Market expectations of recovery rates

Sorana Sarbu[*], Claus Schmitt[†] and Marliese Uhrig-Homburg[‡]

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[*]Chair of Financial Engineering and Derivatives, Karlsruhe Institute of Technology (KIT), Kaiserstr. 12, D-76131 Karlsruhe, Germany, sarbu@kit.edu

[†]Corresponding author. Chair of Financial Engineering and Derivatives, Karlsruhe Institute of Technology (KIT), Kaiserstr. 12, D-76131 Karlsruhe, Germany, claus.schmitt@kit.edu

[‡]Chair of Financial Engineering and Derivatives, Karlsruhe Institute of Technology (KIT), Kaiserstr. 12, D-76131 Karlsruhe, Germany, uhrig@kit.edu

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1 Introduction

Credit risk is primarily driven by two components: the probability that a creditor defaults and the recovery rate. While the first component has received much attention, the literature on the recovery rate is limited. This is particularly true for empirical evidence on the recovery rates of large financial institutions, although they are the most active (non-sovereign) players on bond and credit derivative markets.[1] One reason for this lack of empirical evidence is the limited number of default events for these companies.

We circumvent this problem by extracting the market expectations of recovery rates from prices of credit default swaps (CDS), one of the largest and most liquid derivative market. In order to disentangle the recovery rate from the default probability, we use CDS data on debt instruments of the same company that differ in seniority. As both tiers are subject to an identical default probability, we are able to infer information on recovery rates without making assumptions on the common dependence of the two components. Instead, we treat recovery rates as claims on the firm value at default and empirically determine a company-specific liability structure. We apply our model to a sample covering 65 financial firms between April 2002 and November 2012 located in the United States and Europe. To the best of our knowledge, our dataset is the most comprehensive empirical evidence on recovery rates of large financial institutions and covers a total book value of assets of 37,284bn USD.[2] We also add 26 non-financial companies that have CDS data on subordinated debt to our sample to investigate differences between both company types.

We make three contributions to the existing literature. First, we propose an approach to isolate recovery rates that combines advantages of existing methodologies. In particular, our setup uses information from credit default swap spreads on debt instruments of different seniorities, incorporates information on the firm-specific liability structure and allows for deviations from the absolute priority rule.[3] Applying the model to our sample, we find that

[1] The Depository Trust & Clearing Corporation (DTCC) reports an outstanding gross notional of 2,422bn USD for credit default swaps with a financial underlying in November 2013.

[2] We are also not aware of any other study that collects empirical data on the liability structure of financial institutions (grouped by seniority) on a large scale. For a study on the debt structure of non-financial companies see e.g. Colla et al. (2013).

[3] For a review of existing approaches to extract recovery rates from market prices see Doshi (2011). Under the absolute priority rule, creditors with a lower seniority only receive payments in case of a default if more

the mean implied recovery rate for the senior unsecured tier is 50% for the financial companies and therefore much higher than the mean of 20% for the non-financial companies. A result that is consistent with the remarkably high recovery rates observed in the CDS market for financial companies in recent years.[4] Second, we relate the recovery rate estimates to economic determinants using a panel regression. We find that firm fundamentals and macroeconomic factors that influence realized recovery rates exert a similar influence on market expectations of recovery rates. Both, cross-sectional and time-series information thereby explain a large amount of the variation in recovery rates. Third, we elucidate why and to what extent market expectations of recovery rates differ for financial and non-financial companies. We therefore regress our recovery estimates on a rating-based measure of expected government support and find that anticipated government support leads to an increase in expected recovery rates and that this effect is particularly strong during the financial crisis. Expected government support actions are part of the explaination why unsecured creditors expect to realize comparatively high recovery rates, although their claims are ranked far below those of other creditors (e.g. depositors). This finding is consistent with previous evidence on market reactions to government support. Hoggarth et al. (2004) review banking crisis from 1977 to 2002 and show that government support protects unsecured creditors from losses during times of market-wide distress. Kelly et al. (2012) show that the default likelihood of the financial sector in the United States is reduced by expected government support by comparing individual put option prices with those written on an index. Our study complements the latter by adding a recovery rate perspective.

Our results are important for a number of applications: studies that calculate implied default probabilities or counterparty risk exposures based on CDS data frequently use a fixed recovery rate assumption (see e.g. Veronesi and Zingales (2010)). As we show, implied recovery rates exhibit a large cross-sectional and time-series variation. Neglecting these dynamics leads to potentially misleading conclusions. Another application concerns the regulatory re-

senior creditors have fully recovered their claims. Weiss (1990), Franks and Torous (1994) and Bris et al. (2006) document that this assumption is frequently violated.

[4]The recovery rate on senior unsecured debt is 57% for Washington Mutual, 68% for CIT Group, 92% for Fannie Mae, 94% for Freddie Mac, 75% for Anglo Irish Bank (SNR/SUB Bucket 1) and 83% for Irish Life and Permanent (Senior Bucket 1). Low recovery rates on the other hand have been realized for Lehman Brothers (9%) and all banks located in Island. Realized recovery rates are based on CDS auction results (available at www.creditfixings.com).

quirements of Basel III that allow banks to specify recovery rates for their exposures including an estimate for bad states of the economy (downturn loss given default). Relying only on the limited number of realizations of recovery rates for large banks might be misleading for research in this area.

The rest of the paper is structured as follows: in Section 2, we show how implied recovery rates can be inferred from data on CDS spreads that differ in seniority. Section 3 presents the data we have used to estimate the recovery rates. In Section 4, we discuss the steps for the implementation of our model. Section 5 presents our recovery rate estimates. Section 6 describes the results of regressing the implied recovery rates on empirical determinants including government support. Section 7 discusses the results of our panel regression, Section 8 concludes.

2 Modeling the implied recovery rate

In the following paragraphs, we show how to extract an implied recovery rate from CDS of senior unsecured and subordinate debt. We attribute a payout function to each type of debt that maps the firm value at default to the instrument-specific payoff depending on the firm's individual debt structure and a parameter that determines the strength of the seniority violation. Our setup is based on the methodology of Schläfer and Uhrig-Homburg (2013) augmented by accounting for seniority violations.[5]

Unlike methodologies that use equity (option) market data to achieve an isolation of recovery rates (see e.g. Jarrow (2001), Le (2007), Carr and Wu (2010) and Conrad et al. (2013)), we do not need to rely on integrated markets. We also do not need to assume that the dependence between the default probability and the recovery rate is exclusively governed by the risk-free rate as in Doshi (2011) or set the subordinated recovery rate to a fixed value as in the approach of Norden and Weber (2012).

[5] The latter feature is also present in the approach of Unal et al. (2003) who use bonds with different seniorities to isolate (time-fixed) recovery rate estimates.

