a covered bond.

- **Currency mismatch ( $CM$ )** - Mismatch between the currencies of the cash flows on the asset and liability sides, defined as:

$$CM = \sum_{i=1}^I \max\left(\frac{CB_i - CP_i}{CB}; 0\right), \quad (5)$$

where  $CB_i$  ( $CP_i$ ) denotes the nominal value of the cover bond liabilities (cover pool assets) denominated in currency  $i$ , and  $I$  denotes the number of all currencies relevant for the cover pool, reported by the credit rating agency.

- **Interest rate mismatch ( $IRM$ )** - Mismatch between the interest rate characteristics of the cash flows on the asset and liability sides, defined as:

$$IRM = \max\left(\frac{CB_{fixed} - CP_{fixed}}{CB}; 0\right) + \max\left(\frac{CB_{floating} - CP_{floating}}{CB}; 0\right), \quad (6)$$

where  $CB_{fixed}$  ( $CP_{fixed}$ ) denotes the nominal value of the cover bond liabilities (cover pool assets) with the fixed rate and  $CB_{floating}$  ( $CP_{floating}$ ) denotes the nominal value of the cover bond liabilities (cover pool assets) with the floating rate. The data provided for most covered bond programmes does not allow for an identification of the value of the currency or interest rate swaps or the assessment of individual swap counterparties. Therefore, the indicators for the currency mismatch and the interest rate mismatch do not take possible swap arrangements into account. However, based on the data from one credit rating agency, where the information on the currency and interest rate exposures before and after swap is provided, the effect of hedging on the currency and interest rate mismatches seems to be relatively limited (see Figure C-1 in Annex C).

- **Maturity mismatch** - Mismatch between the average maturities of the cash flows on the asset and liability sides, defined as the difference between the weighted average life of the cover pool assets and the covered bond liabilities (as defined in Table 2).

### 3.1.5 Maturity type

This category captures the risks of payment delays, relative to the initial scheduled maturity date, due to the embedded options for maturity extension in soft bullet and pass-through covered bonds, as defined in Table 4.

### **3.2 Summary overview of credit ratings and new information provided by granular risk indicators**

This section discusses the distributions of credit ratings, as well as illustrates the new information provided by granular risk indicators comparable across the whole asset class. Tables 5-6 present the descriptive statistics of credit ratings and proposed risk indicators, also separately for several countries with the largest number of covered bond programmes, as well as for main cover pool asset types. Country-specific descriptive statistics are presented for all countries with more than 10 covered bonds in the sample. For the sake of comparison, we also report some risk indicators as published by the credit rating agencies (i.e. collateral score, cover pool losses and the timely payment indicator by Moody's, payment continuity uplift by Fitch, target credit enhancement by S&P and cover pool credit assessment by DBRS). To complement the overall descriptive statistics, Figures 1 and 2 show the distributions of credit ratings and selected risk indicators for all European bonds, while Figure 3 presents the distributions of risk indicators within the highest rating class. The highest rated bonds are those with the maximum rating (i.e., Aaa in Moody's terminology and AAA in the Fitch, S&P and DBRS terminology, see also Table A-1 in Annex A) ascribed by all agencies which rate the respective bonds. There are 101 bonds within the highest rating class, out of 198 bonds in the whole dataset.

Risk indicators	Units	All covered bonds					Number of bonds (with mismatch or asset/ maturity type)
		Number of observations	Average	Median	Min	Max	
Covered bond amounts	(EUR bn)	189	7.3	3.6	0.0	62.7	
Cover pool amounts	(EUR bn)	189	11.1	5.3	0.2	93.2	
<b>Covered bond and issuer ratings</b>							
Covered bond rating	(notches, AAA=1, Aa1=2,...)	189	2.6	1.0	1.0	16.0	
Covered bond rating incl. leeway	(notches)	160	-0.5	-1.0	-9.0	8.0	
Issuer rating	(notches)	150	7.9	7.0	2.0	24.0	
Covered bond uplift vs issuer incl. leeway	(notches)	135	7.9	8.0	2.0	13.0	
Covered bond uplift vs issuer	(notches)	150	5.3	5.0	1.0	10.0	
Country rating	(notches)	189	4.3	2.0	1.0	16.0	
<b>Overcollateralisation</b>							
Overcollateralisation	(%)	189	72%	43%	0%	65%	
Committed Overcollateralisation	(%)	189	10%	5%	0%	55%	
<b>Cover pool risk</b>							
Arrears	(% of cover pool)	177	2%	0%	0%	102%	
High LTV assets	(% of cover pool)	177	13%	5%	0%	100%	
Very high LTV assets	(% of cover pool)	173	4%	0%	0%	100%	
Commercial assets	(% of cover pool)	189	14%	0%	0%	97%	
Regional concentration	(% of cover pool)	179	41%	35%	5%	100%	
Macroeconomic risk of assets	(notches)	185	4.4	2.7	0.0	16.0	
Real estate risk	(% of cover pool)	189	19%	0%	0%	100%	
Collateral score (Moody's)	(% of cover pool)	137	11%	8%	3%	30%	
Cover pool losses (Moody's)	(% of cover pool)	137	21%	18%	5%	50%	
Timely payment indicator (Moody's)	(units 1="very high",...,6="very improbable")	138	3.2	3.0	0.0	6.0	
Payment continuity uplift (Fitch)	(notches)	48	4.2	5.0	0.0	8.0	
Cover pool credit assessment (DBRS)	(notches)	21	8.1	10.0	1.0	12.0	
Target credit enhancement (S&P)	(units)	53	25.3	20.6	2.5	90.0	
<b>Cash flow mismatch</b>							
Asset-liability mismatch (3 years)	(% of covered bond amounts)	161	14%	0%	0%	93%	0
Asset-liability mismatch (5 years)	(% of covered bond amounts)	165	20%	6%	0%	94%	0
Currency mismatch	(% of covered bond amounts)	187	2%	0%	0%	67%	39
Interest rate mismatch	(% of covered bond amounts)	189	20%	2%	0%	100%	103
Maturity mismatch	(years)	183	4.6	3.7	-7.4	22.3	
<b>Maturity type</b>							
Hard bullet	(number of bonds)	189					106
Soft bullet	(number of bonds)	189					41
Pass-through	(number of bonds)	189					14
Mixed	(number of bonds)	189					28
<b>Main collateral asset type</b>							
Residential	(number of bonds)	189					120
Commercial	(number of bonds)	189					20
Public sector	(number of bonds)	189					47
Number of covered bonds	(units)	198					189

Table 5: Descriptive statistics (1/2)

NOTE: The table shows descriptive statistics of risk indicators, as defined in this section, also presenting median values for covered bond programs within a given country and a given asset type. Country-specific descriptive statistics presented for all countries with more than 10 covered bonds in the sample.<sup>a</sup>

<sup>a</sup>For Germany, the table shows maturity type "mixed" for 4 covered bond programmes, due to the imprecise reporting. These bonds are hard bullet bonds, as no other type is allowed by this country's legal framework.

Risk indicators	Units	Covered bonds per country (median per indicator)					Covered bonds per main asset type (median per indicator)		
		Austria	France	Germany	Italy	Spain	Residential	Commercial	Public Sector
Covered bond amounts	(EUR bn)	1.1	9.1	4.0	3.5	3.5	3.6	4.6	3.0
Cover pool amounts	(EUR bn)	2.1	10.9	5.5	4.3	10.3	6.7	6.5	4.0
<b>Covered bond and issuer ratings</b>									
Covered bond rating	(notches, AAA=1, Aa1=2,...)	1.0	1.0	1.0	4.5	3.0	1.0	1.0	1.0
Covered bond rating incl. leeway	(notches)	0.0	-3.0	-3.0	2.0	2.0	-1.0	-3.0	-1.0
Issuer rating	(notches)	7.0	5.5	5.5	11.5	8.5	8.0	6.0	7.0
Covered bond uplift vs issuer incl. leeway	(notches)	8.0	8.0	9.0	7.0	7.0	8.0	8.0	8.0
Covered bond uplift vs issuer	(notches)	6.0	4.3	4.5	6.0	5.5	5.0	5.0	5.0
Country rating	(notches)	2.0	3.0	1.0	9.0	8.0	3.0	1.0	2.0
<b>Overcollateralisation</b>									
Overcollateralisation	(%)	43%	35%	35%	38%	168%	45%	34%	33%
Committed Overcollateralisation	(%)	2%	8%	2%	8%	25%	8%	2%	2%
<b>Cover pool risk</b>									
Arrears	(% of cover pool)	0%	0%	0%	1%	6%	0%	0%	0%
High LTV assets	(% of cover pool)	5%	27%	0%	3%	10%	11%	6%	0%
Very high LTV assets	(% of cover pool)	2%	0%	0%	0%	3%	1%	2%	0%
Commercial assets	(% of cover pool)	6%	0%	1%	0%	15%	0%	76%	0%
Regional concentration	(% of cover pool)	54%	23%	28%	26%	34%	38%	28%	34%
Macroeconomic risk of assets	(notches)	2.0	3.0	1.1	9.0	8.0	3.2	1.7	2.0
Real estate risk	(% of cover pool)	57%	0%	0%	0%	0%	0%	0%	0%
Collateral score (Moody's)	(% of cover pool)	8%	6%	9%	6%	19%	7%	11%	10%
Cover pool losses (Moody's)	(% of cover pool)	19%	16%	16%	18%	32%	19%	19%	15%
Timely payment indicator (Moody's)	(units 1="very high",...6="very improbable")	4.0	3.0	2.0	4.0	4.0	4.0	2.0	2.0
Payment continuity uplift (Fitch)	(notches)		4.5	4.0	6.0	0.0	6.0	4.0	5.0
Cover pool credit assessment (DBRS)	(notches)				10.0	9.5	10.0		
Target credit enhancement (S&P)	(units)	32.2	20.9	15.8	33.0	46.0	20.6	23.7	21.6
<b>Cash flow mismatch</b>									
Asset-liability mismatch (3 years)	(% of covered bond amounts)	8%	0%	0%	16%	5%	8%	0%	0%
Asset-liability mismatch (5 years)	(% of covered bond amounts)	8%	1%	0%	36%	7%	19%	0%	0%
Currency mismatch	(% of covered bond amounts)	0%	0%	0%	0%	0%	0%	0%	0%
Interest rate mismatch	(% of covered bond amounts)	29%	0%	1%	20%	26%	1%	19%	2%
Maturity mismatch	(years)	3.6	1.4	0.8	5.7	4.8	5.0	1.5	1.7
<b>Maturity type</b>									
Hard bullet	(number of bonds)	20	6	48	0	25	51	15	39
Soft bullet	(number of bonds)	0	2	0	17	0	36	2	3
Pass-through	(number of bonds)	1	0	0	4	0	13	1	0
Mixed	(number of bonds)	2	10	3	1	3	20	2	5
<b>Main collateral asset type</b>									
Residential	(number of bonds)	12	12	15	19	20			
Commercial	(number of bonds)	1	0	15	2	1			
Public sector	(number of bonds)	10	6	21	1	6			
Number of covered bonds	(units)	23	18	51	22	28	120	20	47

Table 6: Descriptive statistics (2/2)

NOTE: The table shows descriptive statistics of risk indicators, as defined in this section, also presenting median values for covered bond programs within a given country and a given asset type. Country-specific descriptive statistics presented for all countries with more than 10 covered bonds in the sample.<sup>a</sup>

<sup>a</sup>For Germany, the table shows maturity type "mixed" for 4 covered bond programmes, due to the imprecise reporting. These bonds are hard bullet bonds, as no other type is allowed by this country's legal framework.

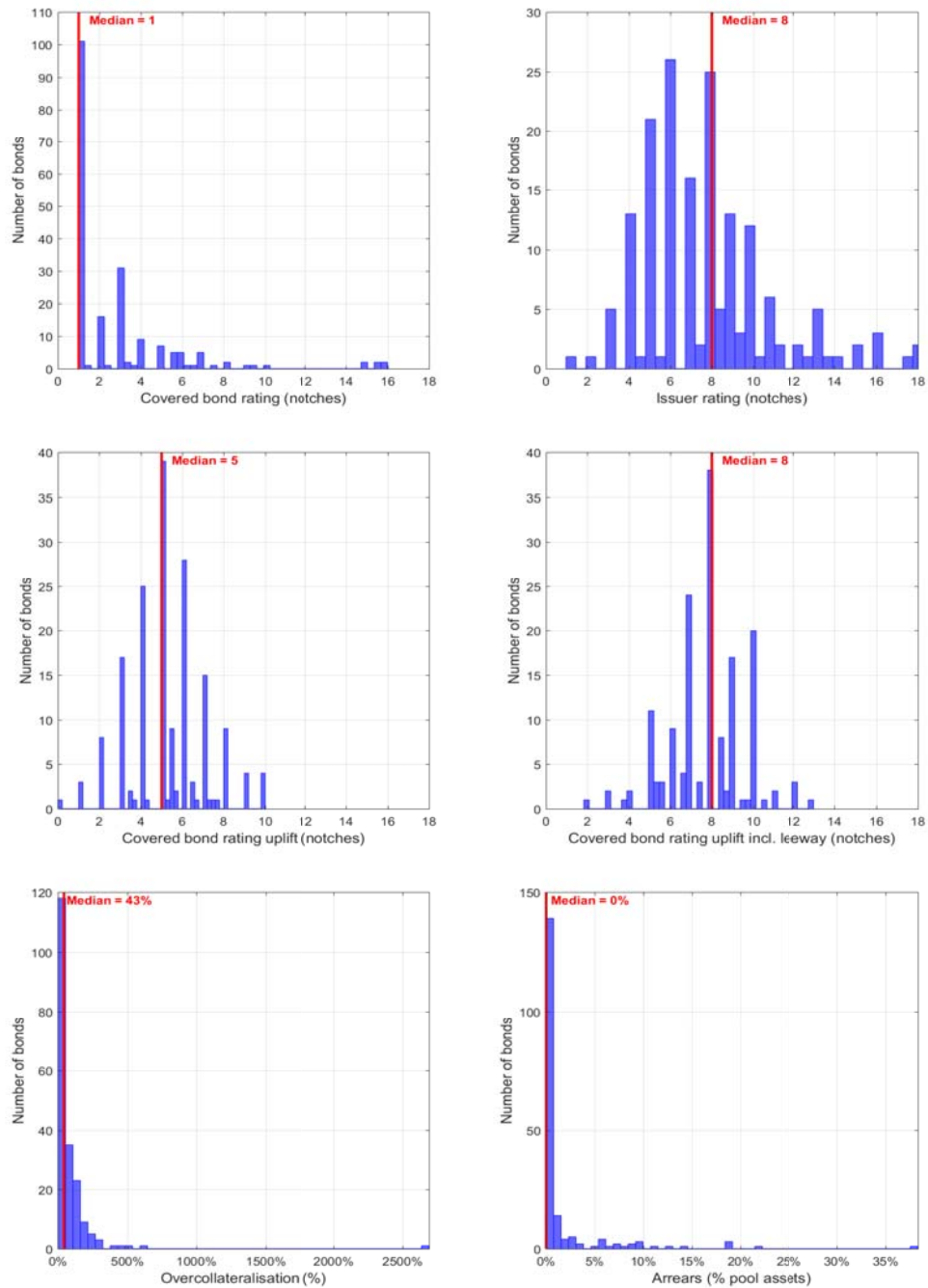


Figure 1: Distributions of covered bond indicators (1/2)

NOTE: The figures show histograms of selected risk indicators (as defined in this section) across all 198 covered bond programmes in the sample. The vertical red lines denote the median.

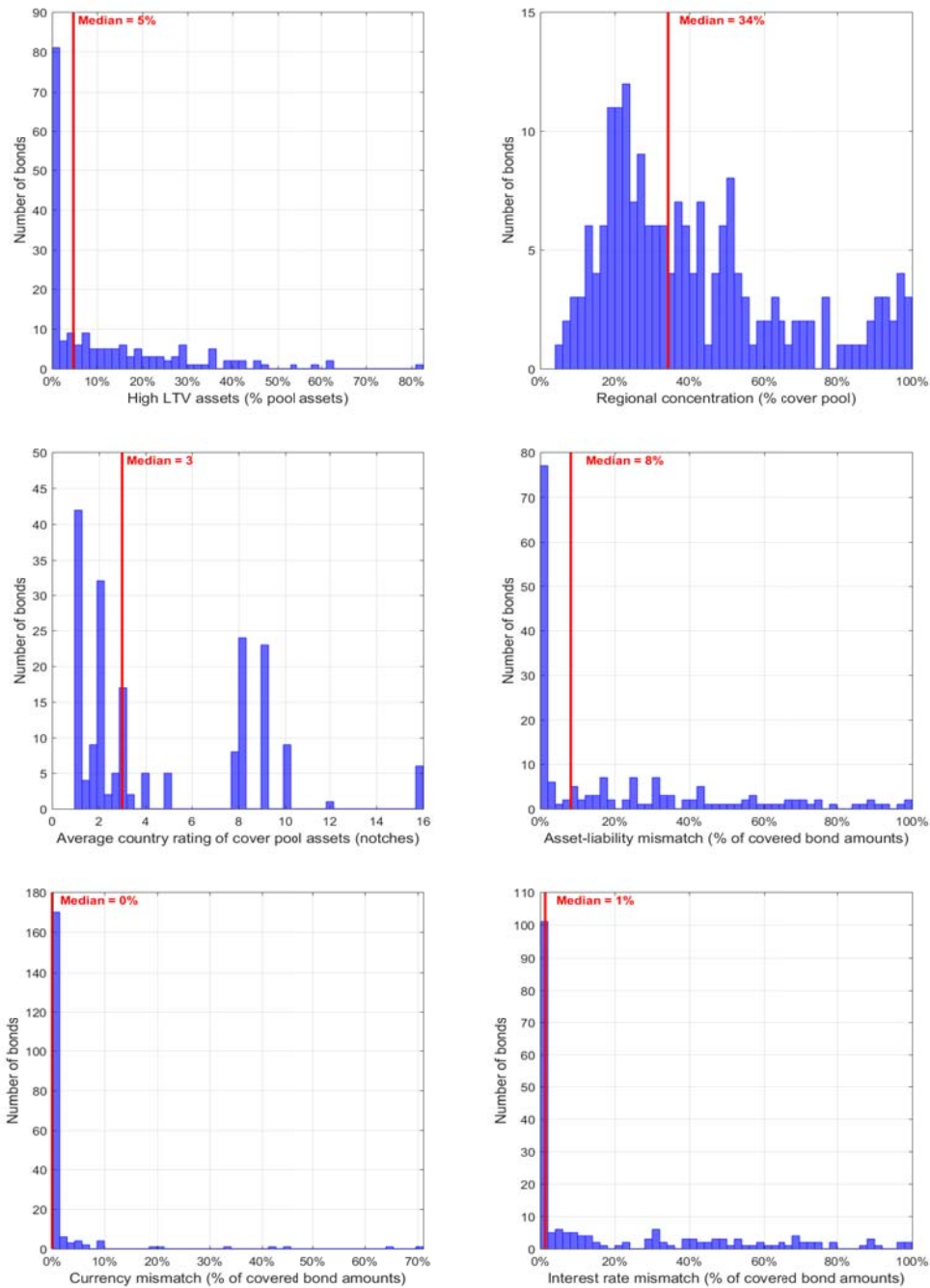


Figure 2: Distributions of covered bond indicators (2/2)

NOTE: The figures show histograms of selected risk indicators (as defined in this section) across all 198 covered bond programmes in the sample. The vertical red lines denote the median.