2.1 Separation of the recovery rate from the default probability

A CDS is a bilateral contract that insures the protection buyer against losses of a reference instrument, usually an unsecured bond. The protection buyer pays a swap rate s until the maturity T of the swap or the occurrence of a default event in τ, whichever happens first. The spread is paid quarterly at times t_1,t_2,..., $min(T, \tau)$. The present value of the swap rates (=premium leg) then is

$$E_{t_0}^{Q}\left[\sum_{i=1}^{4T} \frac{1}{4}\, s(T)\, b(t_0, t_i)\, \mathbf{1}_{\{\tau > t_i\}}\right]. \tag{2.1}$$

$E_{t_0}^{Q}$ is the expectation under the risk-neutral measure conditional on the information in t_0. $b(t_0, t_i)$ is the price of a risk-free zero-coupon bond that pays 1 at t_i. The protection seller compensates the loss on the reference instrument in case of a default event or pays nothing if no default occurs (=protection leg). In order to facilitate the calculation, we assume that the protection seller pays the percentage $1 - \phi$ of a risk-free zero-coupon bond $b(\tau, T)$ with a remaining maturity of $T - \tau$ to the protection buyer in case of a default event.[6] Assuming constant interest rates, the present value of the protection leg is then

$$\begin{aligned} &E_{t_0}^{Q}[(1-\phi)\, b(\tau, T)\, b(t_0, \tau)\, \mathbf{1}_{\{\tau \le T\}}] \\ &= E_{t_0}^{Q}[(1-\phi)\, \mathbf{1}_{\{\tau \le T\}}]\, b(t_0, T). \end{aligned} \tag{2.2}$$

Note that we have not made any assumptions on the process governing the default probability nor on the dependence between the default probability and the recovery rate. By conditioning the expectation in 2.2 on default, one obtains for the value of the protection leg:

$$E_{t_0}^{Q}[(1-\phi)\,|\, \mathbf{1}_{\{\tau \le T\}} = 1]\, Q(\{\mathbf{1}_{\{\tau \le T\}} = 1\})\, b(t_0, T).$$

At inception, the value of the premium leg equals the value of the protection leg. By equating

[6] This assumption effectively neglects the time-dependence of the protection payment between inception of the swap and T. One might equally assume that the protection payment in case of a default event is paid at maturity (see Duffie and Singleton (2003) for an overview of different recovery rate definitions) or employ the forward-risk-neutral measure (see Schläfer and Uhrig-Homburg (2013)) which would also account for stochastic interest rates.

both legs $s(T)$ is given by

$$s(T) = \frac{E^Q_{t_0}[(1-\phi) \mid \mathbf{1}_{\{\tau \leq T\}} = 1]\, Q(\{\mathbf{1}_{\{\tau \leq T\}} = 1\})\, b(t_0, T)}{E^Q_{t_0}\left[\sum_{i=1}^{4T} \frac{1}{4}\, b(t_0, t_i)\, \mathbf{1}_{\{\tau > t_i\}}\right]}. \tag{2.3}$$

The ratio of two CDS spreads $s^{(j)}(T)$ referencing underlyings with a different seniority ($j = 1, 2$) is then

$$R = \frac{s^{(1)}(T)}{s^{(2)}(T)} = \frac{1 - E^Q_{t_0}(\phi^{(1)} \mid \mathbf{1}_{\{\tau \leq T\}} = 1)}{1 - E^Q_{t_0}(\phi^{(2)} \mid \mathbf{1}_{\{\tau \leq T\}} = 1)}. \tag{2.4}$$

$E^Q_{t_0}(\phi^{(j)} \mid \mathbf{1}_{\{\tau \leq T\}} = 1)$ denotes the (instrument-specific) probability-weighted mean recovery rate across all possible default times during the lifetime of the swap.

2.2 Incorporating seniority violations

The conditional expectation $E^Q_{t_0}(\phi^{(j)} \mid \mathbf{1}_{\{\tau \leq T\}} = 1)$ can be viewed as a state-dependent claim on the firm value at default that has a payout which is characteristic for the instrument and company. The expectation is given by

$$\mu^{(j)} \equiv E^Q_{t_0}(\phi^{(j)} \mid \mathbf{1}_{\{\tau \leq T\}} = 1) = \int_0^1 \phi^{(j)}(x, \theta, v)\, f(x)\, dx, \tag{2.5}$$

where $f(x)$ denotes the probability density function of the firm value at default x and $\phi^{(j)}(x, \theta, v)$ is the instrument-specific payoff function. θ is a vector that contains information on the debt structure of the company and v accounts for seniority violations.

The impact of the debt structure and seniority violations on the instrument-specific payouts is best explained using an example. Consider a company that has three types of liabilities which differ in seniority, where θ_0 denotes the size of a priority debt class, θ_1 is the size of a senior debt class and θ_2 is the size of a junior debt class, i.e. $\theta = (\ \theta_0 \quad \theta_1 \quad \theta_2\ )$. For simplicity, we normalize each element of θ by the total amount of liabilities (x is then also given in percent of the total liabilities of the company).

We consider a situation where the priority creditors are always (fully) paid in advance of the other creditors in case of a default, but the senior creditors suffer from a violation of seniority at the benefit of the junior creditors. More specifically, if a company declares bankruptcy, the priority creditors first receive $min(x, \theta_0)$. If the firm value at default is larger than θ_0, the remaining firm value $x - \theta_0$ is split between the other creditors. The senior creditors receive $(1 - v) \cdot (x - \theta_0)$ and transfer $v \cdot (x - \theta_0)$ to the junior creditors. Therefore, the senior creditors can fully recover for $x \geq \theta_0 + \frac{\theta_1}{1-v}$. The instrument-specific payout function for the priority creditors is

$$\phi^{(0)} = \begin{cases} \frac{x}{\theta_0} & 0 < x < \theta_0 \\ 1 & \theta_0 \leq x \leq 1 \end{cases}$$

and

$$\phi^{(1)} = \begin{cases} 0 & 0 < x < \theta_0 \\ \frac{(x-\theta_0)\cdot(1-v)}{\theta_1} & \theta_0 \leq x < \theta_1^* \\ 1 & \theta_1^* \leq x \leq 1 \end{cases}$$

for the senior creditors. For the junior creditors, the payout function is then

$$\phi^{(2)} = \begin{cases} 0 & 0 \leq x < \theta_0 \\ \frac{(x-\theta_0)\cdot v}{\theta_2} & \theta_0 \leq x < \theta_1^* \\ \frac{x-(\theta_0+\theta_1)}{\theta_2} & \theta_1^* \leq x \leq 1 \end{cases}$$

with $\theta_1^* = \theta_0 + \frac{\theta_1}{1-v}$. Figure 1 illustrates the instrument-specific payoffs for the case with and without a seniority violation. The upper left figure shows the instrument-specific payout function for the senior creditors for $v = 0$ (no seniority violation). As soon as x exceeds θ_0, each unit increase of x leads to an increase in the payout function of $\frac{1}{\theta_1}$ for this group. If $x > \theta_0 + \theta_1$, these creditors can fully recovery their claim. From this point on, the junior creditors receive the payment $\frac{1}{\theta_2}$ for each additional unit of x until their claims are fully recovered at $x = \theta_0 + \theta_1 + \theta_2 = 1$. Incorporating seniority violations changes the impact of x on the instrument-specific payout functions for the senior and junior creditors. As the senior creditors transfer the amount $v \cdot (x - \theta_0)$ to the junior creditors, each increase in x will result in an increase for $\phi^{(1)}$ of only $\frac{1-v}{\theta_1}$, while $\phi^{(2)}$ increases by $\frac{v}{\theta_2}$. Once the senior creditors have fully recovered at $x = \theta_1^*$, the junior creditors realize an increase in $\phi^{(2)}$ of $\frac{1}{\theta_2}$ for each additional unit of x.

The given specification could easily be extended to cover more complex seniority violations by adjusting the instrument-specific payout functions. Unal et al. (2003) incorporate seniority violations in a recovery rate model for bonds, which restricts seniority violations to occur only above a certain threshold of x. One could also add an additional payout function to incorporate violations of seniority that benefit stock holders, although seniority violations in favor of equity holders have become rare after 2000 (Bharath and Werner (2009)).