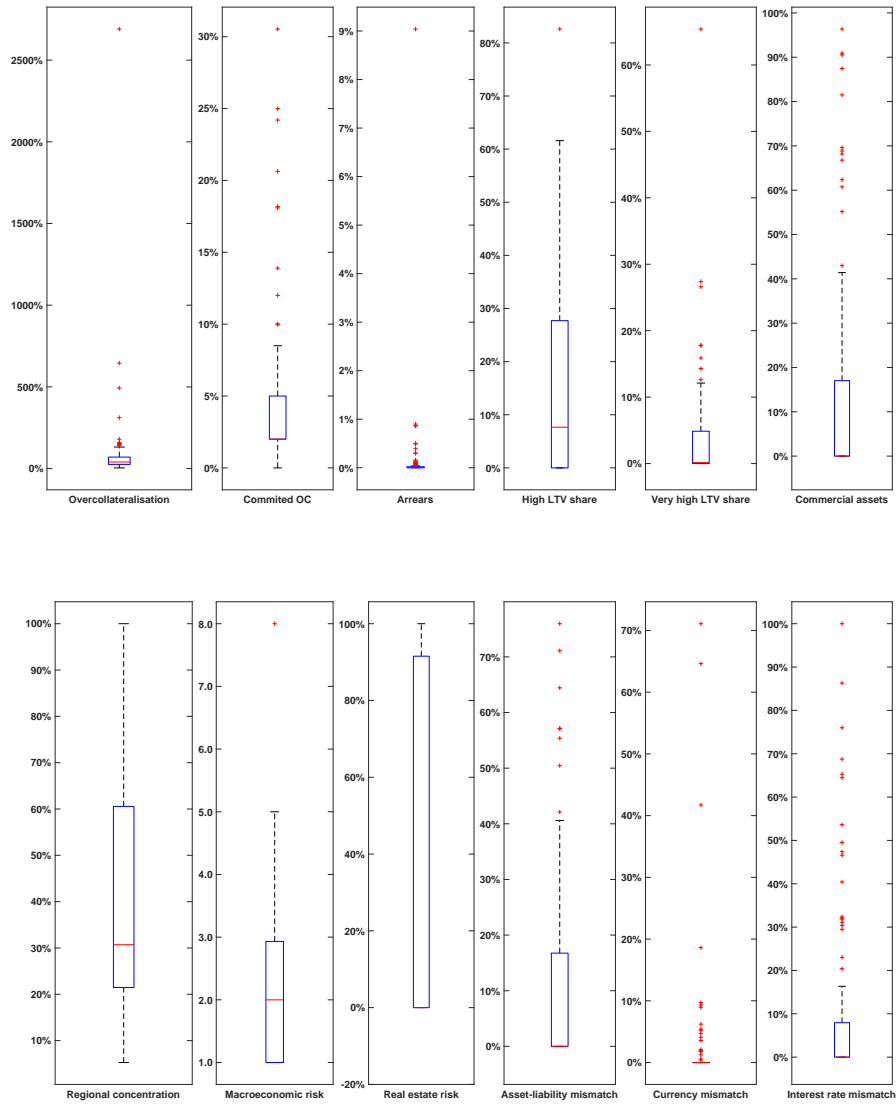


Figure 3: Distributions of covered bond risk indicators within the highest rating class

NOTE: The figure shows the standard box-plot distributions of risk indicators within the highest rating class (Aaa in Moody's terminology and AAA in the Fitch, S&P and DBRS terminology, see also Table A-1 in Annex A). The number of bonds with the highest rating is 101 (out of 198 bonds in the dataset). On each box, the red central mark is the median, the edges of the box are the 25th and 75th percentiles, the whiskers extend to the most extreme data points not considered outliers, and outliers are plotted individually as red crosses. Points are drawn as outliers if they are larger than  $q_3 + 1.5(q_3 - q_1)$  or smaller than  $q_1 - 1.5(q_3 - q_1)$  where  $q_1$  and  $q_3$  are the 25th and 75th percentiles, respectively. The visual representation of the data in this figure (including marking some data points as outliers) is for visualisation purposes only and has no relevance for the descriptive statistics or model-based approaches applied in this paper.



As the first insight, the overview shows that the proposed granular risk indicators extend the universe of comparable covered bonds to the whole European market (see the column with the number of observations in Tables 5 and 6, as compared to the partial coverage of these bonds by specific credit rating agencies). Most indicators are available for 198 bonds, while indicators specific for credit rating agencies cover a much smaller fraction of the market (see, e.g., the coverage for the indicators specific for the credit rating agencies).

The cross-country overview of the markets shows also important heterogeneities (see, e.g., the number of bonds, main asset type and maturity type per country in Tables 5 and 6). For example, some markets are dominated by soft bullet and pass-through structures (e.g., Italy), while other markets include mainly hard bullet bonds (e.g., Germany, Spain and Austria). The markets are also heterogeneous with respect to the main asset type classes, with some countries having all, residential, commercial and public sector covered bonds, and other countries rather focused on residential covered bonds.<sup>15</sup>

With respect to the credit ratings, the descriptive statistics in Tables 5 and 6 and Figure 1 show that covered bonds are on average rated 5 notches above the issuer. If one takes also the leeway into account, i.e. the buffer of the covered bond rating with respect to the issuer rating (as defined in Table 2), covered bonds are rated on average 8 notches above the issuer rating, i.e. almost the whole span of the investment grade class (which is 10 notches). The median uplift including leeway varies somewhat across countries, being close to or exceeding 8 notches in German, Italian, Austrian and French covered bond markets. In result, while the issuer rating of the analysed covered bond universe is rather broadly distributed, with the median rating of 8 (i.e., Baa1 in Moody's terminology, BBB+ in the Fitch and S&P terminology and BBBhigh in the DBRS terminology, see Table A-1 in Annex 1), the covered bond rating is highly concentrated in the highest rating class with 101 out of 198 bonds rated AAA by all

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<sup>15</sup>For this reason, the average values of risk indicators for specific countries need to be interpreted together with the information on the distribution of asset types across covered bonds in these countries.

agencies which rate the respective bonds (see Tables 5 and 6 and Figure 1).

The very high uplift of ratings that most covered bonds receive as compared to the rating of the issuer is a significant feature of the market. It enables a variety of relatively weaker-rated issuers obtain funding at better terms via issuing highly-rated covered bonds. This may not be surprising, when taking into account the nature of the covered bond as an instrument with two layers of protection: issuer and the cover pool. Correspondingly, the high rating of the covered bond often reflects high overcollateralisation available in the cover pool. At the same time, one needs to keep in mind that the overcollateralisation ascribed to a covered bond is not equal to the overcollateralisation which is actually committed to be available in the cover pool in the case of issuer default. In fact, Tables 5 and 6 shows that while the median European covered bond is overcollateralised by 43%, the committed median overcollateralisation is 5%. These values vary across countries and across bonds, but the difference is usually very significant. Also Figure 3 shows that even among the bonds with the AAA rating the actually committed overcollateralisation is much lower than the distribution of nominal overcollateralisation. In fact, for most AAA-rated bonds committed overcollateralisation is below 5% of the bond value, with median being 2%. This shows how important it is to be able to analyse further characteristics of the covered bond, going beyond the credit rating and the overcollateralisation towards more granular information on the cover pool and cash flow mismatches.

Turning to selected pieces of more granular information on covered bond risk characteristics, the data shows a number of interesting stylised facts. In particular, Figure 3 presents an overview of selected granular risk indicators within the highest rating class, encompassing 101 out of 198 bonds in the dataset, showing how much additional valuable information on particular aspects of vulnerabilities is provided by granular covered bond risk indicators beyond the sole credit rating.

The risk indicators show that some market segments are characterised by non-negligible shares of relatively risky assets in the cover pool. For example, the indicator of assets in arrears shows that, while most covered bonds indicate no arrears in the pool (e.g.,

median for the whole sample is 0%), there is quite a number of issues with relatively high shares of arrears in the pool (see Figures 1-2 and Figure 3 for an overview within the highest rating class). For example, the Spanish covered bond market is characterised by the median of 7% of cover pool assets in arrears. Figure 1 shows also that there are instances of covered bonds with a pool in arrears of above 5% or even 10%. Even among the covered bonds with the highest rating, some bonds have a significant share of past-due loans in the asset pool. This is particularly interesting in view of the fact that issuers can (and usually do) reshuffle the cover pool to maintain the best quality loans and thus obtain the highest rating.

Further risk characteristics are related to the distributions of loan-to-value ratios across loans in the cover pool. The risk indicators show that some covered bonds are based on pools with a significant share of high-LTV loans. For example, Figure 2 shows that in some cases, over half of the cover pools are composed of loans having the loan-to-value ratio of above 80%. In aggregate, such high LTV loans constitute a relatively significant share in some covered bond markets. For example, a median French covered bond has around one-fifth of cover pool assets which have high LTV ratios exceeding 80% (labelled as "high LTV loans"). As another example, a median Spanish covered bond has around 3% of cover pool assets with LTV ratios of over 100% (labelled as "very high LTV loans"). Figure 3 shows that even among the highest-rated covered bonds, there are many with the significant share of high or very high LTV loans in the cover pool. For example, for some AAA-rated bonds, over 10% of the cover pool consists of loans with the loan-to-value of above 100%.

In terms of the concentration of cover pool assets across geographical regions (meaning units smaller than countries), usually cover pools are diversified somewhat. However, there are many instances of bonds, even those with the highest rating, with highly concentrated cover pools (see Tables 5 and 6 and Figures 1 - 3). For example, some bonds have cover pools fully or almost fully concentrated in only one region, which may increase correlation among assets in the pool and thus the vulnerability to idiosyncratic shocks.

With respect to risk characteristics related to the mismatches between cash flow promised by the covered bond and the cash flows generated by the cover pool, we can focus on mismatches in terms of maturity, interest rate fixation and the currency. As in the case of other characteristics of the cover pool, the mismatches become relevant in the case of an issuer default. They can thus provide additional information on the vulnerabilities embedded in a covered bond, which can be compared across the whole asset class. Tables 5 and 6 shows that for the European covered bonds, on average 20% of the promised cash flows over a 5-year period are not covered by the corresponding cover pool cash flows. In some cases, the asset-liability mismatch reaches very high levels close to the full face value of the covered bond, even for the bonds rated AAA (see Figures 2 and 3). Moreover, a number of covered bonds is characterised by significant interest rate or currency mismatches (see Tables 5 and 6 and Figures 2 and 3).<sup>16</sup> For example, some AAA-rated covered bonds promise cash flows in a currency different than over half of the cash flows generated by the corresponding cover pools. Finally, a significant number of bonds have built-in options allowing the extension of the repayment period (so-called soft bullet or pass-through structures), which may further delay the repayment flows in the case of an issuer default (see Tables 5 and 6).

Overall, the data shows a significant heterogeneity of covered bond programmes with respect to various dimensions of their risk characteristics, including, e.g., the cover pool risks and mismatches between the covered bond and cover pool cash flows. At the same time, due to the nature of the covered bond as a financial product with double protection, as well as reflecting substantial overcollateralization of the cover pool beyond the covered bond value, the credit ratings of these instruments tend to be relatively high, with 101 out of 198 bonds rated AAA. Consequently, some particular aspects of risk-related information available from the proposed granular indicators, which could be of interest from the perspective of particular investor's risk preferences, may provide useful

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<sup>16</sup>Please note here that the detailed information on currency and interest rate swap values and the credit quality of swap counterparties is not available for a majority of the data. Figure C-1 in Annex C illustrates that the effect of hedging on the currency and interest rate mismatches may be relatively limited, as based on the data from one credit rating agency where the information on the currency and interest rate exposures before and after swap is provided.

information and enable a better risk monitoring and comparability within the European covered bond market.

### 3.3 Illustration of application

As a stylised example of an application of risk indicators for monitoring purposes, we present how the data allows for a comparison of bonds with respect to a set of risk indicators. The indicators used here need to be treated as an example of an information set which could be relevant for investors or other market participants. The exact definition, selection and weighting of indicators need to be chosen from the perspective of individual market participant's preferences. For example, some participants could be interested in analysing only covered bond credit ratings and, additionally, concentration risks, while others could see also, e.g., cash flow mismatch aspects as relevant from their perspective. Here, we show a stylised example using all risk indicators, without any additional restrictions on their relevance.<sup>17</sup>

As an example, we choose to compare two residential mortgage covered bonds from the same country, both rated AAA, with respect to the proposed granular risk indicators, as described earlier in this section. Beyond the value of the indicator, we also include a measure to account for a relative position of the bond within the distribution of its rating class. To this end, we compute a simple rank,  $R_{b,v}$  for bond  $b$  and risk indicator  $v$ , defined as:

$$R_{b,v} = \left( \frac{\sum_{j=1}^{J_v} I(v_j < v_b) + t_{b,v}}{J_v} \right) * 100\%, \quad (7)$$

where  $I$  is the indicator function,  $j$  is the index of all bond observations for a given risk indicator,  $J_v$  denotes the number of observations for a given risk indicator. The variable  $t$  is set to one for the instances where there are several ( $n$ ) bonds with the same observation at the value  $v_b$ , i.e.,  $t_{b,v} = 1$  if  $\sum_n I(v_n = v_b) > 0$ . This ensures

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<sup>17</sup>We use here only the granular indicators proposed in this paper, as they are comparable across the whole covered bond universe. The indicators specific for credit rating agencies are only covering parts of the market.

that the  $n$  bonds with the same risk indicator value ( $v_b$ ) have the same rank among themselves, which is only one step higher than that of the bond with the next lower indicator value. The relative rank gives only information about the positioning of the bond within a distribution of a given risk indicator, but does not say anything about the absolute value of an indicator.<sup>18</sup> Therefore, both pieces of information should be taken into account, when assessing characteristics of a given covered bond programme, as based on a given indicator.

An example comparing two bonds with respect to several indicators is illustrated in Table 7, as well as in Figure 4, which also puts the indicator values into the perspective of distributions within the highest rating class. The example illustrates how different two bonds can be with respect to various risk characteristics. For example, one bond has 40% of cover pool assets with loan-to-value ratios exceeding 80%, as well as high asset-liability and interest rate mismatches. The other bond has a relatively low issuer rating, as well as high concentration of asset exposures to one geographical region, as well as to the commercial real estate sector. As a broader outlook, market participants could also use such risk indicators to build a more complex risk assessment frameworks, suited to their individual preferences, and thus complementing the assessment provided by the credit rating agencies. Still, even single risk indicators may offer useful signals from the market participant perspective.

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<sup>18</sup>A related methodology is also applied in other economic contexts, e.g., systemic risk monitoring of economic and financial vulnerabilities. For some examples, see Bengtsson, Grothe, and Lepers (2020) and the references therein. The rank for overcollateralization indicators is adjusted by  $1 - R_{b,v}$  to result in higher values for less-overcollateralised bonds. For a more detailed overview of indicator ranks, see also the correlation matrix in Table B-4 in Annex B.

Risk indicators	Bond 1			Bond 2		
	Indicator value	Indicator value: difference to median	Relative rank	Indicator value	Indicator value: difference to median	Relative rank
<b>Issuer risk</b>						
Issuer rating	6	0	43%	9	3	96%
<b>Overcollateralisation</b>						
Overcollateralisation	40%	0%	50%	38%	-2%	53%
Committed overcollateralisation	0%	-2%	99%	0%	-2%	99%
<b>Cover pool risk</b>						
Arrears	0%	0%	1%	0%	0%	1%
High LTV assets	40%	33%	91%	13%	6%	55%
Commercial assets	6%	6%	71%	43%	43%	88%
Regional concentration	28%	-3%	43%	52%	21%	71%
Macroeconomic risk of assets	2	0	49%	2	0	49%
Real estate risk	94%	94%	76%	57%	57%	67%
<b>Cash flow mismatch</b>						
Asset-liability mismatch	76%	76%	100%	10%	10%	73%
Currency mismatch	0%	0%	1%	1%	1%	82%
Interest rate mismatch	86%	86%	99%	69%	69%	97%
<b>Maturity type</b>	<b>hard bullet</b>			<b>hard bullet</b>		

Table 7: Example of risk comparison of two covered bond programmes rated AAA

NOTE: The table shows a stylised comparison of two examples of covered bond programmes within the distributions of risk indicators within the highest rating class (Aaa in Moody's terminology and AAA in the Fitch, S&P and DBRS terminology, see also Table A-1 in Annex A). The selected programmes have the same main asset type (residential) and the issuers are based in the same country (Austria). The first column presents the indicator value, the second column presents the absolute deviation of the indicator value from the median, and the third column presents the relative rank of the indicator,  $R_{b,v}$ , as defined in Section 3. The choice of indicators is for illustrative purposes only, not restricted by any specific criteria. Indicator categories, as discussed in Section 2, marked in grey rows.

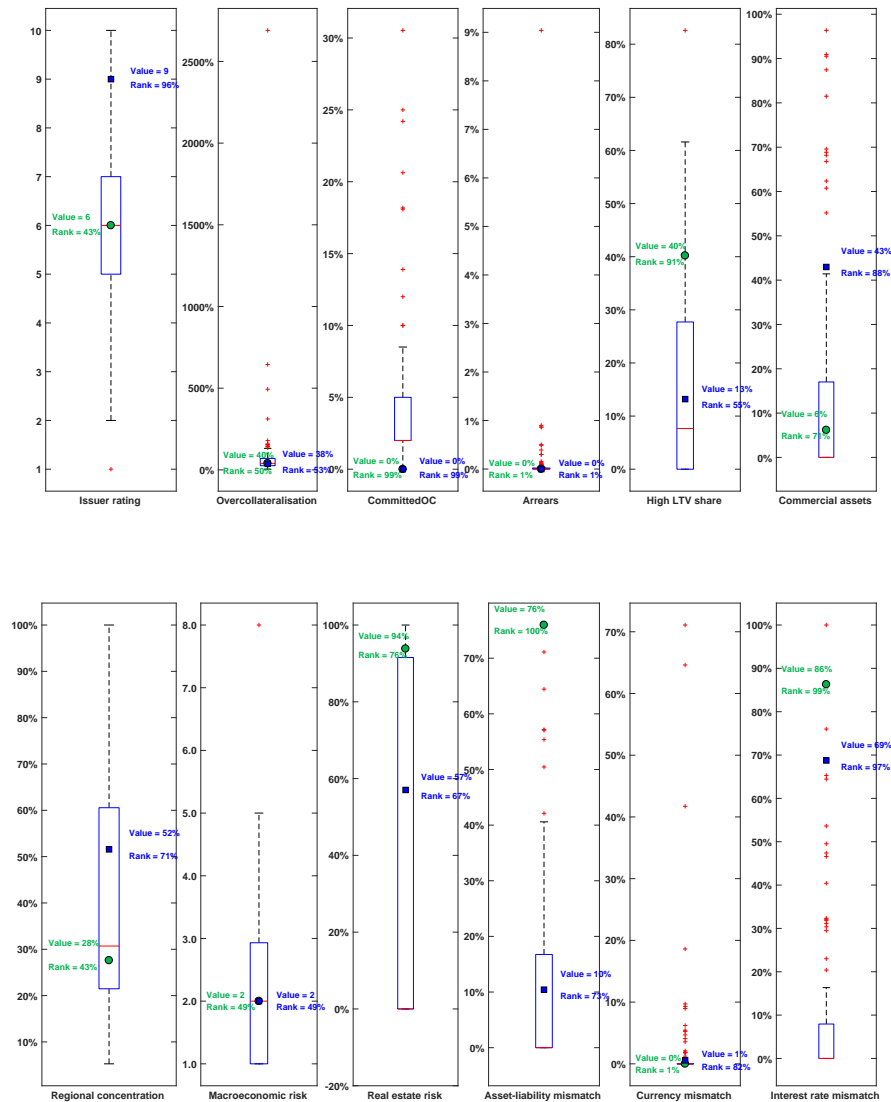


Figure 4: Example of risk comparison of two covered bond programmes rated AAA

NOTE: The figure shows a comparison of two examples of covered bond programmes within the standard box-plot distributions of risk indicators within the highest rating class (Aaa in Moody’s terminology and AAA in the Fitch, S&P and DBRS terminology, see also Table A-1 in Annex A). The selected programmes have the same main asset type (residential) and the issuers are based in the same country (Austria). The labels refer to the value of the indicator and the relative rank of the indicator,  $R_{b,v}$ , as defined in Section 3. The number of bonds with the highest rating is 101 (out of 198 bonds in the dataset). On each box, the red central mark is the median, the edges of the box are the 25th and 75th percentiles, the whiskers extend to the most extreme data points not considered outliers, and outliers are plotted individually as red crosses. Points are drawn as outliers if they are larger than  $q_3 + 1.5(q_3 - q_1)$  or smaller than  $q_1 - 1.5(q_3 - q_1)$  where  $q_1$  and  $q_3$  are the 25th and 75th percentiles, respectively. The visual representation of the data in this figure (including marking some data points as outliers) is for visualisation purposes only and has no relevance for the descriptive statistics or model-based approaches applied in this paper.



## 4 Model-based robustness checks

This section explores further to which extent the information content provided by the granular risk indicators proposed in this paper may be already included in the outcomes of credit rating agencies' assessments. The section starts with a unilateral correlation analysis between credit ratings and granular risk indicators, turning further to a more systematic regression approach as well as the least absolute shrinkage and selection operator algorithm. Within the set of granular risk indicators, the results of this section highlight those which are most correlated with the credit ratings and are thus least likely to provide new information content. These are in particular the issuer rating, nominal overcollateralisation and the macroeconomic risk relevant for the cover pool.

### 4.1 Correlation analysis

Credit rating agencies document their methodologies for the covered bond ratings, reviewing relevant aspects of the cover bond risks and employing models based on detailed loan-level information (see, e.g., Moody's (2016), FitchRatings (2016a), Standard & Poor's (2015 and 2014), and DBRS (2017a)). For the loan-level data, a detailed credit and liquidity analysis can be conducted, the outcome of which is summarised in the credit rating. Market participants, however, do not have the access to loan-level data, but the transparency data offers a possibility to analyse some risk characteristics, for example using the risk indicators proposed in this paper. From market participants' perspective, the question thus arises to which extent the granular risk indicators are correlated with the credit ratings, and are thus relatively less likely to carry information beyond them.

To gain the first impression of relations between covered bond risk indicators and the credit ratings ascribed to the covered bonds by the credit rating agencies, Figures 5 and 6 show simple one-variable dependencies of the following form:

$$CR_i = \alpha + \beta * RI_i + \varepsilon_i, \tag{8}$$

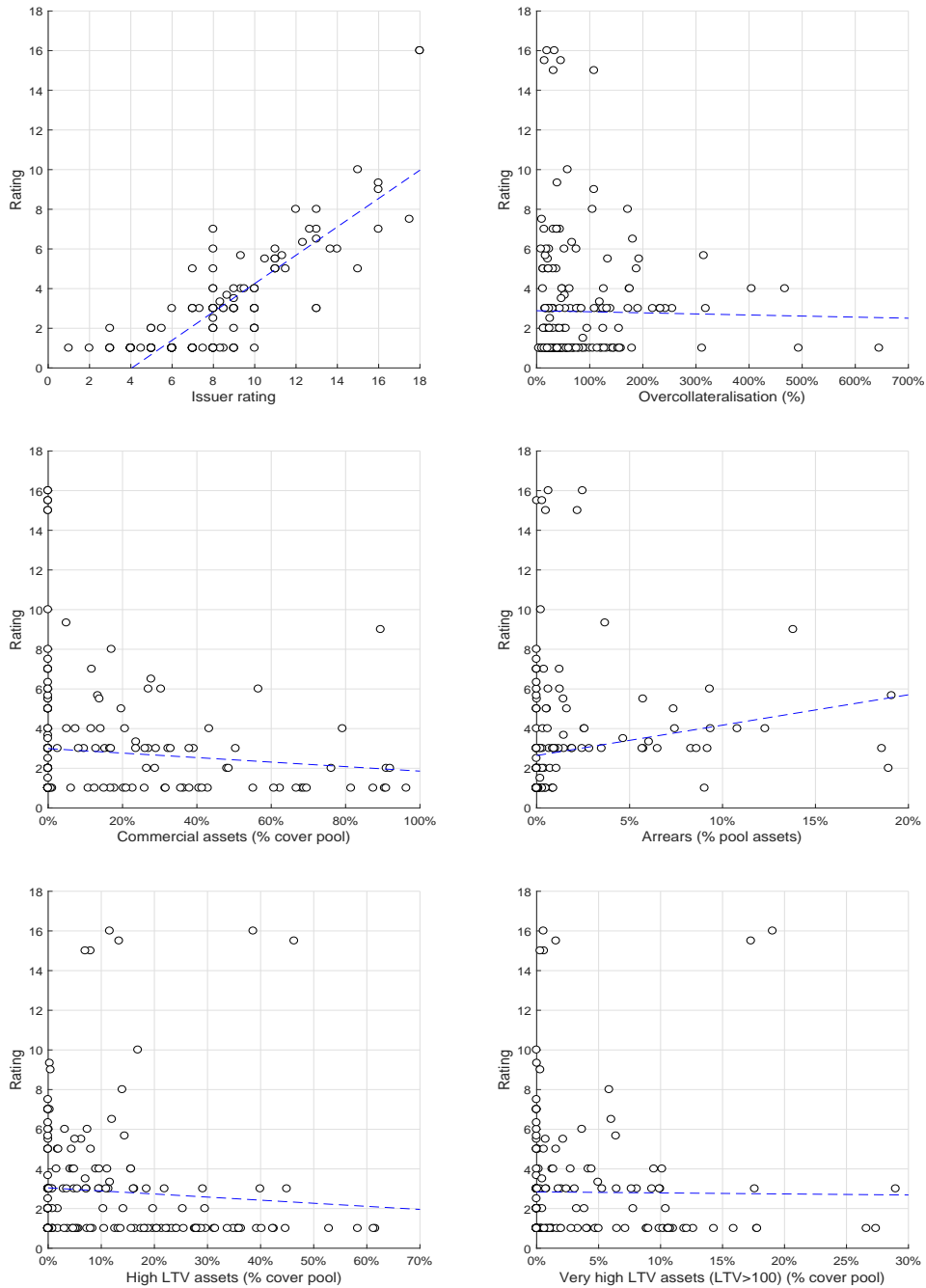


Figure 5: Indicator relations with the covered bond rating (1/2)

NOTE: The figures show the relationship between risk indicators, as defined in this section, (x-axes) and covered bond ratings (y-axes). Blue lines denote the regression lines resulting from simple univariate regressions of ratings on given risk indicator values.

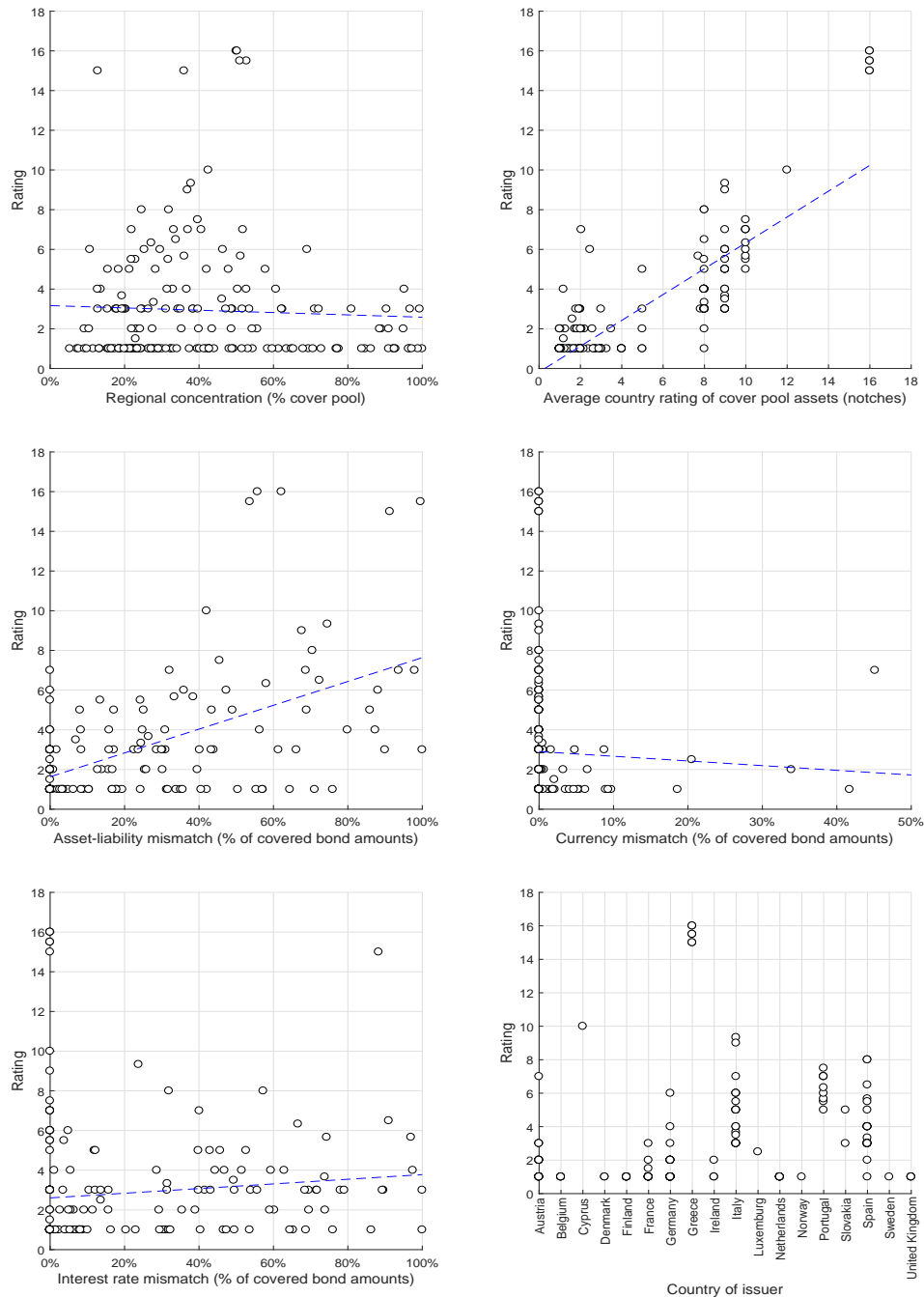


Figure 6: Indicator relations with the covered bond rating (2/2)

NOTE: The figures show the relationship between risk indicators, as defined in this section, (x-axes) and covered bond ratings (y-axes). Blue lines denote the regression lines resulting from simple univariate regressions of ratings on given risk indicator values. The bottom right chart visualises the relationship between the covered bond ratings and the issuer's country.

where  $CR_i$  denotes the credit rating of a given covered bond,  $RI_i$  denotes the value of a chosen risk indicator for the bond  $i$ ,  $\alpha$  is the constant,  $\beta$  is the slope coefficient and  $\varepsilon_i$  is the error term.

Figures 5 and 6 illustrate that in particular the issuer rating and the macroeconomic risk of the cover pool seem to be correlated with the covered bond ratings. Most other risk indicators seem to be rather weakly correlated with the covered bond ratings. For example, the share of commercial assets, the share of pool with high LTV values or regional concentration depict rather flat regression lines in Figures 5 and 6. The scatter plots also illustrate a large variability of indicators within the credit rating classes, for example in terms of the high-LTV cover pool assets or the share of assets in arrears. A similar picture is reflected in the correlation matrix of the variables presented in Tables B-1 to B-3 in Annex B. Already this overview of simple one-to-one relations with the covered bond ratings suggests that some risk indicators may have a potential to carry relevant information, in particular for market participants interested in certain risk dimensions like, e.g., concentration risk or loan-to-value ratios of cover pool exposures.

## 4.2 Regression analysis

To analyse in a more systematic way to which extent the variability in the risk indicators across covered bonds may be already reflected by the variability of credit ratings across covered bonds, we conduct a series of cross-section regressions for the set of covered bond programmes in our universe, where risk indicators are independent variables and credit ratings are dependent variables. This approach allows us to account for interdependencies among various risk indicators, going beyond the results of unilateral checks in the previous section.

In view of the set of several risk indicators to be analysed for a sample of 198 European covered bonds, we face a common issue of model uncertainty and potential for a variable selection bias and/or overfitting. For example, 24 risk indicators<sup>19</sup> can be

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<sup>19</sup>The example includes variables defined in Section 2, including 3 dummy variables for various maturity structures, i.e. hard bullet, soft bullet and pass-through bonds.

written to 42504 various models with 5 variables, 10626 models with 4 variables and 2024 models with 3 variables. Even if we introduce variable choice restrictions, e.g., by taking only one indicator per risk category and taking only one indicator from the pairs correlated by more than 0.7, we still receive 360 various models with 5 variables, 792 models with 4 variables and 584 models with 3 variables, all of which could be plausible and economically reasonable.<sup>20</sup> Given 198 observations, 4 variables result in 5 model parameters (this includes the constant), which corresponds to ca. 40 observations per parameter. With 6 variables, we receive ca. 28 observations per parameter, which is still probably large enough to avoid overfitting, leaving some buffer for the instances where values for some bonds and some risk indicators are missing. An example of one of possible models would be as follows:

$$CR_i = \alpha + \sum_{k=1}^K \beta_k * RI_i^k + \varepsilon_i, \quad (9)$$

where  $CR_i$  denotes the credit rating of a given covered bond,  $RI_i^k$  denotes the value of the risk indicator  $k$  for the bond  $i$ ,  $K$  is the number of risk indicators chosen for the regression,  $\alpha$  is the constant,  $\beta_k$  is the vector of slope coefficients and  $\varepsilon_i$  is the error term.