3 Data

3.1 Selection of CDS data

In order to calculate the ratio of observed CDS spreads, we select all available CDS data of underlyings located in the United States and Europe in the Markit database which have senior unsecured and subordinate data. CDS data is retrieved on a weekly basis. We only include CDS with a maturity of five years and exclude observations for which Markit has only limited data on the respective quotes to ensure that our results are not driven by liquidity effects.[7] For underlyings located in the United States, we select spreads that are quoted in USD and are subject to the 'modified-restructuring' specification. For underlyings located in Europe, we select spreads that are quoted in EUR and which are subject to 'modified-modified restructuring'.[8] Additionally, we drop all observations where the subordinate spread is smaller than the senior unsecured spread. This leaves us with 51,400 weekly observations of 327 companies covering the time period from April 30, 2001 to November 26, 2012.

[7] We consider the data availability to be limited where Markit marks the respective composite quote as "Thin" indicating that the data of only two quote providers has been used.

[8] 'Modified restructuring' used to be the market standard for underlyings located in the United States until the market conventions changed on April 8, 2009 under the so-called 'Big-Bang-Protocol'. A similar development took place for European underlyings on June 20, 2009 ('Small-Bang-Protocol'). In order to remain consistent, we use only one restructuring definition for each geographic region.

3.2 Calculation of the debt structure

We augment the data from Markit with information from Capital IQ on the debt structure of each company.[9] As CDS are frequently issued for different legal entities, we restrict our sample to companies that are publicly listed in order to exclude subsidiaries. After applying this restriction, we are left with 25,450 weekly observations of 114 companies.

We account for non-debt liabilities such as trade claims, taxes and lease obligations.[10] The classification of these items is based on the literature that deals with seniority in case of a default event (see e.g. Barclay and Smith (1995), Russell et al. (2006) and Rauh and Sufi (2010)). As we are using CDS on senior unsecured and subordinate debt, we are interested in the positions of these instruments in the debt structure. We therefore cluster all liability items into three categories for each company for the year that precedes the date of the respective CDS observation: we use a *priority debt class*, which includes all items that are more senior than unsecured debt, a *senior unsecured class* including all senior unsecured bonds and notes and a *subordinate class* which contains all debt claims that are less senior than the previous class. The priority debt class contains all secured debt as well as accounts payable, current and non-current tax liabilities and capitalized leases. For banks, we add the amount of deposits. For insurance companies, we add liabilities that arise due to obligations from insurance contracts. Appendix B provides an overview of all Capital IQ items that are used in the calculation of the liability structure. Although the overall coverage is extensive, not all items are available for each company and point in time. We require each company to have at least information on both items that form the senior unsecured and the subordinate class and set missing items to zero. Adding these data requirements reduces our sample to 95 companies. We then divide the total amount of each debt class by the sum of all items so that the liability structure positions are given as percentages.

[9] In order to match the two databases, we use the historical six-digit cusip from Markit that identifies the firm. We manually check these historical cusips to link it with the respective identifier of Capital IQ, which ensures that firms that have been acquired or merged throughout the sample period receive the correct Capital IQ identifier.

[10] We use the term 'debt' and 'liability' interchangeably throughout the paper, implying that our definition of debt comprises items that are no securities (e.g. taxes or lease obligations) and which are usually not considered as being debt.

3.3 Descriptive statistics

Table 1 shows the means for the CDS spreads and the corresponding ratios of the senior unsecured and subordinate spreads for our final sample.[11] The mean senior unsecured spread is 1.18% for financial and 2.73% for non-financial companies reflecting the fact that financial companies are better rated.

Table 2 describes the average size of the seniority classes. Accordingly, the claims of the priority debt class comprise 79% of all claims for financial companies and 44% for non-financial companies. This difference is primarily driven by the debt structure items that are specific for insurance companies and banks. The mean size of total deposits is 65% and 88% for contractual insurance obligations, wherever the respective item is available. The mean size of senior unsecured claims is 18% for financial and 31% for non-financial companies. Accordingly, the liquidation of a financial company has potentially a much more devastating effect on unsecured creditors than the liquidation of a non-financial company as more creditors with a higher seniority are present. Subordinate debt items account for only 3% of the total debt claims for financial institutions and make up 25% for non-financial companies. In order to compare the debt structure to a sample of 305 issuer-rated non-financial firms of Rauh and Sufi (2010), we divide the average sizes of the debt classes by total capital.[12] The ratio of senior unsecured debt to total capital of 25% is nearly identical to the value of 24% in Rauh and Sufi (2010), while the subordinate debt class in our sample is larger (18% vs. 11%). This difference is not surprising given our sample selection that only includes firms whose subordinated debt is large enough to be traded on a derivative market.

4 Implementation of the model

Our goal is to extract an estimate of the implied firm-wide recovery rate as well as the recovery rates of the senior unsecured and subordinate tier for each company and week where

[11] The final sample is restricted to the companies for which the firm characteristics that we use in the regression analysis in Section 6 are available.

[12] Total capital is defined as the sum of the book value of equity and debt. To enable the comparison, we additionally download the book value of debt from Capital IQ on a yearly basis applying the same criteria as in Section 3.2.

we observe a ratio of CDS spreads. We therefore employ the relationship of 2.4 between the observed ratios of CDS spreads and the model counterpart. In particular, we observe a ratio $R_{i,t}^{obs}$ of senior unsecured and subordinate CDS spreads for each firm i and each week t and solve the model ratio $R_{i,t}^{model}$ for the expectation of a one-parametric firm value probability distribution:

$$R_{i,t}^{obs} = \frac{CDS_{i,t}^{Sen}}{CDS_{i,t}^{Sub}} = R_{i,t}^{model}\left(f(x), v_i, \theta_i\right) \tag{4.1}$$

The model ratio $R_{i,t}^{model}$ thereby depends on the functional form of the firm value distribution at default $f(x)$, the parameter v_i that accounts for seniority violations and the liability structure at default θ_i. The following section elaborates on these components.

4.1 Specification of the firm value distribution $f(x)$

Previous approaches that specify firm value distributions frequently employ a two-parametric beta distribution that can take various shapes and is defined on a bounded interval (see e.g. Russell et al. (2006)). We propose the Rayleigh distribution as a functional specification of $f(x)$ that only depends on one parameter, thereby allowing us to solve 4.1 for each observation. As the Rayleigh distribution is originally defined on the interval $[0, \infty)$, we transform it using the transformation theorem for densities so that it is bounded between zero and one. Appendix A explains the transformation, the corresponding instrument-specific recovery rate functions and shows different shapes of the transformed probability distribution.

4.2 Calculation of the firm-specific liability structure θ_i

θ_i represents the liability structure at default. As the market-expectation of the liability structure at default is non-observable, we approximate it with the latest reported liability structure in the balance sheet of each company (see Section 3.2). We are aware of the fact that there are possibly further claims that can arise in case of a default event, which are usually more senior than the claims of unsecured creditors. Examples include insolvency costs for lawyers and consultants or derivative positions of banks that are either not reported in the balance sheets or whose market values change due to worsening market conditions.

Including these positions would most likely result in larger recovery rate estimates. In the robustness section, we additionally estimate recovery rates without information on the debt composition. Indirect insolvency costs on the other hand, that arise e.g. due to a fire-sale effect (Shleifer and Vishny (1992), Acharya et al. (2007)) and financial distress (Andrade and Kaplan (1998)), lower the firm value at default and do not change the liability structure.