To overcome the issue of model uncertainty, we choose to analyse a broad set of possible models to draw conclusions about the information content of our risk indicators beyond the credit ratings. We analyse all 3- and 4-element combinations of risk indicators from various risk categories as independent variables, including restrictions on the variable choice. In particular, we allow the models to include only one variable for overcollateralization, maturity type and credit rating agency-specific cover pool risk indicators, as well as up to two cash flow mismatch variables and up to three cover pool risk variables. We also exclude the joint use of variable pairs correlated by more than 0.7, which binds only for the issuer risk and the macroeconomic risk of the pool. These restrictions help

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<sup>20</sup>The fact that there are fewer model combinations with 5 variables than with 4 and 3 variables can be explained by the number of categories possible to choose from (i.e., 5 in our example, where we additionally define a subcategory with agency-specific indicators). This constrains the number of choices for 5-variable selection considerably.

avoid estimating regressions with potential multicollinearity issues as well as with a smaller number of observations. The single regressions are estimated with OLS, which seems to be sufficient in view of the restrictions on the number and correlation of variables chosen in each iteration. Our approach to analyse a wide set of possible models is broadly similar in spirit to other approaches commonly applied to economic problems where there is a large set of possible explanatory variables.<sup>21</sup>

We run this analysis for several versions of dependent variables to ensure the broad overview of results. We use the credit rating (denoted above  $CR_i$ ) and ratings uplifts, i.e., the differences of the covered bond rating and the issuer rating, both including and excluding leeway. Including rating uplifts in our analysis enables us to check the results also for the case where the strong correlation between the issuer rating and the covered bond rating is at least partly accounted for (see also Table B-1 in Annex B). For these regressions, we exclude the issuer rating from the set of explanatory variables. Also, we adjust the covered bond rating by the information on leeway, i.e. the buffer of the covered bond rating with respect to the issuer rating (as defined in Tables 2 - 4). Adding leeway to the rating allows us to account for potentially important piece of information on the actual number of notches by which the issuer can be downgraded before the covered bond gets downgraded. It results also in a more granular rating scale, in particular for the AAA-rated bonds.

To generate an informative overview of results, we summarise the explanatory power of each of our risk indicators across regressions. For each risk indicator and within top 25% regressions with the highest  $R^2$ , we analyse the share of regressions where the indicator is significant, as well as the median p-value and median coefficient of significant estimates. The results for all regressions are qualitatively similar and are available upon request.

Tables 8-11 show the results for the covered bond rating, as well as for the covered bond rating uplift as dependent variables, respectively. Overall, the results show that key indicator correlated with the covered bond ratings includes the issuer credit rating.

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<sup>21</sup>For example, broadly related techniques have been applied in the context of the euro area stress tests (see, e.g., Gross, Georgescu, and Hilberg (2017) and Henry and Kok (2013, Box 1 by M. Gross), as well as Gross and Población (2017 and 2015)).

Also, the macroeconomic risk of the cover pool assets seems to be relatively highly correlated with the covered bond credit ratings, also when entering into regressions along other variables. High significance in a large number of regressor combinations can be also observed for the variables which are specific to credit rating agencies, i.e. the timely payment indicator of Moody's, the payment continuity uplift of Fitch, the target credit enhancement of S&P and, to a somewhat lower extent due to the number of observations, the cover pool credit assessment of DBRS (see also Tables 2 - 4 for definitions). Further risk indicators that are in some cases correlated with the credit ratings refer to the overcollateralisation.

The regressions results show also that some variables seem to be less correlated with the credit ratings. For example, some features related to the cover pool risks like the share of high LTV loans and arrears in the pool, as well as the share of commercial assets and regional concentration seem to be only weakly correlated with the overall covered bond rating uplifts (and ratings) in a systematic way (see Tables 8-11). Also most variables related to cash flow mismatches, like the asset-liability mismatch, as well as currency and interest rate mismatches seem to be not significant for explaining the credit rating variation. This result is in line with the findings of Section 3 showing how these variables vary within the same rating class, as well as the one-to-one correlations described earlier in this section.

We check the robustness of these findings for other specifications, repeating the exercise for 5-variable and 6-variable combinations. For completeness, we also present the results, including asset-type and country-related variables. The results are qualitatively similar (see Tables 8-11 and Tables in Annex D and Annex E).<sup>22</sup>

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<sup>22</sup>As further robustness checks, we also repeated the analysis for the data subset encompassing information from only one credit rating agency with the largest number of covered bond programmes rated (i.e., Moody's, see also Table 1), and the results are qualitatively the same.

Risk indicators	Rating incl. leeway							
	4-var				3-var			
	% reg's where indicator significant	median p-value	median coeff. if significant	number of regressions	% reg's where indicator significant	median p-value	median coeff. if significant	number of regressions
<b>Issuer risk</b>								
Issuer rating	100%	0.00	0.93	1116	100%	0.00	0.94	211
<b>Overcollateralisation</b>								
Overcollateralisation	15%	0.50	0.01	232	6%	0.50	0.02	32
Committed Overcollateralisation	22%	0.31	0.07	241	49%	0.17	0.07	43
<b>Cover pool risk</b>								
Arrears	84%	0.08	0.17	316	83%	0.09	0.17	60
High LTV assets	55%	0.24	-0.08	272	61%	0.22	-0.05	38
Very high LTV assets	11%	0.45	0.05	236	9%	0.45	0.05	33
Commercial assets	21%	0.48	0.08	236	18%	0.49	0.06	33
Regional concentration	11%	0.56	0.01	225	6%	0.67	0.01	33
Macroeconomic risk of assets	99%	0.01	0.60	153	100%	0.00	0.69	110
Real estate risk	31%	0.31	-0.02	244	29%	0.30	-0.02	34
Collateral score (Moody's)	9%	0.51	0.04	116	3%	0.59	0.04	32
Cover pool losses (Moody's)	99%	0.00	0.05	117	50%	0.39	0.05	32
Timely payment indicator (Moody's)	98%	0.00	1.08	118	69%	0.07	0.90	32
Payment continuity uplift (Fitch)	100%	0.00	-0.85	308	100%	0.00	-0.92	65
Cover pool credit assessment (DBRS)	0%	0.59	0.00	66	0%	0.77	0.00	17
Target credit enhancement (S&P)	64%	0.12	0.06	365	92%	0.03	0.07	63
<b>Cash flow mismatch</b>								
Asset-liability mismatch (3 years)	29%	0.36	0.05	290	52%	0.22	0.05	60
Asset-liability mismatch (5 years)	74%	0.14	0.04	341	87%	0.06	0.04	63
Currency mismatch	12%	0.42	-1.56	239	9%	0.35	0.04	34
Interest rate mismatch	76%	0.12	0.02	251	70%	0.20	0.02	37
Maturity mismatch	25%	0.37	0.09	231	24%	0.35	0.09	34
<b>Maturity type</b>								
Hard bullet	44%	0.38	0.98	212	44%	0.38	1.06	32
Soft bullet	66%	0.15	0.81	188	57%	0.19	0.74	30
Pass-through	85%	0.05	-0.70	259	79%	0.11	0.15	42

Table 8: Results for covered bond rating (1/2)

NOTE: The table shows the results across regressions with all 4- and 3-variable combinations of risk indicators as independent variables for covered bond rating and covered bond rating including leeway as dependent variables. The results are computed for 25% regressions with the highest goodness of fit (measured by adjusted  $R^2$ ). Risk indicators as defined in Section 2.



Risk indicators	Rating							
	4-var				3-var			
	% reg's where indicator significant	median p-value	median coeff. if significant	number of regressions	% reg's where indicator significant	median p-value	median coeff. if significant	number of regressions
<b>Issuer risk</b>								
Issuer rating	100%	0.00	0.64	1144	100%	0.00	0.65	211
<b>Overcollateralisation</b>								
Overcollateralisation	20%	0.40	0.00	219	15%	0.39	0.00	39
Committed Overcollateralisation	37%	0.26	-0.05	270	45%	0.19	-0.05	38
<b>Cover pool risk</b>								
Arrears	22%	0.35	-0.01	268	17%	0.29	-0.04	42
High LTV assets	8%	0.54	0.00	239	3%	0.54	0.02	40
Very high LTV assets	6%	0.58	-0.03	253	3%	0.57	-0.05	40
Commercial assets	38%	0.20	-0.01	226	20%	0.33	-0.01	40
Regional concentration	4%	0.48	-0.01	226	0%	0.58	0.00	40
Macroeconomic risk of assets	100%	0.00	0.66	435	99%	0.00	0.65	181
Real estate risk	23%	0.29	-0.01	218	12%	0.46	-0.02	41
Collateral score (Moody's)	100%	0.00	0.09	167	100%	0.00	0.08	32
Cover pool losses (Moody's)	95%	0.02	0.04	124	50%	0.27	0.04	32
Timely payment indicator (Moody's)	94%	0.02	0.44	140	84%	0.05	0.20	32
Payment continuity uplift (Fitch)	48%	0.24	-0.14	217	50%	0.22	-0.13	34
Cover pool credit assessment (DBRS)	21%	0.20	0.14	68	73%	0.08	0.17	15
Target credit enhancement (S&P)	94%	0.02	0.03	134	100%	0.00	0.04	23
<b>Cash flow mismatch</b>								
Asset-liability mismatch (3 years)	91%	0.04	0.03	322	95%	0.02	0.03	42
Asset-liability mismatch (5 years)	84%	0.06	0.02	302	93%	0.03	0.02	46
Currency mismatch	29%	0.46	0.07	267	49%	0.33	0.05	43
Interest rate mismatch	34%	0.48	-0.01	244	50%	0.41	-0.01	40
Maturity mismatch	2%	0.49	0.07	248	0%	0.49	0.00	40
<b>Maturity type</b>								
Hard bullet	67%	0.15	-0.19	189	51%	0.22	-0.23	37
Soft bullet	81%	0.11	0.04	225	86%	0.06	-0.09	36
Pass-through	42%	0.21	0.39	227	50%	0.13	1.01	36

Table 9: Results for covered bond rating (2/2)

NOTE: The table shows the results across regressions with all 4- and 3-variable combinations of risk indicators as independent variables for covered bond rating and covered bond rating including leeway as dependent variables. The results are computed for 25% regressions with the highest goodness of fit (measured by adjusted  $R^2$ ). Risk indicators as defined in Section 2.

Risk indicators	Rating uplift incl. leeway							
	4-var				3-var			
	% reg's where indicator significant	median p-value	median coeff. if significant	number of regressions	% reg's where indicator significant	median p-value	median coeff. if significant	number of regressions
<i>Issuer risk</i>								
<i>Issuer rating</i>								
<i>Overcollateralisation</i>								
Overcollateralisation	2%	0.57	0.01	253	12%	0.51	0.01	42
Committed Overcollateralisation	74%	0.12	0.05	278	86%	0.07	0.05	50
<i>Cover pool risk</i>								
Arrears	15%	0.30	-0.11	276	9%	0.27	-0.11	46
High LTV assets	5%	0.41	0.03	258	2%	0.40	0.02	44
Very high LTV assets	0%	0.59	0.00	259	0%	0.59	0.00	39
Commercial assets	0%	0.77	0.00	252	0%	0.81	0.00	37
Regional concentration	34%	0.24	0.01	255	36%	0.21	0.01	42
Macroeconomic risk of assets	14%	0.45	-0.10	226	27%	0.33	-0.21	48
Real estate risk	44%	0.40	0.01	241	41%	0.42	0.01	39
Collateral score (Moody's)	0%	0.54	0.00	3	0%	0.13	0.00	1
Cover pool losses (Moody's)	50%	0.14	-0.03	2	80%	0.19	-0.04	5
Timely payment indicator (Moody's)	100%	0.00	-1.06	693	100%	0.00	-1.06	148
Payment continuity uplift (Fitch)	100%	0.00	0.82	693	100%	0.00	0.81	148
Cover pool credit assessment (DBRS)	0%	0.43	0.00	82	0%	0.47	0.00	15
Target credit enhancement (S&P)	58%	0.16	-0.05	120	79%	0.09	-0.06	76
<i>Cash flow mismatch</i>								
Asset-liability mismatch (3 years)	0%	0.66	0.00	276	0%	0.67	0.00	45
Asset-liability mismatch (5 years)	1%	0.61	0.00	276	2%	0.56	-0.01	47
Currency mismatch	9%	0.59	1.01	288	24%	0.47	0.28	46
Interest rate mismatch	11%	0.52	-0.04	298	26%	0.39	-0.03	50
Maturity mismatch	2%	0.40	0.08	269	11%	0.40	0.04	45
<i>Maturity type</i>								
Hard bullet	8%	0.71	-3.92	224	11%	0.63	-2.03	38
Soft bullet	0%	0.52	0.00	208	5%	0.47	-1.32	37
Pass-through	56%	0.16	3.07	360	65%	0.10	3.29	68

Table 10: Results for covered bond rating uplift vs. issuer (1/2)

NOTE: The table shows the results across regressions with all 4- and 3-variable combinations of risk indicators as independent variables for covered bond rating uplift vs. issuer rating and covered bond rating uplift including leeway as dependent variables. The results are computed for 25% regressions with the highest goodness of fit (measured by adjusted  $R^2$ ). Risk indicators as defined in Section 2.

Risk indicators	Rating uplift							
	4-var				3-var			
	% reg's where indicator significant	median p-value	median coeff. if significant	number of regressions	% reg's where indicator significant	median p-value	median coeff. if significant	number of regressions
<i>Issuer risk</i>								
Issuer rating								
<i>Overcollateralisation</i>								
Overcollateralisation	22%	0.37	0.00	232	14%	0.37	0.00	37
Committed Overcollateralisation	32%	0.26	0.10	302	44%	0.17	0.08	63
<i>Cover pool risk</i>								
Arrears	13%	0.34	-0.05	256	20%	0.30	0.05	50
High LTV assets	21%	0.43	-0.08	268	19%	0.36	-0.08	47
Very high LTV assets	15%	0.51	-0.03	262	15%	0.53	-0.07	41
Commercial assets	37%	0.22	0.00	251	29%	0.22	0.00	42
Regional concentration	6%	0.50	-0.02	265	2%	0.48	-0.06	43
Macroeconomic risk of assets	31%	0.29	0.25	77	41%	0.37	0.17	29
Real estate risk	22%	0.28	0.01	201	16%	0.25	0.00	38
Collateral score (Moody's)	100%	0.00	-0.09	116	100%	0.00	-0.08	16
Cover pool losses (Moody's)	100%	0.01	-0.04	116	100%	0.01	-0.04	16
Timely payment indicator (Moody's)	100%	0.00	-0.53	116	100%	0.00	-0.53	16
Payment continuity uplift (Fitch)	55%	0.12	0.24	252	81%	0.06	0.30	79
Cover pool credit assessment (DBRS)	19%	0.44	-0.18	271	26%	0.40	-0.17	46
Target credit enhancement (S&P)	76%	0.07	-0.04	224	61%	0.13	-0.04	49
<i>Cash flow mismatch</i>								
Asset-liability mismatch (3 years)	76%	0.13	-0.02	243	71%	0.12	-0.01	35
Asset-liability mismatch (5 years)	70%	0.15	-0.01	248	71%	0.13	0.00	41
Currency mismatch	5%	0.60	-1.30	255	2%	0.67	-0.21	41
Interest rate mismatch	8%	0.60	-0.01	240	18%	0.43	0.01	49
Maturity mismatch	6%	0.48	0.05	249	7%	0.51	0.09	42
<i>Maturity type</i>								
Hard bullet	64%	0.19	0.09	181	65%	0.22	0.19	26
Soft bullet	78%	0.12	-1.30	232	76%	0.13	-1.27	34
Pass-through	61%	0.14	2.61	338	84%	0.04	2.61	109

Table 11: Results for covered bond rating uplift vs. issuer (2/2)

NOTE: The table shows the results across regressions with all 4- and 3-variable combinations of risk indicators as independent variables for covered bond rating uplift vs. issuer rating and covered bond rating uplift including leeway as dependent variables. The results are computed for 25% regressions with the highest goodness of fit (measured by adjusted  $R^2$ ). Risk indicators as defined in Section 2.

### 4.3 Least absolute shrinkage and selection operator algorithm

As a final robustness check for the usefulness of the granular risk indicators introduced in this paper, we conduct indicator selection using the least absolute shrinkage and selection operator, or lasso, algorithm.<sup>23</sup> This algorithm allows for selecting a parsimonious set of variables which are significant, as based on an out-of-sample forecast validation.

In the context of our dataset, we try to explore whether some of the granular risk indicators have the out-of-sample predictive power for the covered bond credit ratings. As a result, we can assess the indicators where this predictive power is relatively large, to be relatively closely related to the already available information content of credit ratings in the form of the overall rating or the rating uplift, including or excluding the leeway.

The results of the lasso algorithm are presented in Table 12. This robustness check shows that the indicators which are most often significant across a set of regressions, i.e. the issuer rating as well as the macroeconomic risk of the cover pool assets (see the previous subsection) are also those chosen in the lasso algorithm as most suitable to forecast the credit ratings in an out-of sample setting. Also agency-specific variables of the cover pool risk assessment are good out-of-sample predictors of the credit rating. The bottom row of Table 12 shows that it is in fact possible to build models with only a small subset of the above mentioned chosen indicators, which forecasts the credit rating with around 1 notch of out-of-sample precision. This suggests that the indicators like the issuer rating, the macroeconomic risk of the cover pool assets or credit rating agency-specific cover pool risk assessment are not likely to offer much additional signals beyond the already available credit rating. At the same time, some specific granular indicators of the cover pool do not act as good out-of-sample predictors of the credit rating, which together with the high variability of these indicators within the same rating classes suggests that they may be a useful complementary granular information for risk monitoring purposes.

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<sup>23</sup>For related literature on the lasso algorithm, see also Tibshirani (1996) and Hastie, Tibshirani, and Friedman (2008).

Risk indicators	Rating uplift incl. leeway	Rating uplift	Rating incl. leeway	Rating
<b>Issuer risk</b>				
Issuer rating			+	+
<b>Overcollateralisation</b>				
Overcollateralisation	+	+	+	+
Committed Overcollateralisation	+			
<b>Cover pool risk</b>				
<b>Arrears</b>				
High LTV assets	+		+	
Very high LTV assets				
Commercial assets		+		+
Regional concentration		+		
Macroeconomic risk of assets	+		+	+
Real estate risk		+		+
Collateral score (Moody's)		+		+
Cover pool losses (Moody's)				
Timely payment indicator (Moody's)	+	+	+	+
Payment continuity uplift (Fitch)	+		+	
<b>Cash flow mismatch</b>				
Asset-liability mismatch (3 years)	+			
Asset-liability mismatch (5 years)				+
Currency mismatch				
Interest rate mismatch				
Maturity mismatch		+		
<b>Maturity type</b>				
Hard bullet		+		
Soft bullet				
Pass-through		+		
Root mean squared error	1.1	1.4	0.9	1.4

Table 12: Results of lasso regressions for a set of risk indicators

NOTE: The table shows the results of indicator selection using least absolute shrinkage and selection operator algorithm for risk indicators, defined in Section 2, as independent variables and dependent variables, as specified in column headers (covered bond rating and rating uplift, including and excluding leeway). The markers indicate the set of variables of the most parsimonious model with the minimum mean squared error (computed using 10-fold cross-validation). For related literature on the lasso algorithm, see also Tibshirani (1996) and Hastie, Tibshirani, and Friedman (2008). The bottom row presents the root mean squared error of the selected regression, which can be interpreted as an average out-of-sample forecast error in notches, as compared to the observed covered bond rating or covered bond rating uplift.

## 5 Conclusion

Covered bonds constitute an important asset class, both from the perspective of issuers and investors. In terms of the risk assessment, the analysis of these assets needs to combine the information on the issuer and the cover pool, to some extent resembling the assessment conducted for an unsecured bank bond and an asset-backed security, respectively. This paper analyses indicators that shed some light on the risk profile of covered bonds.

Based on publicly available transparency data on individual covered bond programmes, we propose a set of risk indicators comparable across European covered bonds issued by different issuers and rated by different credit rating agencies. The indicators capture various aspects of cash flow risks, grouped into the following categories: (a) issuer risk, (b) overcollateralization, (c) cover pool risk, (d) mismatches between the covered bond and the cover pool cash flows, and (e) maturity type.

The distributions of risk indicators show the heterogeneity of equally-rated covered bond programmes with respect to their risk characteristics, e.g., cover pool risks and mismatches between the covered bond and cover pool cash flows. Due to the nature of the covered bond as a financial product with double protection, the credit ratings of these instruments tend to be relatively high (101 out of 198 bonds rated AAA). Consequently, some particular aspects of risk-related information available from the granular indicators, which could be of interest from the perspective of particular investor's risk preferences, may provide useful insights and enable a better risk monitoring and comparability within the European covered bond market. These findings are confirmed by a set of regression-based robustness checks. More generally, the availability of granular risk indicators comparable for the European covered bond universe adds to the market transparency in the context of risk monitoring.

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## Annex A: Rating scale

Rating	Moody's	Fitch	S&P	DBRS
1	Aaa	AAA	AAA	AAA
2	Aa1	AA+	AA+	Aahigh
3	Aa2	AA	AA	AA
4	Aa3	AA-	AA-	Aalow
5	A1	A+	A+	Ahigh
6	A2	A	A	A
7	A3	A-	A-	Alow
8	Baa1	BBB+	BBB+	BBBhigh
9	Baa2	BBB	BBB	BBB
10	Baa3	BBB-	BBB-	BBBlow
11	Ba1	BB+	BB+	BBhigh
12	Ba2	BB	BB	BB
13	Ba3	BB-	BB-	Bblow
14	B1	B+	B+	Bhigh
15	B2	B	B	B
16	B3	B-	B-	Blow
17	Caa1	CCC+	CCC+	CCC
18	Caa2	CCC	CCC	CC
19	Caa3	CCC-	CCC-	CC
20	Ca	CC	CC	C
21	C	C	C	C
22		DDD	D	D
23		DD		
24		D		

Table A-1: Rating scale

NOTE: The table shows the rating scales applied by Moody's, Fitch, S&P and DBRS, along with the corresponding number (first column) applied in the analysis. The line in the table marks the split between the investment and non-investment grades.

## Annex B: Indicator correlations

	Risk indicators	1	2	3	4	5	6	7	8	9	10
1	Covered bond amounts	1.0	0.9	-0.2	-0.1	-0.2	-0.2	-0.2	-0.1	-0.2	-0.1
2	Cover pool amounts	0.9	1.0	-0.1	0.0	-0.2	-0.3	-0.1	0.0	0.0	0.1
	<i>Covered bond and issuer ratings</i>										
3	Covered bond rating	-0.2	-0.1	1.0	0.8	0.9	-0.3	0.1	0.8	0.1	0.4
4	Covered bond rating incl. leeway	-0.1	0.0	0.8	1.0	0.8	-0.6	0.5	0.7	0.2	0.4
5	Issuer rating	-0.2	-0.2	0.9	0.8	1.0	0.0	0.6	0.8	0.0	0.4
6	Covered bond uplift vs issuer incl. leeway	-0.2	-0.3	-0.3	-0.6	0.0	1.0	0.3	-0.4	-0.1	-0.1
7	Covered bond uplift vs issuer	-0.2	-0.1	0.1	0.5	0.6	0.3	1.0	0.2	0.0	0.2
8	Country rating	-0.1	0.0	0.8	0.7	0.8	-0.4	0.2	1.0	0.2	0.6
	<i>Overcollateralisation</i>										
9	Overcollateralisation	-0.2	0.0	0.1	0.2	0.0	-0.1	0.0	0.2	1.0	0.3
10	Committed Overcollateralisation	-0.1	0.1	0.4	0.4	0.4	-0.1	0.2	0.6	0.3	1.0
	<i>Cover pool risk</i>										
11	Arrears	0.0	0.0	0.2	0.3	0.2	-0.2	0.2	0.2	0.1	0.2
12	High LTV assets	0.1	0.1	0.0	-0.2	0.0	0.1	0.0	-0.1	0.0	0.0
13	Very high LTV assets	0.0	0.0	0.1	0.1	0.1	0.0	0.1	0.0	0.0	0.1
14	Commercial assets	0.0	0.0	-0.1	0.0	0.0	0.0	0.0	-0.2	0.0	-0.1
15	Regional concentration	-0.3	-0.3	0.0	-0.1	-0.1	0.0	0.0	0.0	0.3	0.0
16	Macroeconomic risk of assets	-0.1	0.0	0.8	0.7	0.7	-0.4	0.1	1.0	0.2	0.5
17	Real estate risk	0.0	-0.1	-0.3	-0.3	-0.3	0.0	-0.2	-0.3	-0.1	-0.1
18	Collateral score (Moody's)	-0.2	-0.1	0.5	0.2	0.4	-0.1	0.0	0.4	0.4	0.6
19	Cover pool losses (Moody's)	-0.1	0.0	0.3	0.4	0.3	-0.3	0.0	0.5	0.3	0.7
20	Timely payment indicator (Moody's)	0.0	0.1	0.3	0.5	0.2	-0.7	-0.1	0.6	0.2	0.3
21	Payment continuity uplift (Fitch)	-0.2	-0.3	-0.1	-0.7	0.1	0.9	0.3	-0.2	-0.4	-0.1
22	Cover pool credit assessment (DBRS)	-0.2	-0.4	0.5	0.3	0.3	0.2	0.0	0.3	-0.1	-0.2
23	Target credit enhancement (S&P)	-0.1	0.1	0.6	0.6	0.4	-0.6	0.0	0.5	0.4	0.4
	<i>Cash flow mismatch</i>										
24	Asset-liability mismatch (3 years)	-0.2	-0.1	0.5	0.3	0.5	-0.1	0.1	0.4	0.0	0.2
25	Asset-liability mismatch (5 years)	-0.1	-0.1	0.5	0.4	0.5	-0.2	0.2	0.4	-0.1	0.2
26	Currency mismatch	0.1	0.1	-0.1	0.0	-0.1	-0.1	0.0	-0.2	-0.1	-0.1
27	Interest rate mismatch	-0.1	0.0	0.3	0.3	0.3	-0.3	0.0	0.4	0.2	0.2
28	Maturity mismatch	-0.1	0.0	0.3	0.2	0.3	-0.1	0.2	0.3	0.0	0.2
	<i>Maturity type</i>										
29	Hard bullet	0.0	0.0	-0.2	-0.1	-0.2	0.1	0.0	-0.3	0.2	0.0
30	Soft bullet	-0.1	-0.2	0.1	0.3	0.0	-0.3	-0.1	0.3	-0.1	-0.1
31	Pass-through	-0.1	-0.1	0.5	0.0	0.5	0.3	0.2	0.3	-0.1	0.2
32	Mixed	0.3	0.2	-0.2	-0.2	-0.2	0.1	-0.1	-0.1	-0.1	0.0
	<i>Main collateral asset type</i>										
33	Residential	0.1	0.2	0.1	0.2	0.2	-0.2	0.1	0.3	0.1	0.2
34	Commercial	-0.1	-0.1	-0.1	-0.1	-0.1	0.0	0.0	-0.2	-0.1	-0.2
35	Public sector	-0.1	-0.2	-0.1	-0.1	-0.2	0.2	0.0	-0.2	-0.1	-0.1

Table B-1: Correlation matrix for risk indicators (1/3)

NOTE: The table shows the correlation matrix for risk indicators, as defined in Section 2.

Risk indicators		11	12	13	14	15	16	17	18	19	20	21	22	23
1	Covered bond amounts	0.0	0.1	0.0	0.0	-0.3	-0.1	0.0	-0.2	-0.1	0.0	-0.2	-0.2	-0.1
2	Cover pool amounts	0.0	0.1	0.0	0.0	-0.3	0.0	-0.1	-0.1	0.0	0.1	-0.3	-0.4	0.1
<i>Covered bond and issuer ratings</i>														
3	Covered bond rating	0.2	0.0	0.1	-0.1	0.0	0.8	-0.3	0.5	0.3	0.3	-0.1	0.5	0.6
4	Covered bond rating incl. leeway	0.3	-0.2	0.1	0.0	-0.1	0.7	-0.3	0.2	0.4	0.5	-0.7	0.3	0.6
5	Issuer rating	0.2	0.0	0.1	0.0	-0.1	0.7	-0.3	0.4	0.3	0.2	0.1	0.3	0.4
6	Covered bond uplift vs issuer incl. leeway	-0.2	0.1	0.0	0.0	0.0	-0.4	0.0	-0.1	-0.3	-0.7	0.9	0.2	-0.6
7	Covered bond uplift vs issuer	0.2	0.0	0.1	0.0	0.0	0.1	-0.2	0.0	0.0	-0.1	0.3	0.0	0.0
8	Country rating	0.2	-0.1	0.0	-0.2	0.0	1.0	-0.3	0.4	0.5	0.6	-0.2	0.3	0.5
<i>Overcollateralisation</i>														
9	Overcollateralisation	0.1	0.0	0.0	0.0	0.3	0.2	-0.1	0.4	0.3	0.2	-0.4	-0.1	0.4
10	Committed Overcollateralisation	0.2	0.0	0.1	-0.1	0.0	0.5	-0.1	0.6	0.7	0.3	-0.1	-0.2	0.4
<i>Cover pool risk</i>														
11	Arrears	1.0	0.5	0.5	0.0	0.0	0.1	-0.1	0.1	0.1	0.0	-0.1	-0.4	0.6
12	High LTV assets	0.5	1.0	0.7	0.0	-0.1	-0.1	0.2	0.0	0.0	0.0	0.3	-0.4	-0.3
13	Very high LTV assets	0.5	0.7	1.0	0.1	0.0	0.0	0.1	0.1	0.0	0.1	0.1	-0.3	-0.1
14	Commercial assets	0.0	0.0	0.1	1.0	0.0	-0.1	-0.1	0.2	0.1	-0.2	-0.2	-0.1	0.2
15	Regional concentration	0.0	-0.1	0.0	0.0	1.0	-0.1	0.0	0.2	0.1	0.1	0.0	-0.1	0.3
16	Macroeconomic risk of assets	0.1	-0.1	0.0	-0.1	-0.1	1.0	-0.3	0.4	0.5	0.6	-0.2	0.3	0.4
17	Real estate risk	-0.1	0.2	0.1	-0.1	0.0	-0.3	1.0	-0.3	-0.1	0.2	0.4	0.0	-0.3
18	Collateral score (Moody's)	0.1	0.0	0.1	0.2	0.2	0.4	-0.3	1.0	0.7	0.2	-0.2	-0.1	0.6
19	Cover pool losses (Moody's)	0.1	0.0	0.0	0.1	0.1	0.5	-0.1	0.7	1.0	0.5	-0.6	0.0	0.5
20	Timely payment indicator (Moody's)	0.0	0.0	0.1	-0.2	0.1	0.6	0.2	0.2	0.5	1.0	-0.5	0.1	0.5
21	Payment continuity uplift (Fitch)	-0.1	0.3	0.1	-0.2	0.0	-0.2	0.4	-0.2	-0.6	-0.5	1.0	-0.1	-0.9
22	Cover pool credit assessment (DBRS)	-0.4	-0.4	-0.3	-0.1	-0.1	0.3	0.0	-0.1	0.0	0.1	-0.1	1.0	0.0
23	Target credit enhancement (S&P)	0.6	-0.3	-0.1	0.2	0.3	0.4	-0.3	0.6	0.5	0.5	-0.9	0.0	1.0
<i>Cash flow mismatch</i>														
24	Asset-liability mismatch (3 years)	0.0	0.1	0.1	-0.1	0.1	0.4	0.0	0.1	0.1	0.1	0.1	0.3	0.1
25	Asset-liability mismatch (5 years)	0.2	0.2	0.2	-0.2	0.0	0.4	0.1	0.0	0.1	0.3	-0.1	0.3	0.1
26	Currency mismatch	-0.1	0.0	0.0	0.0	-0.1	-0.2	0.0	-0.1	0.0	-0.1	0.1	-0.3	0.2
27	Interest rate mismatch	0.1	0.0	0.1	0.1	0.0	0.3	-0.1	0.2	0.2	0.2	-0.4	0.2	0.4
28	Maturity mismatch	0.2	0.2	0.1	-0.1	0.0	0.3	0.2	0.1	0.2	0.3	0.1	-0.1	-0.2
<i>Maturity type</i>														
29	Hard bullet	-0.1	-0.2	0.0	0.3	0.2	-0.3	-0.2	0.2	0.1	-0.3	-0.5	-0.4	0.3
30	Soft bullet	0.0	0.0	0.0	-0.2	-0.1	0.3	0.1	-0.3	0.0	0.4	0.1	0.3	-0.1
31	Pass-through	0.1	0.2	0.1	0.0	-0.1	0.3	0.1	0.2	0.0	-0.1	0.5	-0.1	-0.3
32	Mixed	-0.1	0.1	0.0	-0.1	-0.2	-0.1	0.1	-0.1	-0.1	-0.1	0.2	0.2	-0.1
<i>Main collateral asset type</i>														
33	Residential	0.1	0.3	0.2	-0.3	0.1	0.3	0.4	-0.2	0.0	0.5	0.1	-0.1	-0.1
34	Commercial	0.0	0.0	0.0	0.9	-0.1	-0.2	-0.1	0.2	0.0	-0.3	0.0	0.0	0.0
35	Public sector	-0.1	-0.4	-0.2	-0.3	0.0	-0.2	-0.3	0.1	0.0	-0.3	0.0	0.0	0.1

Table B-2: Correlation matrix for risk indicators (2/3)

NOTE: The table shows the correlation matrix for risk indicators, as defined in Section 2.