4.3 Calibration of the parameter v_i

To calibrate the parameter v_i, we use historical data on defaults of financial and non-financial companies. Specifically, we are interested in firm defaults where senior unsecured creditors receive a payment and subordinate creditors exist. We collect data on defaults from Moody's annual default review (see e.g. Ou et al. (2013)) for the years from 2008 until 2012 and all recovery rates that are reported in CDS auctions. Appendix D provides details on the preparation of this data and contains a complete list of all 26 default events, where we have information for both tiers. In all cases, subordinate creditors receive a payment, although senior unsecured creditors do not fully recover, which underscores the necessity to account for seniority violations between both debt types.

Figure 2 shows the realized senior unsecured and the corresponding subordinate recovery rates (in percent). Subordinate creditors achieve a median recovery rate of 22.90% of the senior unsecured recovery rate. The ratio of both recovery rates exhibits a remarkably stable relationship, which seems to be unaffected by the defaulted company being a financial (indicated by crosses) or a non-financial company (indicated by dots). We therefore choose the parameter v_i so that the relative instrument-specific payout functions (see Section 2.2) reflect this finding. In particular, we choose v_i for each firm i so that the ratio of the subordinate payoff ϕ_i^{Sub} and the senior unsecured payoff ϕ_i^{Sen} for $\theta_{1,i} < x < \theta_{1,i}^*$ equals the historical value of $z = 22.90\%$:

$$\frac{\phi_i^{Sub}}{\phi_i^{Sen}} = \frac{\frac{(x-\theta_{0,i})\cdot v_i}{\theta_{2,i}}}{\frac{(x-\theta_{0,i})\cdot(1-v_i)}{\theta_{1,i}}} = 0.2290 \;\forall\; \theta_0 < x < \theta_1^*.$$

This leads to $v_i = (1 + \frac{\theta_{1,i}}{\theta_{2,i}} \cdot \frac{1}{z})^{-1}$. Note that the expected instrument-specific recovery rates μ^{Sen} and μ^{Sub} themselves do not need to be in a constant ratio to each other as both figures still depend on the expectation of x (compare 2.5).

5 Recovery rate estimates

We numerically solve 4.1 for each week and firm for the expectation of the firm value distribution $f(x)$ and obtain 16,604 weekly recovery rate estimates for 91 companies (65 financial and 26 non-financial companies). Using the firm-specific liability structure, we also obtain the expected senior unsecured μ^{Sen} and subordinate recovery rates μ^{Sub}. Appendix E provides a complete list of all companies with the respective means.

Table 3 summarizes the averages of the three recovery rate types for financial and non-financial companies for the full sample as well as for the crisis- and non-crisis period. The first apparent finding concerns the differences between financial and non-financial companies. The mean firm value at default is 83% for financial and 42% for non-financial companies. The mean senior unsecured (subordinate) recovery rate is 50% (23%) for financial and 20% (6%) for non-financial companies. This large difference might be caused by the fact that the financial companies have a lower credit risk level as indicated by the average credit spreads (see Section 3.3). Altman and Kishore (2002) find that companies with a high pre-default rating (fallen angels) achieve a mean recovery rate for the senior unsecured (subordinate) tier of 58% (30%), while the overall mean of their sample is 39% (31%).[13] Given that our sample composition is comparable to the former study, market expectations of recovery rates are lower than realizations for both types of companies, with the difference being larger for non-financial firms. That is consistent with the intuition that recovery rates under the pricing measure contain a risk premium (Schläfer and Uhrig-Homburg (2013)). The high average recovery rates of financial institutions are nonetheless surprising as unsecured creditors only receive a payment at very high firm values at default due to the liability structure. Figure 3 shows the distribution of the recovery rate types for financial and non-financial companies. Accordingly, the firm-values at default of non-financial firms are not only lower but also exhibit a greater dispersion.

[13] In a more recent study, Ou and Metz (2011) report a historical average of 39% for the senior unsecured and 25% for the subordinate recovery rate for the period 1983-2007 (excluding distressed exchanges) not differentiating for the pre-default level of credit risk.

The second apparent finding concerns the different time-series pattern for financial and non-financial companies. Accordingly, all recovery rate types decline during the crisis period. That effect is strongest for non-financial companies, whose average senior unsecured recovery rate declines from 21% to 10%, while that of financial institutions declines from 50% to 46%. Figure 4 shows the time-series of the average senior unsecured recovery rate for a subsample of 60 financial and non-financial companies that have observations before 2006. The average senior unsecured recovery rate of non-financial companies declines in the pre-crisis period and remains at a comparatively low level, while that of financial institutions first exhibit a larger decrease from 2007 on, but recover after 2008. One possible explanation for this difference are government support measures that benefited the financial sector and whose magnitude rose with the unfolding of the crisis (Brunnermeier (2009)). In Figure 4, we also differentiate for financial companies that are highly likely to receive government support. While the average recovery rate of the senior unsecured tier is nearly identical before the crisis and declines during the early period of the financial crisis for both groups, those of financial institutions that are likely to receive support recover more quickly. Conrad et al. (2013) find a similar development of the expected recovery rate for 9 financial institutions that are considered to be systemically relevant.

As 6 (financial) companies in our sample defaulted during the observation period, we are able to compare the realized recovery rates with market expectations. In Table 4, we show the latest available senior unsecured recovery rate estimate and those determined in the auction that followed default. We also show descriptive statistics on bonds that are listed as a deliverable security for the respective CDS using the ISINs as provided by the ISDA. Note that the final auction results do not necessarily equal the average bond prices due to a cheapest-to-deliver option and deviations that are caused by the auction process (Gupta and Sundaram (2013)). For Fannie Mae, Allied Irish Banks and Irish Life and Permanent, market expectations seem to anticipate the resulting realizations quite well given the large time span between our latest model observations and auction dates. This difference between the model expectation and the realized auction result is larger for Lehman Brothers, Washington Mutual and Glitnir Banki. These companies also exhibit a much stronger fluctuation in bond prices indicating that the market had difficulties to assess the outcome of those defaults.[14]

[14]After the default of Glitnir Banki, the government in Iceland announced that it would take control of

Overall, we conclude from the descriptive analysis that expected recovery rates exhibit large differences between financial and non-financial companies and that government support might change the time-series behavior of recovery rates of financial institutions. In the following section, we will investigate the influence of economic determinants and the role of government support in more detail.

6 Empirical determinants of recovery rate expectations

6.1 Regression setup

Using a panel regression, we study whether firm-level government support anticipations contribute to the differences between the market expectations of recovery rates of financial and non-financial firms. Motivated by earlier findings in the literature that show that government support is particularly strong during a crisis period (Hoggarth et al. (2004), Kelly et al. (2012)) and by the results of our descriptive analysis, we also determine time-series differences and quantify their impact. In order to control for other cross-sectional and time-series influences, we select variables from the literature that are known to have an influence on realized recovery rates and are comparable for financial and non-financial companies. For this purpose, we estimate several variants of the following regression:

$$\mu_{i,t}^{(j)} = \alpha + \beta_1\, SupportProb_{i,t} + \beta_2\, SupportProb_{i,t} \cdot crisis_t + \beta_3 \cdot Leverage_{i,t} + \beta_4 \cdot QRatio_{i,t} + \beta_5 \cdot Ln(assets)_{i,t} + \beta_6 \cdot r_{MSCI,i,t} + D_i(Firm) + D_t(Quarter) + \epsilon_{i,t} \quad (6.1)$$

$\mu_{i,t}^{(j)}$ denotes the expected recovery rate for each firm and week (in percent). Instrument-specific recovery rates are non-linear functions of the expectation of the firm value at default. Besides the firm value at default, we therefore include the senior unsecured and subordinate recovery rate as a dependent variable to capture the influence of the regressors for these types of claims. We estimate the regression using ordinary least squares and correct the standard errors for heteroscedasticity. We also control for firm- and (quarterly) time-fixed effects.

the bank. This action greatly disadvantaged senior unsecured creditors.

SupportProb: we add the Fitch Support Rating as a proxy for the likelihood of government support which is the variable we are mainly interested in. The support rating is intended to represent the likelihood of support for a particular company and the ability of the supporter to provide support. The rating is expressed on a scale ranging from 1 (extremely high probability) to 5 (no reliable support). We follow Gropp et al. (2010) who transform the five different values to a probability measure between 0 and 1. Table 9 provides an overview of the transformation and the definitions of the different rating scales. As the rating is only available for banks, we implicitly assume that non-banks are not subject to government support. As we control for firm- and time-fixed-effects, we identify the impact of government support by the time-series differences in the cross-section of our sample companies. Using the ex-ante expectation of government support is also more consistent than employing (ex-post) realized support transactions as these could also negatively affect our dependent variables if a higher support payment has been anticipated. The Fitch Support Rating provides a quantitative measure that is available for a large scale of global banks and therefore much more comprehensive than other approaches that have been employed as e.g. in Conrad et al. (2013), who use a dummy variable for 6 firms that are considered to be systemically relevant by the Financial Stability Board. We use the interaction term between the crisis dummy and our measure for expected support to identify a different pattern during the financial crisis.

Leverage: leverage is defined as the ratio of the book value of liabilities divided by the book value of all assets. This measure is included in order to capture bankruptcy costs. The higher the leverage of a firm, the more complex and therefore the more expensive is the resolution of the bankruptcy process (Jankowitsch et al. (2013)). We expect a negative relationship between this variable and the expected recovery rates.

QRatio: firms with higher growth prospects should exhibit larger recovery rates (Varma and Cantor (2005)). To control for this effect, we use the *QRatio* defined as the market value of assets divided by the book value of assets.

Ln(*assets*): we also add the logarithm of the book value of assets as a measure for the size of the company. The effect of firm size on recovery rates can have different causes. Bris et al. (2006) find that larger firms are more likely to default after chapter 11 which causes higher recovery rates for creditors. On the other hand, firm size might be associated with a higher systemic relevance of a company that might not be captured in our measure for expected government support.

r_{MSCI} : Covitz and Han (2005) and Jankowitsch et al. (2013) find that worsening macroeconomic conditions result in lower realized recovery rates. We therefore include the weekly logarithmic return of the MSCI World Index which comprises the stocks of more than 1500 constituents in developed countries.

We retrieve the book value of liabilities and assets from Capital IQ based on the quarter that precedes the respective spread observation and the market value of equity from Bloomberg (all items are retrieved in USD). In order to ensure that our results are not driven by firms that defaulted, we exclude a limited number of observations with a negative book value of equity. We calculate leverage as the book value of liabilities divided by the book value of assets, the q-ratio as the ratio of the market and book value of assets, where we approximate the former by the sum of the market value of equity and the book value of liabilities. We follow Conrad et al. (2013) by using a *Crisis* dummy for the time between August 3, 2007, the freeze of payments from the BNP Paribas subprime fund and June 30, 2009, the end date of the recession in the United States according to NBER. We add the Fitch Support Rating using Thomson Reuters. A time-series of the rating is available for 43 out of the 65 financial companies. 23 banks received the highest possible support rating at least once during the observation period.

Table 5 presents descriptive statistics on these variables. The mean leverage ratio of financial institutions is higher than that of non-financial companies (94% vs. 72%). The average q-ratio of financial companies is 1.01 versus 1.48 for non-financial companies. Financial institutions are on average much larger than non-financial companies (652bn USD vs. 11bn USD). The most negative weekly return of the MSCI World Index is realized on October 27, 2008 (-17.10%) followed by the most positive return on November 3, 2008 (14.22%).

6.2 Regression results

Table 6 shows the regression results for the different specifications. The adjusted R^2 is 90% for the firm-wide recovery rate as a dependent variable and 68% (65%) for the senior unsecured (subordinate) recovery rate, indicating that the regressors explain a remarkably high amount of the variation in recovery rates. The explanatory power of our regressors for the instrument-specific recovery rates is relatively close to the adjusted R^2 of 66% that Jankowitsch et al. (2013) find for determinants of realized recovery rates. Firm values at default in general exhibit a smaller variation compared to senior unsecured recovery rates. Regressing only either the firm- or time-fixed-effects on the firm values at default shows that cross-sectional determinants matter more than time-series differences (adjusted R^2 of 88% and 2%).[15] For the senior unsecured recovery rate, the firm-dummies alone result in an adjusted R^2 of 61% while quarterly time dummies alone lead to an adjusted R^2 of 5%. Excluding fixed-effects, we obtain an adjusted R^2 of 47% for the firm value at default and 20% for the senior unsecured recovery rate.

We find that a higher support probability leads to higher firm-wide recovery rates. In case of the highest possible support probability, the firm-wide recovery rate increases by 0.89%, the senior unsecured recovery rate by 4.24% and the subordinate recovery rate by 1.53%. Adding the interaction term shows that government support matters especially during the time of the financial crisis which is associated with a maximum increase of 2.83% in the firm value at default. The senior unsecured (subordinate) recovery rate increases up to 7.74% (3.83%) during the financial crisis, which is statistically and economically significant. These results translate to a huge absolute level of market-wide government support. The group of 29 banks that are listed as global systemically important banks by the Financial Stability Board as of November 2013 have an aggregated amount of liabilities of 44,711bn USD. The aggregated rise in the firm value at default therefore corresponds to 1,265bn USD assuming that these companies are highly likely to receive support.

Leverage has a negative effect on the senior unsecured and the subordinate recovery rate as expected. A one standard deviation increase in leverage causes the senior unsecured recovery rate to fall by 1.56%. The q-ratio is also significant and leads to an increase in expected recovery rates. Firm size has a positive influence on the firm recovery rate, but a negative influence on the subordinate recovery rate. A one percent higher book value of assets leads to a rise in the firm value at default of 2.79%. Consistent with the evidence on realized recovery rates, market expectations of recovery rates are larger for positive aggregated stock market returns.

In summary, we show that market expectations of recovery rates are driven by similar

[15] The results for the differences in the adjusted R^2 are not reported in Table 6, but are available on request.

cross-sectional and time-series determinants than realized recovery rates. Expected government support increases all three types of recovery rates and this effect is particularly strong during the time of the financial crisis. We also find that cross-sectional and time-series regressors explain a large amount of the variation in recovery rates.