Risk indicators		24	25	26	27	28	29	30	31	32	33	34	35
1	Covered bond amounts	-0.2	-0.1	0.1	-0.1	-0.1	0.0	-0.1	-0.1	0.3	0.1	-0.1	-0.1
2	Cover pool amounts	-0.1	-0.1	0.1	0.0	0.0	0.0	-0.2	-0.1	0.2	0.2	-0.1	-0.2
<i>Covered bond and issuer ratings</i>													
3	Covered bond rating	0.5	0.5	-0.1	0.3	0.3	-0.2	0.1	0.5	-0.2	0.1	-0.1	-0.1
4	Covered bond rating incl. leeway	0.3	0.4	0.0	0.3	0.2	-0.1	0.3	0.0	-0.2	0.2	-0.1	-0.1
5	Issuer rating	0.5	0.5	-0.1	0.3	0.3	-0.2	0.0	0.5	-0.2	0.2	-0.1	-0.2
6	Covered bond uplift vs issuer incl. leeway	-0.1	-0.2	-0.1	-0.3	-0.1	0.1	-0.3	0.3	0.1	-0.2	0.0	0.2
7	Covered bond uplift vs issuer	0.1	0.2	0.0	0.0	0.2	0.0	-0.1	0.2	-0.1	0.1	0.0	0.0
8	Country rating	0.4	0.4	-0.2	0.4	0.3	-0.3	0.3	0.3	-0.1	0.3	-0.2	-0.2
<i>Overcollateralisation</i>													
9	Overcollateralisation	0.0	-0.1	-0.1	0.2	0.0	0.2	-0.1	-0.1	-0.1	0.1	-0.1	-0.1
10	Committed Overcollateralisation	0.2	0.2	-0.1	0.2	0.2	0.0	-0.1	0.2	0.0	0.2	-0.2	-0.1
<i>Cover pool risk</i>													
11	Arrears	0.0	0.2	-0.1	0.1	0.2	-0.1	0.0	0.1	-0.1	0.1	0.0	-0.1
12	High LTV assets	0.1	0.2	0.0	0.0	0.2	-0.2	0.0	0.2	0.1	0.3	0.0	-0.4
13	Very high LTV assets	0.1	0.2	0.0	0.1	0.1	0.0	0.0	0.1	0.0	0.2	0.0	-0.2
14	Commercial assets	-0.1	-0.2	0.0	0.1	-0.1	0.3	-0.2	0.0	-0.1	-0.3	0.9	-0.3
15	Regional concentration	0.1	0.0	-0.1	0.0	0.0	0.2	-0.1	-0.1	-0.2	0.1	-0.1	0.0
16	Macroeconomic risk of assets	0.4	0.4	-0.2	0.3	0.3	-0.3	0.3	0.3	-0.1	0.3	-0.2	-0.2
17	Real estate risk	0.0	0.1	0.0	-0.1	0.2	-0.2	0.1	0.1	0.1	0.4	-0.1	-0.3
18	Collateral score (Moody's)	0.1	0.0	-0.1	0.2	0.1	0.2	-0.3	0.2	-0.1	-0.2	0.2	0.1
19	Cover pool losses (Moody's)	0.1	0.1	0.0	0.2	0.2	0.1	0.0	0.0	-0.1	0.0	0.0	0.0
20	Timely payment indicator (Moody's)	0.1	0.3	-0.1	0.2	0.3	-0.3	0.4	-0.1	-0.1	0.5	-0.3	-0.3
21	Payment continuity uplift (Fitch)	0.1	-0.1	0.1	-0.4	0.1	-0.5	0.1	0.5	0.2	0.1	0.0	0.0
22	Cover pool credit assessment (DBRS)	0.3	0.3	-0.3	0.2	-0.1	-0.4	0.3	-0.1	0.2	-0.1	0.0	0.0
23	Target credit enhancement (S&P)	0.1	0.1	0.2	0.4	-0.2	0.3	-0.1	-0.3	-0.1	-0.1	0.0	0.1
<i>Cash flow mismatch</i>													
24	Asset-liability mismatch (3 years)	1.0	0.8	0.0	0.1	0.4	-0.1	0.1	0.3	-0.1	0.2	-0.2	-0.2
25	Asset-liability mismatch (5 years)	0.8	1.0	0.0	0.1	0.5	-0.3	0.2	0.3	0.0	0.3	-0.1	-0.3
26	Currency mismatch	0.0	0.0	1.0	0.0	-0.1	-0.1	0.0	-0.1	0.1	-0.2	0.1	0.1
27	Interest rate mismatch	0.1	0.1	0.0	1.0	0.1	0.0	0.1	0.1	-0.1	0.1	0.0	-0.2
28	Maturity mismatch	0.4	0.5	-0.1	0.1	1.0	-0.3	0.2	0.3	0.0	0.3	-0.2	-0.3
<i>Maturity type</i>													
29	Hard bullet	-0.1	-0.3	-0.1	0.0	-0.3	1.0	-0.6	-0.3	-0.5	-0.4	0.1	0.3
30	Soft bullet	0.1	0.2	0.0	0.1	0.2	-0.6	1.0	-0.1	-0.2	0.3	-0.1	-0.2
31	Pass-through	0.3	0.3	-0.1	0.1	0.3	-0.3	-0.1	1.0	-0.1	0.2	0.0	-0.2
32	Mixed	-0.1	0.0	0.1	-0.1	0.0	-0.5	-0.2	-0.1	1.0	0.1	0.0	-0.1
<i>Main collateral asset type</i>													
33	Residential	0.2	0.3	-0.2	0.1	0.3	-0.4	0.3	0.2	0.1	1.0	-0.5	-0.8
34	Commercial	-0.2	-0.1	0.1	0.0	-0.2	0.1	-0.1	0.0	0.0	-0.5	1.0	-0.2
35	Public sector	-0.2	-0.3	0.1	-0.2	-0.3	0.3	-0.2	-0.2	-0.1	-0.8	-0.2	1.0

Table B-3: Correlation matrix for risk indicators (3/3)

NOTE: The table shows the correlation matrix for risk indicators, as defined in Section 2.

Risk indicators		1	2	3	4	5	6	7	8	9	10	11	12
<b>Issuer risk</b>	1	1,0	-0,2	0,0	0,0	0,0	0,1	0,2	0,0	0,0	0,0	-0,2	0,1
<b>Overcollateralisation</b>													
Overcollateralisation	2	-0,2	1,0	0,0	0,2	0,2	0,0	-0,3	-0,1	0,1	0,2	0,2	0,2
Committed Overcollateralisation	3	0,0	0,0	1,0	-0,2	-0,3	0,5	0,1	-0,4	-0,3	-0,4	0,0	0,3
<b>Cover pool risk</b>													
Arrears	4	0,0	0,2	-0,2	1,0	0,3	0,1	-0,1	-0,1	0,3	0,2	0,1	0,0
High LTV assets	5	0,0	0,2	-0,3	0,3	1,0	0,2	-0,1	0,0	0,3	0,3	0,0	0,0
Commercial assets	6	0,1	0,0	0,5	0,1	0,2	1,0	0,1	-0,2	-0,1	-0,3	-0,1	0,3
Regional concentration	7	0,2	-0,3	0,1	-0,1	-0,1	0,1	1,0	0,1	0,0	0,0	-0,3	-0,2
Macroeconomic risk of assets	8	0,0	-0,1	-0,4	-0,1	0,0	-0,2	0,1	1,0	0,0	0,2	-0,1	0,0
Real estate risk	9	0,0	0,1	-0,3	0,3	0,3	-0,1	0,0	0,0	1,0	0,4	-0,1	0,0
<b>Cash flow mismatch</b>													
Asset-liability mismatch	10	0,0	0,2	-0,4	0,2	0,3	-0,3	0,0	0,2	0,4	1,0	0,1	0,0
Currency mismatch	11	-0,2	0,2	0,0	0,1	0,0	-0,1	-0,3	-0,1	-0,1	0,1	1,0	0,1
Interest rate mismatch	12	0,1	0,2	0,3	0,0	0,0	0,3	-0,2	0,0	0,0	0,0	0,1	1,0

Table B-4: Correlation matrix for indicator ranks

NOTE: The table shows the correlation matrix for risk indicator ranks within the highest rating class, as defined in Section 3.



## Annex C: Currency and interest rate hedging

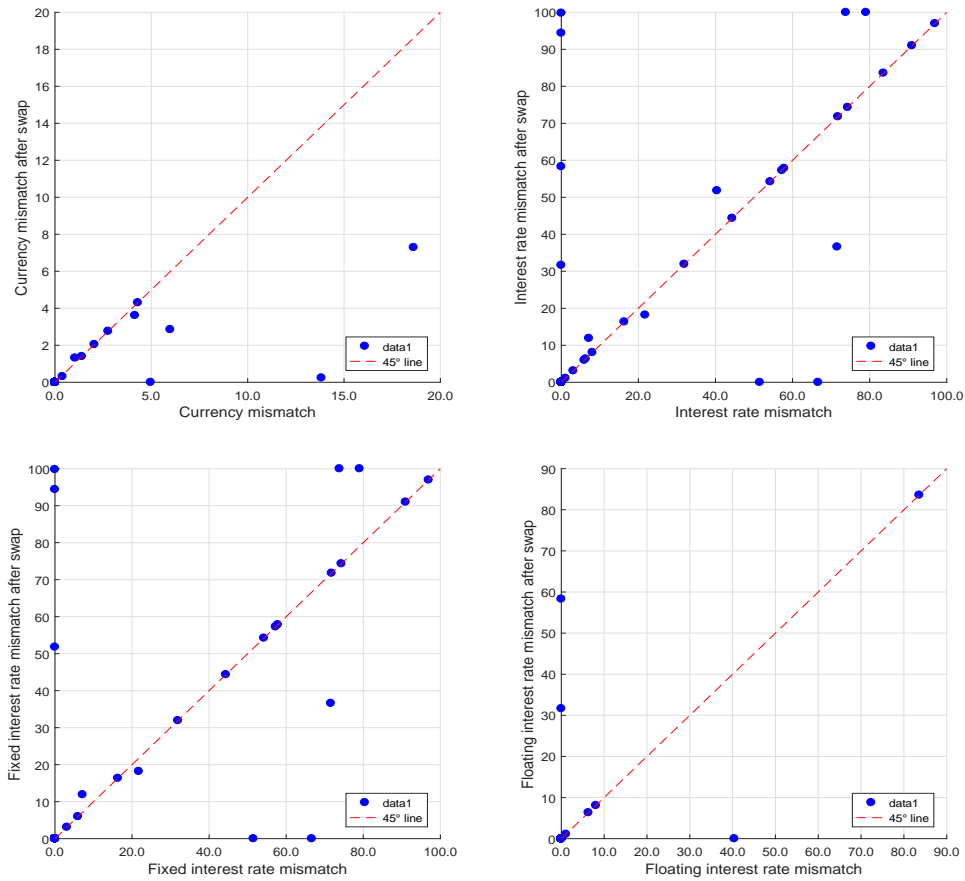


Figure C-1: Currency and interest rate mismatches before and after swaps

NOTE: The table shows the currency and interest rate mismatches (also divided by the type of the interest rate mismatch) before (x-axis) and after swaps (y-axis), as based on the data provided by Fitch (overall 58 covered bond programmes, see also Table 1).

## Annex D: Robustness check: results for 6- and 5-variable combinations

Risk indicators	Rating uplift incl. leeway							
	6-var				5-var			
	% reg's where indicator significant	median p-value	median coeff. if significant	number of regressions	% reg's where indicator significant	median p-value	median coeff. if significant	number of regressions
<b>Issuer risk</b>								
<b>Issuer rating</b>								
<b>Overcollateralisation</b>								
Overcollateralisation	3%	0.54	0.00	1825	1%	0.57	0.00	935
Committed Overcollateralisation	56%	0.18	0.05	2152	64%	0.14	0.05	991
<b>Cover pool risk</b>								
Arrears	27%	0.36	-0.11	1921	19%	0.34	-0.10	909
High LTV assets	16%	0.36	0.05	1511	8%	0.39	0.03	852
Very high LTV assets	0%	0.57	-0.14	1439	0%	0.60	-0.13	835
Commercial assets	0%	0.72	0.02	1439	0%	0.75	0.04	831
Regional concentration	34%	0.30	0.01	1613	34%	0.25	0.01	858
Macroeconomic risk of assets	25%	0.41	-0.08	1002	18%	0.43	-0.07	651
Real estate risk	47%	0.33	0.01	1662	46%	0.36	0.01	840
Collateral score (Moody's)	0%	0.00	0.00	0	0%	0.00	0.00	0
Cover pool losses (Moody's)	0%	0.00	0.00	0	0%	0.00	0.00	0
Timely payment indicator (Moody's)	100%	0.00	-1.05	2510	100%	0.00	-1.06	1918
Payment continuity uplift (Fitch)	100%	0.00	0.82	3255	100%	0.00	0.82	1957
Cover pool credit assessment (DBRS)	2%	0.47	0.23	179	0%	0.47	0.00	65
Target credit enhancement (S&P)	21%	0.35	-0.04	343	32%	0.32	-0.04	114
<b>Cash flow mismatch</b>								
Asset-liability mismatch (3 years)	1%	0.63	-0.06	1823	0%	0.66	-0.06	976
Asset-liability mismatch (5 years)	6%	0.59	-0.01	1853	2%	0.62	-0.01	999
Currency mismatch	3%	0.67	1.54	1924	2%	0.66	2.29	1027
Interest rate mismatch	9%	0.62	-0.04	2034	6%	0.60	-0.04	1043
Maturity mismatch	3%	0.36	0.04	2162	1%	0.38	0.07	1003
<b>Maturity type</b>								
Hard bullet	8%	0.68	-3.33	1452	5%	0.73	-3.89	777
Soft bullet	1%	0.56	-1.23	1433	0%	0.52	-1.16	770
Pass-through	37%	0.28	2.32	1821	34%	0.26	2.18	887

Table D-1: Detailed results for covered bond rating uplift vs. issuer – 6- and 5-variable combinations (1/2)

NOTE: The table shows the results across regressions with all 6- and 5-variable combinations of risk indicators as independent variables for covered bond rating uplift vs. issuer rating and covered bond rating uplift including leeway as dependent variables. The results are computed for 25% regressions with the highest goodness of fit (measured by adjusted  $R^2$ ). Risk indicators as defined in Section 2.

Risk indicators	Rating uplift							
	6-var				5-var			
	% reg's where indicator significant	median p-value	median coeff. if significant	number of regressions	% reg's where indicator significant	median p-value	median coeff. if significant	number of regressions
<b>Issuer risk</b>								
Issuer rating								
<b>Overcollateralisation</b>								
Overcollateralisation	25%	0.34	0.00	1651	18%	0.37	0.00	808
Committed Overcollateralisation	19%	0.41	-0.01	1603	12%	0.39	0.00	789
<b>Cover pool risk</b>								
Arrears	22%	0.43	-0.05	1592	19%	0.41	-0.06	852
High LTV assets	11%	0.47	-0.03	1595	14%	0.48	-0.05	865
Very high LTV assets	14%	0.46	0.00	1616	13%	0.49	-0.03	884
Commercial assets	37%	0.24	0.00	1779	40%	0.20	0.00	951
Regional concentration	12%	0.43	0.00	1560	9%	0.43	0.00	828
Macroeconomic risk of assets	13%	0.38	0.41	175	20%	0.43	0.53	82
Real estate risk	39%	0.28	0.01	1250	35%	0.26	0.01	711
Collateral score (Moody's)	100%	0.00	-0.10	986	100%	0.00	-0.09	476
Cover pool losses (Moody's)	100%	0.01	-0.04	310	100%	0.01	-0.04	367
Timely payment indicator (Moody's)	100%	0.00	-0.52	798	100%	0.00	-0.53	476
Payment continuity uplift (Fitch)	52%	0.17	0.21	1083	65%	0.12	0.20	476
Cover pool credit assessment (DBRS)	5%	0.51	-0.17	1493	10%	0.48	-0.17	761
Target credit enhancement (S&P)	72%	0.14	-0.03	1155	88%	0.07	-0.03	476
<b>Cash flow mismatch</b>								
Asset-liability mismatch (3 years)	72%	0.12	-0.02	2336	78%	0.10	-0.02	984
Asset-liability mismatch (5 years)	57%	0.19	-0.02	1877	69%	0.14	-0.02	975
Currency mismatch	2%	0.66	-0.89	1511	1%	0.66	-0.74	801
Interest rate mismatch	19%	0.49	-0.02	1545	11%	0.57	-0.02	798
Maturity mismatch	10%	0.47	0.03	1751	8%	0.51	0.04	884
<b>Maturity type</b>								
Hard bullet	54%	0.24	0.62	1405	60%	0.20	0.59	674
Soft bullet	58%	0.25	-1.41	1496	71%	0.17	-1.24	843
Pass-through	52%	0.24	2.51	1491	50%	0.21	2.62	831

Table D-2: Detailed results for covered bond rating uplift vs. issuer – 6- and 5-variable combinations (2/2)

NOTE: The table shows the results across regressions with all 6- and 5-variable combinations of risk indicators as independent variables for covered bond rating uplift vs. issuer rating and covered bond rating uplift including leeway as dependent variables. The results are computed for 25% regressions with the highest goodness of fit (measured by adjusted  $R^2$ ). Risk indicators as defined in Section 2.