7 Robustness

We add a robustness test in order to verify whether our results hold regardless of the assumptions we have made concerning the functional form of the firm value distribution at default, the calculation of the liability structure and the specification of the seniority violation. We keep the expected subordinate recovery rate constant to achieve a separation of the implied recovery rate and the default probability. In particular, by setting μ^{Sub} to a constant $\bar{\mu}^{Sub}$, we can rewrite 4.1 as

$$
\begin{aligned}
R_{i,t}^{obs} = \frac{CDS_{i,t}^{Sen}}{CDS_{i,t}^{Sub}} = \frac{1-\mu_{i,t}^{Sen}}{1-\bar{\mu}_{i,t}^{Sub}} \\
\Longleftrightarrow \mu_{i,t}^{Sen} = 1 - \frac{CDS_{i,t}^{Sen}}{CDS_{i,t}^{Sub}} \cdot (1-\bar{\mu}_{i,t}^{Sub}).
\end{aligned}
$$

The setup is employed by Norden and Weber (2012) who use the same methodology for a sample of 20 European banks and set $\bar{\mu}^{Sub}$ to zero arguing that once a financial institution defaults, subordinate creditors are unlikely to recover anything given the seniority of their claims. As we have shown, this assumption is not reflected in realized recovery rates of subordinate debt (as seniority violations occur). We therefore estimate μ^{Sen} using the specification above while setting $\bar{\mu}^{Sub}$ to zero as well as setting it to the historical mean recovery rate of subordinate debt of 24.6% (Ou and Metz (2011)). We then estimate the regression 6.1 including and excluding the interaction dummy using μ^{Sen} as a dependent variable for both specifications of $\bar{\mu}^{Sub}$.

Table 7 reports the results of the regression. The overall explanatory power is 70% as given by the adjusted R^2 and therefore slightly higher than in the previous setup. The regressors exhibit the same sign and statistical significance for both specifications of $\bar{\mu}^{Sub}$, although the magnitude of the influence is higher for the case $\bar{\mu}^{Sub} = 0$. As before, government support positively influences the expected senior unsecured recovery rate and this effect is stronger for the period of the financial crisis. A higher leverage has a negative and higher growth prospects measured with the q-ratio have a positive effect on the senior unsecured recovery rate. Firm size is now statistically significant and increases the implied recovery rate while the results were insignificant before. The return of the MSCI world index still has a positive influence. Overall, we conclude that the regression results concerning the influence of government support hold, regardless of the assumptions we have made in our previous model.

8 Conclusion

We present a methodology that allows the extraction of the time-series of market expectations of recovery rates using CDS referencing different tiers for the same company. Our setup incorporates violations of the absolute priority rule between the senior unsecured and subordinate tier. For this purpose, we empirically determine a firm-specific liability structure to link instrument-specific recovery rates to an expectation of the firm value at default.

An application of our model to a sample of financial and non-financial companies located in the United States and Europe shows that expected recovery rates of financial companies are larger than those of non-financial companies. We quantify the impact that economic factors have on these recovery rate estimates and find that a strong cross-sectional and time-series variation is present. We specifically look at the role of government support and show that market participants seem to anticipate government support actions which leads to higher recovery rate expectations especially during the time of the financial crisis.

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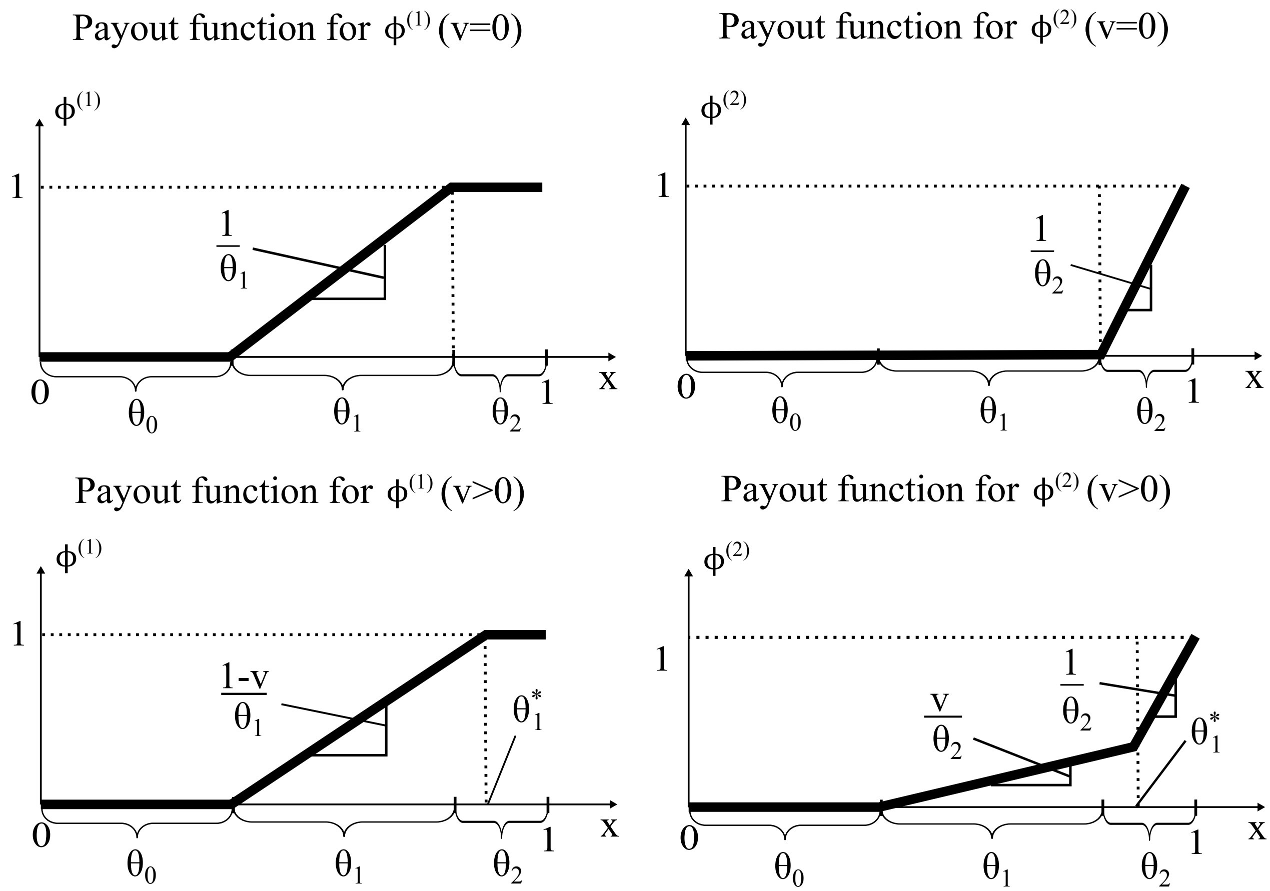

Figure 1: **Instrument-specific payout functions with and without seniority violations:** the figures depict the instrument-specific payout functions for the senior and subordinate creditors dependent on the firm value at default x. The left (right) column shows the instrument specific payout functions for the senior (junior) creditors $\phi^{(1)}$ ($\phi^{(2)}$) for the case without ($v = 0$) and with seniority violations ($v > 0$).

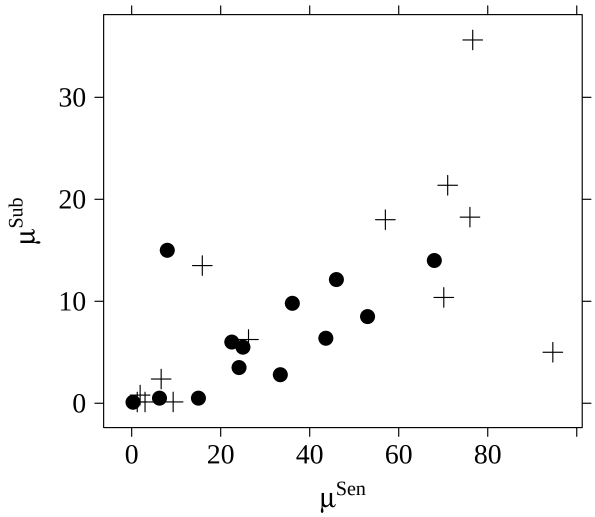

Figure 2: **Realized recovery rates for senior unsecured and subordinate creditors**: the figure shows the realized senior unsecured and subordinate recovery rates in percent for 26 default events. Crosses indicate financial companies, dots indicate non-financial companies. The data on defaults is derived from Moody's annual default reviews of the years 2008-2012 and CDS auction results (see Appendix D for more details on the data preparation).

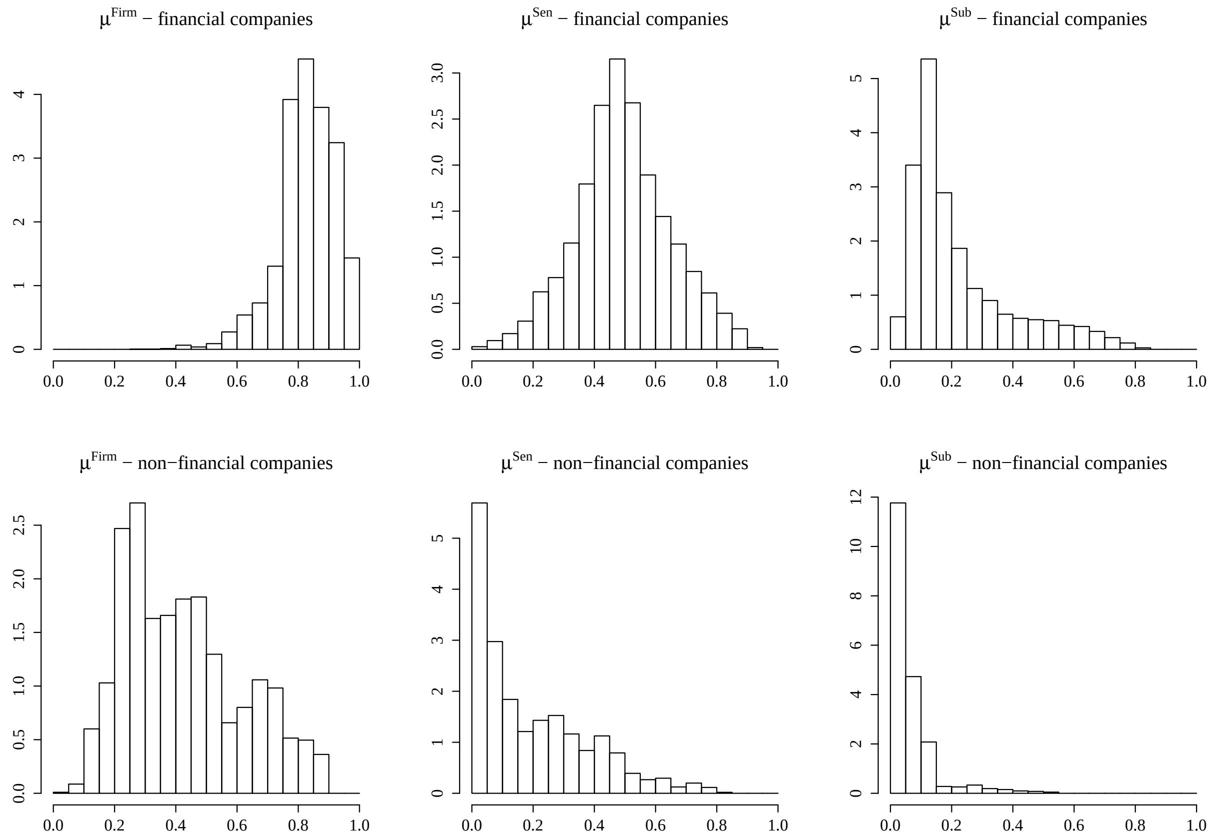

Figure 3: **Histogram of recovery rate estimates:** the first (second) row shows the distribution of the estimates for the firm value at default, the senior unsecured and the subordinate expected recovery rate for financial (non-financial) companies.

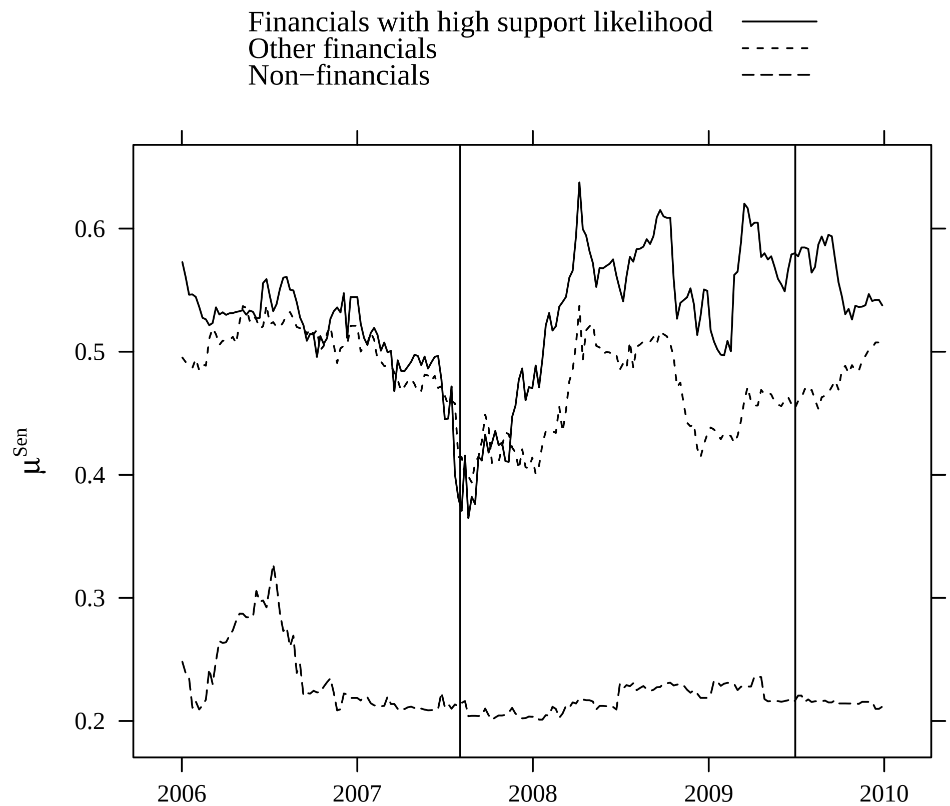

Figure 4: **Time-series of senior unsecured recovery rates:** the figure shows the mean senior unsecured recovery rate from January 2006 until December 2010 for 60 firms (52 financial and 8 non-financial) that have recovery rate estimates before 2006. We further group financial companies into those having an expected support probability of 90%-100% at least once during the observation period (24 of the 52 financial companies) and carry forward the latest recovery rate value if it is missing. The vertical lines indicate the start and end date of the financial crisis.