Risk indicators	Rating incl. leeway							
	6-var				5-var			
	% reg's where indicator significant	median p-value	median coeff. if significant	number of regressions	% reg's where indicator significant	median p-value	median coeff. if significant	number of regressions
<b>Issuer risk</b>								
Issuer rating	100%	0.00	0.88	5566	100%	0.00	0.91	3205
<b>Overcollateralisation</b>								
Overcollateralisation	12%	0.50	0.00	1622	11%	0.54	0.01	792
Committed Overcollateralisation	11%	0.43	0.00	1649	12%	0.42	0.02	807
<b>Cover pool risk</b>								
Arrears	70%	0.17	0.16	1932	81%	0.10	0.16	1191
High LTV assets	20%	0.40	-0.08	1484	32%	0.33	-0.06	820
Very high LTV assets	1%	0.56	0.17	1411	7%	0.53	0.03	739
Commercial assets	17%	0.46	0.00	1445	19%	0.43	0.04	770
Regional concentration	23%	0.32	0.00	1503	17%	0.42	0.00	755
Macroeconomic risk of assets	92%	0.03	0.53	298	95%	0.02	0.59	428
Real estate risk	30%	0.38	-0.01	1434	30%	0.37	-0.01	782
Collateral score (Moody's)	14%	0.47	0.05	1007	11%	0.49	0.05	476
Cover pool losses (Moody's)	100%	0.00	0.05	1155	100%	0.00	0.05	476
Timely payment indicator (Moody's)	100%	0.00	1.08	1155	100%	0.00	1.08	476
Payment continuity uplift (Fitch)	100%	0.00	-0.83	1384	100%	0.00	-0.80	850
Cover pool credit assessment (DBRS)	20%	0.31	-0.24	95	6%	0.38	-0.22	82
Target credit enhancement (S&P)	34%	0.29	0.05	1423	49%	0.21	0.06	917
<b>Cash flow mismatch</b>								
Asset-liability mismatch (3 years)	17%	0.53	0.03	1826	20%	0.46	0.03	895
Asset-liability mismatch (5 years)	34%	0.35	0.03	1966	57%	0.23	0.03	1076
Currency mismatch	10%	0.57	-0.84	1633	12%	0.53	-0.91	817
Interest rate mismatch	50%	0.29	0.02	1835	62%	0.19	0.02	907
Maturity mismatch	42%	0.27	0.09	1651	28%	0.37	0.09	791
<b>Maturity type</b>								
Hard bullet	57%	0.29	0.32	1370	55%	0.30	0.72	656
Soft bullet	44%	0.25	1.35	1285	54%	0.18	0.89	655
Pass-through	67%	0.11	-1.95	1593	79%	0.07	-2.13	907

Table D-3: Detailed results for covered bond rating – 6- and 5-variable combinations (1/2)

NOTE: The table shows the results across regressions with all 6- and 5-variable combinations of risk indicators as independent variables for covered bond rating and covered bond rating including leeway as dependent variables. The results are computed for 25% regressions with the highest goodness of fit (measured by adjusted  $R^2$ ). Risk indicators as defined in Section 2.

Risk indicators	6-var				Rating				5-var			
	% reg's where indicator significant	median p-value	median coeff. if significant	number of regressions	% reg's where indicator significant	median p-value	median coeff. if significant	number of regressions	% reg's where indicator significant	median p-value	median coeff. if significant	number of regressions
<b>Issuer risk</b>												
Issuer rating	99%	0.00	0.58	5523	100%	0.00	0.63	3594				
<b>Overcollateralisation</b>												
Overcollateralisation	25%	0.36	0.00	1640	17%	0.40	0.00	810				
Committed Overcollateralisation	18%	0.39	0.04	1643	14%	0.37	0.01	834				
<b>Cover pool risk</b>												
Arrears	26%	0.39	0.05	1630	21%	0.37	0.05	911				
High LTV assets	7%	0.49	0.00	1497	10%	0.49	0.00	833				
Very high LTV assets	13%	0.47	-0.04	1570	11%	0.52	-0.04	848				
Commercial assets	40%	0.20	0.00	1645	47%	0.16	0.00	891				
Regional concentration	11%	0.37	-0.01	1472	7%	0.43	-0.01	842				
Macroeconomic risk of assets	100%	0.00	0.71	633	100%	0.00	0.73	397				
Real estate risk	34%	0.30	-0.01	1449	31%	0.28	-0.01	817				
Collateral score (Moody's)	100%	0.00	0.10	1010	100%	0.00	0.10	511				
Cover pool losses (Moody's)	100%	0.01	0.04	302	100%	0.01	0.04	365				
Timely payment indicator (Moody's)	100%	0.00	0.53	1155	100%	0.00	0.53	476				
Payment continuity uplift (Fitch)	43%	0.25	-0.12	1695	46%	0.25	-0.12	802				
Cover pool credit assessment (DBRS)	2%	0.53	0.14	282	7%	0.36	0.14	148				
Target credit enhancement (S&P)	61%	0.17	0.03	1076	79%	0.09	0.03	399				
<b>Cash flow mismatch</b>												
Asset-liability mismatch (3 years)	83%	0.06	0.03	2482	87%	0.05	0.03	979				
Asset-liability mismatch (5 years)	64%	0.16	0.02	1928	78%	0.10	0.02	1000				
Currency mismatch	14%	0.60	0.09	1656	11%	0.59	0.09	907				
Interest rate mismatch	29%	0.38	0.00	1546	20%	0.53	0.00	865				
Maturity mismatch	10%	0.46	0.07	1667	6%	0.48	0.07	897				
<b>Maturity type</b>												
Hard bullet	66%	0.18	-0.19	1413	70%	0.14	-0.26	709				
Soft bullet	52%	0.27	0.44	1503	72%	0.17	0.43	739				
Pass-through	25%	0.33	-0.90	1305	26%	0.28	-0.97	696				

Table D-4: Detailed results for covered bond rating – 6- and 5-variable combinations (2/2)

NOTE: The table shows the results across regressions with all 6- and 5-variable combinations of risk indicators as independent variables for covered bond rating and covered bond rating including leeway as dependent variables. The results are computed for 25% regressions with the highest goodness of fit (measured by adjusted  $R^2$ ). Risk indicators as defined in Section 2.

## Annex E: Robustness check: results for specifications including variables related to the main asset type and the country of issuer

Risk indicators	Rating uplift incl. leeway							
	4-var				3-var			
	% reg's where indicator significant	median p-value	median coeff. if significant	number of regressions	% reg's where indicator significant	median p-value	median coeff. if significant	number of regressions
<b>Issuer and country risk</b>								
Issuer rating								
Country rating	22%	0.39	-0.16	426	47%	0.26	-0.20	79
<b>Overcollateralisation</b>								
Overcollateralisation	5%	0.56	0.01	595	13%	0.51	0.01	69
Committed Overcollateralisation	76%	0.10	0.05	665	85%	0.09	0.06	86
<b>Cover pool risk</b>								
Arrears	18%	0.28	-0.10	704	12%	0.27	-0.10	74
High LTV assets	4%	0.44	0.04	634	1%	0.42	0.02	72
Very high LTV assets	0%	0.61	0.15	614	0%	0.63	0.00	66
Commercial assets	1%	0.74	-0.04	472	0%	0.74	0.00	60
Regional concentration	31%	0.24	0.00	639	31%	0.26	0.00	74
Macroeconomic risk of assets	27%	0.37	-0.17	638	43%	0.28	-0.22	91
Real estate risk	43%	0.38	0.01	571	43%	0.37	0.00	67
Collateral score (Moody's)	1%	0.44	0.05	98	3%	0.66	0.05	37
Cover pool losses (Moody's)	41%	0.32	-0.03	133	47%	0.17	-0.04	49
Timely payment indicator (Moody's)	100%	0.00	-1.06	2043	100%	0.00	-1.06	302
Payment continuity uplift (Fitch)	100%	0.00	0.82	1844	100%	0.00	0.82	281
Cover pool credit assessment (DBRS)	0%	0.51	0.00	321	0%	0.48	0.00	39
Target credit enhancement (S&P)	66%	0.13	-0.05	577	84%	0.07	-0.06	174
<b>Cash flow mismatch</b>								
Asset-liability mismatch (3 years)	0%	0.65	0.02	624	0%	0.69	0.00	79
Asset-liability mismatch (5 years)	6%	0.58	-0.01	666	8%	0.54	-0.02	83
Currency mismatch	13%	0.56	0.50	666	27%	0.45	0.13	78
Interest rate mismatch	19%	0.46	-0.03	729	27%	0.36	-0.03	84
Maturity mismatch	7%	0.41	0.06	654	16%	0.39	-0.01	70
<b>Maturity type</b>								
Hard bullet	7%	0.68	-2.73	526	7%	0.65	-2.03	58
Soft bullet	16%	0.41	-1.45	547	26%	0.34	-1.34	76
Pass-through	65%	0.12	3.22	1005	76%	0.07	3.43	150
<b>Main collateral asset type</b>								
Residential	10%	0.43	0.50	510	11%	0.35	-0.29	63
Commercial	1%	0.67	-2.72	462	2%	0.64	-2.94	56
Public sector	2%	0.49	-0.23	470	0%	0.44	0.00	56
<b>Country effects</b>								
Austria	36%	0.36	-3.94	330	46%	0.30	-3.90	41
Germany	35%	0.30	1.50	615	56%	0.23	1.72	109
Italy	32%	0.29	2.97	600	32%	0.29	2.95	71
Spain	12%	0.46	-2.46	475	17%	0.45	-1.82	58

Table E-1: Results for covered bond rating uplift vs. issuer (1/2)

NOTE: The table shows the results across regressions with all 4- and 3-variable combinations of risk indicators as independent variables for covered bond rating uplift vs. issuer rating and covered bond rating uplift including leeway as dependent variables. The results are computed for 25% regressions with the highest goodness of fit (measured by adjusted  $R^2$ ). Risk indicators as defined in Section 2.

Risk indicators	Rating uplift							
	4-var				3-var			
	% reg's where indicator significant	median p-value	median coeff. if significant	number of regressions	% reg's where indicator significant	median p-value	median coeff. if significant	number of regressions
<b>Issuer and country risk</b>								
Issuer rating								
Country rating	36%	0.33	0.16	237	42%	0.36	0.18	45
<b>Overcollateralisation</b>								
Overcollateralisation	14%	0.37	0.00	565	9%	0.38	0.00	66
Committed Overcollateralisation	42%	0.23	0.08	902	50%	0.17	0.07	101
<b>Cover pool risk</b>								
Arrears	15%	0.34	0.02	690	20%	0.32	0.06	82
High LTV assets	20%	0.39	-0.07	743	14%	0.35	-0.08	84
Very high LTV assets	13%	0.50	-0.01	612	9%	0.59	-0.09	79
Commercial assets	31%	0.24	0.01	532	26%	0.24	0.01	68
Regional concentration	5%	0.48	-0.01	702	4%	0.46	-0.03	79
Macroeconomic risk of assets	39%	0.30	0.17	365	40%	0.36	0.17	52
Real estate risk	24%	0.28	0.00	603	24%	0.26	0.00	79
Collateral score (Moody's)	92%	0.06	-0.09	258	82%	0.13	-0.08	28
Cover pool losses (Moody's)	93%	0.06	-0.04	256	79%	0.17	-0.04	29
Timely payment indicator (Moody's)	95%	0.01	-0.53	283	86%	0.03	-0.48	43
Payment continuity uplift (Fitch)	77%	0.08	0.30	1006	90%	0.04	0.30	218
Cover pool credit assessment (DBRS)	22%	0.39	-0.20	529	25%	0.36	-0.19	80
Target credit enhancement (S&P)	61%	0.12	-0.04	653	53%	0.20	-0.04	85
<b>Cash flow mismatch</b>								
Asset-liability mismatch (3 years)	67%	0.16	-0.02	542	47%	0.38	-0.01	72
Asset-liability mismatch (5 years)	66%	0.16	-0.01	572	52%	0.23	0.00	87
Currency mismatch	4%	0.64	-0.74	627	3%	0.66	-0.21	72
Interest rate mismatch	11%	0.47	0.01	700	18%	0.42	0.01	76
Maturity mismatch	5%	0.52	0.07	644	14%	0.46	0.08	87
<b>Maturity type</b>								
Hard bullet	49%	0.26	0.24	411	60%	0.25	0.32	42
Soft bullet	69%	0.15	-1.26	514	76%	0.13	-1.31	62
Pass-through	82%	0.06	2.49	1380	92%	0.02	2.51	297
<b>Main collateral asset type</b>								
Residential	14%	0.46	-0.56	472	7%	0.43	-0.63	59
Commercial	3%	0.62	0.86	413	2%	0.72	0.80	55
Public sector	8%	0.48	0.30	439	4%	0.43	0.57	57
<b>Country effects</b>								
Austria	93%	0.05	1.26	456	96%	0.03	1.25	48
Germany	56%	0.19	1.20	464	44%	0.25	0.90	55
Italy	32%	0.28	1.56	587	42%	0.21	1.78	95
Spain	16%	0.40	-1.54	497	9%	0.35	-1.21	69

Table E-2: Results for covered bond rating uplift vs. issuer (2/2)

NOTE: The table shows the results across regressions with all 4- and 3-variable combinations of risk indicators as independent variables for covered bond rating uplift vs. issuer rating and covered bond rating uplift including leeway as dependent variables. The results are computed for 25% regressions with the highest goodness of fit (measured by adjusted  $R^2$ ). Risk indicators as defined in Section 2.

Risk indicators	Rating incl. leeway							
	4-var				3-var			
	% reg's where indicator significant	median p-value	median coeff. if significant	number of regressions	% reg's where indicator significant	median p-value	median coeff. if significant	number of regressions
<b>Issuer and country risk</b>								
Issuer rating	100%	0.00	0.93	2686	100%	0.00	0.95	369
Country rating	99%	0.00	0.67	588	100%	0.00	0.69	172
<b>Overcollateralisation</b>								
Overcollateralisation	9%	0.53	0.01	510	4%	0.54	0.02	55
Committed Overcollateralisation	50%	0.21	0.02	703	58%	0.15	0.04	74
<b>Cover pool risk</b>								
Arrears	81%	0.09	0.17	850	85%	0.08	0.16	107
High LTV assets	55%	0.22	-0.06	644	57%	0.16	-0.04	92
Very high LTV assets	16%	0.43	0.02	535	10%	0.57	0.03	77
Commercial assets	28%	0.40	0.04	487	31%	0.40	0.03	59
Regional concentration	6%	0.65	0.00	638	3%	0.71	0.01	64
Macroeconomic risk of assets	100%	0.00	0.70	921	100%	0.00	0.71	231
Real estate risk	39%	0.28	-0.02	573	30%	0.31	-0.02	61
Collateral score (Moody's)	6%	0.49	0.04	422	3%	0.59	0.04	65
Cover pool losses (Moody's)	56%	0.20	0.05	410	35%	0.49	0.05	65
Timely payment indicator (Moody's)	65%	0.09	0.89	518	49%	0.10	0.89	65
Payment continuity uplift (Fitch)	100%	0.00	-0.89	963	100%	0.00	-0.93	162
Cover pool credit assessment (DBRS)	0%	0.61	0.00	121	0%	0.74	0.00	22
Target credit enhancement (S&P)	70%	0.10	0.06	844	86%	0.05	0.07	96
<b>Cash flow mismatch</b>								
Asset-liability mismatch (3 years)	37%	0.30	0.05	773	62%	0.18	0.05	119
Asset-liability mismatch (5 years)	78%	0.10	0.03	937	89%	0.05	0.03	121
Currency mismatch	16%	0.39	-0.96	563	33%	0.26	0.05	67
Interest rate mismatch	67%	0.17	0.02	561	59%	0.23	0.03	66
Maturity mismatch	29%	0.36	0.10	629	18%	0.35	0.10	67
<b>Maturity type</b>								
Hard bullet	57%	0.25	1.08	609	66%	0.21	1.14	80
Soft bullet	59%	0.18	0.63	458	46%	0.25	0.67	54
Pass-through	80%	0.09	-0.04	597	72%	0.16	0.31	65
<b>Main collateral asset type</b>								
Residential	41%	0.31	0.81	435	40%	0.36	0.87	53
Commercial	8%	0.44	-0.85	396	4%	0.48	-0.88	50
Public sector	24%	0.39	-0.82	428	20%	0.45	-0.73	51
<b>Country effects</b>								
Austria	38%	0.40	2.17	359	52%	0.34	1.84	46
Germany	56%	0.22	-1.55	383	53%	0.26	-1.64	43
Italy	24%	0.41	1.15	440	39%	0.29	2.43	61
Spain	66%	0.20	1.04	455	68%	0.24	1.35	44

Table E-3: Results for covered bond rating (1/2)

NOTE: The table shows the results across regressions with all 4- and 3-variable combinations of risk indicators as independent variables for covered bond rating and covered bond rating including leeway as dependent variables. The results are computed for 25% regressions with the highest goodness of fit (measured by adjusted  $R^2$ ). Risk indicators as defined in Section 2.



Risk indicators	Rating							
	4-var				3-var			
	% reg's where indicator significant	median p-value	median coeff. if significant	number of regressions	% reg's where indicator significant	median p-value	median coeff. if significant	number of regressions
<b>Issuer and country risk</b>								
Issuer rating	100%	0.00	0.65	2707	100%	0.00	0.66	369
Country rating	100%	0.00	0.65	715	100%	0.00	0.64	236
<b>Overcollateralisation</b>								
Overcollateralisation	18%	0.41	0.00	539	14%	0.38	0.00	73
Committed Overcollateralisation	51%	0.23	-0.05	718	59%	0.16	-0.05	73
<b>Cover pool risk</b>								
Arrears	23%	0.34	-0.04	723	16%	0.29	-0.06	77
High LTV assets	6%	0.55	0.01	613	3%	0.54	0.02	76
Very high LTV assets	4%	0.54	-0.02	645	1%	0.53	-0.05	76
Commercial assets	30%	0.25	0.00	443	13%	0.33	-0.01	67
Regional concentration	3%	0.52	-0.01	546	0%	0.56	0.00	76
Macroeconomic risk of assets	100%	0.00	0.68	1636	100%	0.00	0.67	328
Real estate risk	27%	0.32	-0.01	548	13%	0.49	-0.01	76
Collateral score (Moody's)	100%	0.00	0.09	454	100%	0.00	0.08	65
Cover pool losses (Moody's)	88%	0.06	0.04	298	38%	0.32	0.04	64
Timely payment indicator (Moody's)	83%	0.05	0.32	381	80%	0.07	0.06	65
Payment continuity uplift (Fitch)	40%	0.28	-0.10	583	38%	0.27	-0.11	65
Cover pool credit assessment (DBRS)	33%	0.17	0.16	102	78%	0.07	0.17	18
Target credit enhancement (S&P)	93%	0.03	0.04	295	100%	0.00	0.04	29
<b>Cash flow mismatch</b>								
Asset-liability mismatch (3 years)	95%	0.02	0.03	827	97%	0.01	0.03	79
Asset-liability mismatch (5 years)	90%	0.04	0.02	811	95%	0.02	0.02	80
Currency mismatch	47%	0.33	0.06	681	62%	0.25	0.05	78
Interest rate mismatch	47%	0.37	-0.01	624	63%	0.30	-0.01	76
Maturity mismatch	6%	0.47	0.06	648	3%	0.51	0.05	76
<b>Maturity type</b>								
Hard bullet	58%	0.19	0.04	473	38%	0.29	-0.12	71
Soft bullet	87%	0.07	-0.28	583	90%	0.05	-0.35	70
Pass-through	58%	0.15	0.82	594	63%	0.09	1.24	70
<b>Main collateral asset type</b>								
Residential	56%	0.19	-0.52	531	63%	0.12	-0.65	67
Commercial	31%	0.41	0.72	471	44%	0.30	0.80	66
Public sector	23%	0.30	0.43	460	20%	0.23	0.47	66
<b>Country effects</b>								
Austria	86%	0.05	-0.12	391	94%	0.04	0.04	48
Germany	80%	0.10	0.19	440	91%	0.05	0.23	47
Italy	45%	0.25	-1.39	456	50%	0.24	-1.37	48
Spain	53%	0.23	-1.58	504	50%	0.23	-1.68	48

Table E-4: Results for covered bond rating (2/2)

NOTE: The table shows the results across regressions with all 4- and 3-variable combinations of risk indicators as independent variables for covered bond rating and covered bond rating including leeway as dependent variables. The results are computed for 25% regressions with the highest goodness of fit (measured by adjusted  $R^2$ ). Risk indicators as defined in Section 2.

Risk indicators	Rating uplift incl. leeway							
	6-var				5-var			
	% reg's where indicator significant	median p-value	median coeff. if significant	number of regressions	% reg's where indicator significant	median p-value	median coeff. if significant	number of regressions
<b>Issuer and country risk</b>								
Issuer rating								
Country rating	15%	0.43	-0.07	4446	13%	0.45	-0.08	1662
<b>Overcollateralisation</b>								
Overcollateralisation	2%	0.56	0.00	10336	2%	0.56	0.00	3176
Committed Overcollateralisation	62%	0.14	0.05	11663	68%	0.12	0.06	3515
<b>Cover pool risk</b>								
Arrears	20%	0.35	-0.10	11105	18%	0.32	-0.10	3403
High LTV assets	8%	0.42	0.04	9896	5%	0.44	0.04	3222
Very high LTV assets	1%	0.62	0.00	9712	0%	0.62	0.09	3205
Commercial assets	1%	0.72	-0.02	5057	1%	0.74	-0.06	2049
Regional concentration	32%	0.26	0.01	10485	31%	0.25	0.01	3207
Macroeconomic risk of assets	20%	0.42	-0.07	6755	15%	0.45	-0.08	2465
Real estate risk	42%	0.34	0.01	10230	42%	0.36	0.01	3037
Collateral score (Moody's)	0%	0.68	0.00	5	13%	0.39	0.02	32
Cover pool losses (Moody's)	6%	0.16	-0.02	16	53%	0.27	-0.03	57
Timely payment indicator (Moody's)	100%	0.00	-1.05	22860	100%	0.00	-1.05	8811
Payment continuity uplift (Fitch)	100%	0.00	0.83	21249	100%	0.00	0.83	7725
Cover pool credit assessment (DBRS)	0%	0.71	0.23	1252	0%	0.57	0.00	809
Target credit enhancement (S&P)	28%	0.36	-0.04	1823	48%	0.21	-0.05	1381
<b>Cash flow mismatch</b>								
Asset-liability mismatch (3 years)	0%	0.67	-0.05	10833	0%	0.68	-0.06	3445
Asset-liability mismatch (5 years)	2%	0.64	-0.01	11083	2%	0.63	-0.01	3458
Currency mismatch	4%	0.67	2.06	11352	7%	0.61	1.10	3652
Interest rate mismatch	8%	0.60	-0.04	11893	11%	0.54	-0.04	3732
Maturity mismatch	4%	0.36	0.05	11761	5%	0.38	0.07	3446
<b>Maturity type</b>								
Hard bullet	5%	0.66	-2.35	8391	6%	0.68	-3.35	2769
Soft bullet	10%	0.46	-1.24	9025	8%	0.44	-1.37	2742
Pass-through	39%	0.25	2.35	10825	50%	0.19	2.78	3783
<b>Main collateral asset type</b>								
Residential	17%	0.47	0.56	8212	14%	0.46	0.54	2483
Commercial	0%	0.66	-0.84	7628	0%	0.67	-1.53	2353
Public sector	4%	0.53	-0.52	7692	4%	0.52	-0.50	2405
<b>Country effects</b>								
Austria	10%	0.53	-3.83	3650	19%	0.47	-4.05	1369
Germany	23%	0.27	1.03	7475	17%	0.33	1.08	2353
Italy	18%	0.36	2.16	8195	21%	0.34	2.68	2704
Spain	12%	0.44	-2.11	7246	12%	0.46	-2.47	2408

Table E-5: Results for covered bond rating uplift vs. issuer – 6- and 5-variable (1/2)

NOTE: The table shows the results across regressions with all 6- and 5-variable combinations of risk indicators as independent variables for covered bond rating uplift vs. issuer rating and covered bond rating uplift including leeway as dependent variables. The results are computed for 25% regressions with the highest goodness of fit (measured by adjusted  $R^2$ ). Risk indicators as defined in Section 2.

Risk indicators	Rating uplift							
	6-var				5-var			
	% reg's where indicator significant	median p-value	median coeff. if significant	number of regressions	% reg's where indicator significant	median p-value	median coeff. if significant	number of regressions
<b>Issuer and country risk</b>								
Issuer rating								
Country rating	12%	0.41	0.43	395	25%	0.34	0.20	591
<b>Overcollateralisation</b>								
Overcollateralisation	18%	0.38	0.00	9894	17%	0.38	0.00	2936
Committed Overcollateralisation	15%	0.42	0.02	10139	35%	0.30	0.09	3884
<b>Cover pool risk</b>								
Arrears	15%	0.42	-0.03	10770	12%	0.37	-0.03	3349
High LTV assets	8%	0.50	-0.04	10925	17%	0.45	-0.06	3412
Very high LTV assets	11%	0.48	0.02	10790	14%	0.47	0.02	3285
Commercial assets	39%	0.22	0.01	6643	36%	0.24	0.01	2394
Regional concentration	8%	0.44	0.01	10826	6%	0.49	0.00	3416
Macroeconomic risk of assets	22%	0.34	0.30	788	32%	0.31	0.19	1042
Real estate risk	39%	0.27	0.01	9611	35%	0.28	0.01	2819
Collateral score (Moody's)	100%	0.00	-0.10	5426	98%	0.01	-0.09	1456
Cover pool losses (Moody's)	100%	0.01	-0.04	5426	97%	0.02	-0.04	1460
Timely payment indicator (Moody's)	100%	0.00	-0.55	5426	99%	0.01	-0.54	1519
Payment continuity uplift (Fitch)	53%	0.18	0.20	4832	55%	0.15	0.26	3083
Cover pool credit assessment (DBRS)	12%	0.49	-0.19	4507	18%	0.43	-0.22	2096
Target credit enhancement (S&P)	70%	0.12	-0.03	5946	65%	0.11	-0.03	2854
<b>Cash flow mismatch</b>								
Asset-liability mismatch (3 years)	82%	0.08	-0.02	10410	71%	0.14	-0.02	3075
Asset-liability mismatch (5 years)	71%	0.14	-0.02	10550	65%	0.17	-0.01	3248
Currency mismatch	2%	0.66	-0.67	10496	4%	0.61	-0.54	3312
Interest rate mismatch	10%	0.56	-0.02	10427	8%	0.56	-0.01	3185
Maturity mismatch	5%	0.55	0.03	10614	6%	0.52	0.05	3237
<b>Maturity type</b>								
Hard bullet	59%	0.19	0.55	7858	53%	0.22	0.37	2273
Soft bullet	67%	0.17	-1.19	8879	70%	0.16	-1.20	2735
Pass-through	42%	0.25	1.83	9375	65%	0.14	2.31	4323
<b>Main collateral asset type</b>								
Residential	23%	0.40	-0.71	7250	19%	0.44	-0.63	2257
Commercial	10%	0.53	0.91	6154	6%	0.56	0.88	1962
Public sector	11%	0.44	0.58	6553	10%	0.46	0.41	2048
<b>Country effects</b>								
Austria	90%	0.06	1.15	5396	90%	0.07	1.24	2124
Germany	55%	0.19	1.60	7503	60%	0.17	1.52	2363
Italy	24%	0.32	0.86	7560	27%	0.32	1.35	2462
Spain	23%	0.40	-1.18	7467	20%	0.40	-1.47	2335

Table E-6: Results for covered bond rating uplift vs. issuer – 6- and 5-variable (2/2)

NOTE: The table shows the results across regressions with all 6- and 5-variable combinations of risk indicators as independent variables for covered bond rating uplift vs. issuer rating and covered bond rating uplift including leeway as dependent variables. The results are computed for 25% regressions with the highest goodness of fit (measured by adjusted  $R^2$ ). Risk indicators as defined in Section 2.

Risk indicators	Rating incl. leeway							
	6-var				5-var			
	% reg's where indicator significant	median p-value	median coeff. if significant	number of regressions	% reg's where indicator significant	median p-value	median coeff. if significant	number of regressions
<b>Issuer and country risk</b>								
Issuer rating	100%	0.00	0.91	36528	100%	0.00	0.92	12949
Country rating	91%	0.03	0.58	2752	93%	0.02	0.59	1211
<b>Overcollateralisation</b>								
Overcollateralisation	8%	0.56	0.00	9423	10%	0.55	0.01	2950
Committed Overcollateralisation	21%	0.40	-0.02	9655	25%	0.34	0.03	3206
<b>Cover pool risk</b>								
Arrears	74%	0.12	0.15	13663	78%	0.10	0.17	3946
High LTV assets	39%	0.29	-0.05	9845	49%	0.25	-0.06	3384
Very high LTV assets	11%	0.47	0.00	9078	15%	0.43	0.00	3073
Commercial assets	15%	0.45	0.02	5720	17%	0.46	0.07	2167
Regional concentration	18%	0.44	0.00	9471	11%	0.54	0.00	3013
Macroeconomic risk of assets	93%	0.02	0.62	3943	95%	0.02	0.64	1639
Real estate risk	38%	0.33	-0.01	9586	38%	0.30	-0.02	3157
Collateral score (Moody's)	13%	0.48	0.05	5426	12%	0.48	0.05	1460
Cover pool losses (Moody's)	95%	0.02	0.05	5426	93%	0.03	0.05	1465
Timely payment indicator (Moody's)	100%	0.00	1.07	5426	98%	0.01	1.07	1467
Payment continuity uplift (Fitch)	100%	0.00	-0.82	10484	100%	0.00	-0.83	3996
Cover pool credit assessment (DBRS)	3%	0.52	-0.23	843	1%	0.53	-0.22	480
Target credit enhancement (S&P)	42%	0.27	0.06	9252	49%	0.21	0.06	4121
<b>Cash flow mismatch</b>								
Asset-liability mismatch (3 years)	16%	0.49	0.03	10424	23%	0.41	0.05	3552
Asset-liability mismatch (5 years)	52%	0.24	0.03	11757	67%	0.16	0.04	3977
Currency mismatch	13%	0.51	-0.81	9983	16%	0.44	-0.87	3090
Interest rate mismatch	54%	0.21	0.02	11087	68%	0.14	0.02	3313
Maturity mismatch	25%	0.38	0.09	9709	21%	0.41	0.09	3115
<b>Maturity type</b>								
Hard bullet	54%	0.28	0.75	8008	47%	0.30	1.06	2763
Soft bullet	55%	0.18	0.95	8028	59%	0.16	0.87	2485
Pass-through	81%	0.06	-1.52	10367	84%	0.06	-0.84	3099
<b>Main collateral asset type</b>								
Residential	38%	0.33	0.80	7442	41%	0.30	0.87	2310
Commercial	15%	0.43	-0.84	6138	12%	0.42	-0.86	1979
Public sector	23%	0.40	-0.78	7175	26%	0.36	-0.85	2271
<b>Country effects</b>								
Austria	15%	0.47	3.32	4262	16%	0.50	2.99	1582
Germany	63%	0.14	-1.47	7574	59%	0.17	-1.51	2136
Italy	22%	0.46	-0.28	7060	20%	0.43	-0.11	2356
Spain	46%	0.27	1.82	7695	54%	0.24	1.65	2383

Table E-7: Results for covered bond rating – 6- and 5-variable (1/2)

NOTE: The table shows the results across regressions with all 6- and 5-variable combinations of risk indicators as independent variables for covered bond rating and covered bond rating including leeway as dependent variables. The results are computed for 25% regressions with the highest goodness of fit (measured by adjusted  $R^2$ ). Risk indicators as defined in Section 2.

Risk indicators	Rating							
	6-var				5-var			
	% reg's where indicator significant	median p-value	median coeff. if significant	number of regressions	% reg's where indicator significant	median p-value	median coeff. if significant	number of regressions
<b>Issuer and country risk</b>								
Issuer rating	100%	0.00	0.62	37648	100%	0.00	0.63	12985
Country rating	100%	0.00	0.74	2645	100%	0.00	0.70	1480
<b>Overcollateralisation</b>								
Overcollateralisation	18%	0.41	0.00	9605	18%	0.40	0.00	2789
Committed Overcollateralisation	19%	0.41	0.00	9986	35%	0.32	-0.05	3614
<b>Cover pool risk</b>								
Arrears	23%	0.39	0.04	10620	25%	0.35	0.00	3310
High LTV assets	8%	0.50	0.01	9685	7%	0.53	0.01	3000
Very high LTV assets	10%	0.48	-0.04	10358	8%	0.51	-0.02	3079
Commercial assets	41%	0.21	0.00	6308	39%	0.22	0.00	2095
Regional concentration	8%	0.46	-0.01	9780	6%	0.49	-0.01	2923
Macroeconomic risk of assets	100%	0.00	0.72	5772	100%	0.00	0.70	4020
Real estate risk	38%	0.27	-0.01	9891	32%	0.29	-0.01	2888
Collateral score (Moody's)	100%	0.00	0.10	6473	100%	0.00	0.10	2212
Cover pool losses (Moody's)	99%	0.01	0.04	4192	96%	0.02	0.04	1636
Timely payment indicator (Moody's)	97%	0.01	0.54	5613	88%	0.04	0.48	1721
Payment continuity uplift (Fitch)	38%	0.31	-0.05	10149	40%	0.30	-0.07	3078
Cover pool credit assessment (DBRS)	13%	0.41	0.15	685	19%	0.26	0.16	395
Target credit enhancement (S&P)	62%	0.15	0.03	5195	84%	0.06	0.03	1778
<b>Cash flow mismatch</b>								
Asset-liability mismatch (3 years)	89%	0.05	0.03	12026	92%	0.04	0.03	3976
Asset-liability mismatch (5 years)	79%	0.10	0.02	11736	85%	0.07	0.02	3659
Currency mismatch	15%	0.56	0.09	10593	27%	0.46	0.08	3402
Interest rate mismatch	25%	0.45	-0.01	9971	28%	0.45	-0.01	3005
Maturity mismatch	10%	0.50	0.08	10661	8%	0.50	0.07	3319
<b>Maturity type</b>								
Hard bullet	70%	0.14	0.02	8852	67%	0.14	0.09	2469
Soft bullet	72%	0.15	0.09	9391	79%	0.12	-0.10	2795
Pass-through	30%	0.30	-0.62	7896	38%	0.25	0.04	2676
<b>Main collateral asset type</b>								
Residential	28%	0.35	0.23	7293	40%	0.28	-0.22	2409
Commercial	10%	0.54	-0.73	6424	16%	0.50	0.32	2190
Public sector	15%	0.43	-0.05	7019	19%	0.37	0.22	2203
<b>Country effects</b>								
Austria	96%	0.02	-0.16	6028	87%	0.06	-0.24	1787
Germany	50%	0.21	-0.59	6591	64%	0.16	-0.11	2137
Italy	33%	0.29	-1.05	6386	34%	0.29	-1.28	2195
Spain	38%	0.32	-1.00	8238	50%	0.25	-1.51	2940

Table E-8: Results for covered bond rating – 6- and 5-variable (2/2)

NOTE: The table shows the results across regressions with all 6- and 5-variable combinations of risk indicators as independent variables for covered bond rating and covered bond rating including leeway as dependent variables. The results are computed for 25% regressions with the highest goodness of fit (measured by adjusted  $R^2$ ). Risk indicators as defined in Section 2.

## Acknowledgements

The views expressed in this paper are those of the authors and do not necessarily represent the views of the European Central Bank, the Deutsche Bundesbank, the European Systemic Risk Board, any of its Member Institutions or the ESRB Secretariat. Magdalena Grothe worked on this project within the Schuman Programme encompassing the European System of Central Banks and the Single Supervisory Mechanism. We are grateful to Wolfgang Föttinger for his valuable comments and guidance throughout this project. We are also grateful to Jörg Binder, Jonas Böhmer, Manuel Polley and Bijan Sahamie for valuable comments on the earlier versions of this work.

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ISBN 978-92-899-4036-8

ISSN 1725-2806

doi:10.2866/395233

QB-AR-20-045-EN-N