Full sample				
	Mean	Std.	Min	Max
CDS_{Sen}	1.37	2.06	0.04	29.68
CDS_{Sub}	1.99	2.89	0.06	48.81
Ratio	66.99	12.58	14.00	99.99

Financial companies				
	Mean	Std.	Min	Max
CDS_{Sen}	1.18	1.87	0.04	26.69
CDS_{Sub}	1.82	2.82	0.06	48.81
Ratio	64.48	9.99	14.00	99.46

Non-financial companies				
	Mean	Std.	Min	Max
CDS_{Sen}	2.73	2.69	0.15	29.68
CDS_{Sub}	3.20	3.07	0.18	30.12
Ratio	84.38	14.70	25.75	99.99

Table 1: **Descriptive statistics of the CDS data:** this table shows the means, standard deviations, minima and maxima of CDS spreads and the respective ratios of senior unsecured and subordinate spreads for our sample of 16,604 weekly observations covering 65 financial and 26 non-financial companies located in the United States and Europe for the time period April 2002 until November 2012. All values are given in percent.

	Full sample		**Financials**		**Non-financials**	
	Mean	Std.	Mean	Std.	Mean	Std.
Percentage of priority class of all claims	74.54	20.34	78.94	16.00	44.13	21.11
Percentage of senior unsecured class of all claims	19.41	17.12	17.78	15.58	30.70	22.26
Percentage of subordinate class of all claims	6.04	10.41	3.28	2.40	25.17	19.97
Sum of all claims	100.00	-	100.00	-	100.00	-

Table 2: **Width of seniority classes:** this table shows the mean width of each seniority class in percent of all liability claims.

Financial companies			
	All time	Crisis	No-crisis
μ^{Firm}	82.69	81.52	83.01
	(9.30)	(9.21)	(9.30)
μ^{Sen}	49.50	46.00	50.46
	(15.46)	(16.02)	(15.16)
μ^{Sub}	22.50	19.59	23.31
	(16.99)	(15.06)	(17.40)

Non-financial companies			
	All time	Crisis	No-crisis
μ^{Firm}	42.33	35.35	43.38
	(19.25)	(16.83)	(19.38)
μ^{Sen}	19.70	9.81	21.18
	(18.35)	(11.29)	(18.74)
μ^{Sub}	5.97	3.21	6.38
	(7.87)	(6.04)	(8.02)

Table 3: **Recovery rate estimates:** the table shows the means and standard deviations (given in parenthesis) of the expected recovery rates of the firm (μ^{Firm}), the senior unsecured (μ^{Sen}) and the subordinate debt class (μ^{Sub}) for financial and non-financial companies. The first column reports the average for the entire time period. The second and third column differentiate for the period of the financial crisis from 08-03-2007 to 06-30-2009. The entire sample consists of 16,604 observations. All values are given in percent.

Company name	Last model obs.	Bond prices				Auction
		Median	Std.	Min	Max	
Fannie Mae	90.47 (8-25-2008)	96.82	0.89	95.86	98.87	91.51 (10-6-2008)
Lehman Brothers	22.53 (9-8-2008)	17.00	24.77	8.50	81.08	8.63 (10-10-2008)
Washington Mutual	21.12 (9-22-2008)	62.00	15.06	23.00	71.00	57.00 (10-23-2008)
Glitnir Banki	43.63 (9-29-2008)	3.00	32.39	1.00	81.51	3.00 (11-5-2008)
Allied Irish Banks	84.98 (2-21-2011)	87.27	2.35	82.25	90.50	70.13 (6-30-2011)
Irish Life and Permanent	82.19 (3-28-2011)	88.51	2.73	77.27	92.03	83.00 (7-29-2011)

Table 4: **Comparison of recovery rate estimates and CDS auction results:** this table shows the last available senior unsecured and subordinate recovery rate estimate (*Last model obs.*) in our sample as well as the corresponding realizations (*Auction*) from the auction. We also include the median, standard deviation, minimum and maximum of the prices of bonds that are listed as deliverable obligations for the CDS for the time between our latest model observation and the auction date (*Bond prices*). Auction results are available at www.creditfixings.com, bond prices are obtained from Interactive Data. The recovery rate of Irish Life and Permanent corresponds to the Senior Bucket1 tier. All recovery rates are given in percent.

Full sample				
	Mean	Std.	Min	Max
Leverage [%]	91.31	9.88	22.93	99.82
QRatio	1.07	0.23	0.63	3.49
Total assets [bn USD]	570.92	668.31	1.04	3,649.13
r_{MSCI} [% peer week]	0.05	2.76	-17.10	14.22

Financial companies				
	Mean	Std.	Min	Max
Leverage [%]	94.15	4.03	28.50	99.82
QRatio	1.01	0.04	0.63	1.27
Total assets [bn USD]	651.87	677.76	4.70	3,649.13
r_{MSCI} [% peer week]	0.04	2.79	-17.10	14.22

Non-financial companies				
	Mean	Std.	Min	Max
Leverage [%]	71.64	14.77	22.93	99.59
QRatio	1.48	0.48	0.64	3.49
Total assets [bn USD]	11.24	10.02	1.04	53.39
r_{MSCI} [% peer week]	0.08	2.57	-17.10	14.22

Table 5: **Descriptive statistics of the variables used in the regression analysis:** the table provides descriptive statistics for the regression variables of the financial and non-financial companies in our sample. The entire sample consists of 16,604 weekly observations between 04-08-2002 and 11-26-2012. *Leverage* is defined as the book value of liabilities divided by the book value of total assets in percent, *QRatio* is the market value of assets divided by the book value of assets, *Total assets* is the book value of total assets in bn USD and r_{MSCI} is the weekly return of the MSCI World index in percent.

	μ^{Firm}	μ^{Firm}	μ^{Sen}	μ^{Sen}	μ^{Sub}	μ^{Sub}
SupportProb	0.89***	0.04	4.24***	2.75***	1.53***	0.38
	(0.20)	(0.21)	(0.41)	(0.43)	(0.39)	(0.42)
SupportProb · Crisis		2.83***		4.99***		3.83***
		(0.29)		(0.54)		(0.50)
Leverage	-3.28	-3.32	-15.76***	-15.84***	-8.62***	-8.68***
	(3.87)	(3.89)	(3.63)	(3.63)	(1.76)	(1.78)
QRatio	2.33***	2.02**	5.29***	4.75***	1.07*	0.66
	(0.80)	(0.79)	(1.07)	(1.08)	(0.58)	(0.59)
Ln(assets)	2.79***	2.66***	-0.24	-0.47	-3.37***	-3.55***
	(0.27)	(0.28)	(0.47)	(0.47)	(0.47)	(0.46)
r_{MSCI}	4.63**	4.72**	11.30***	11.46***	7.72**	7.84**
	(1.90)	(1.88)	(3.49)	(3.47)	(3.15)	(3.15)
Firm and quarterly FE	Y	Y	Y	Y	Y	Y
Obs.	16,604	16,604	16,604	16,604	16,604	16,604
$Adj.R^2$	90%	90%	68%	68%	65%	65%

Table 6: **Multivariate evidence on implied recovery rates:** the table shows the regression results for different recovery rates (given in percent). The two columns on the left have the firm recovery rate (ϕ^{Firm}), the two columns in the middle the recovery rate of the senior unsecured tier (ϕ^{Sen}) and the two columns on the right the recovery rate of the subordinate tier (ϕ^{Sub}) as the dependent variable. *SupportProb* is the transformed measure of the support likelihood based on the Fitch Support Rating. A dummy for the financial crisis (*Crisis* indicates the period from 08-03-2007 to 06-30-2009), *Leverage* (book value of liabilities / book value of assets), *QRatio* (market value of assets / book value of assets), the logarithm of the book value of total assets (*Ln*(*total assets*)) and the weekly return of the MSCI World Index (r_{MSCI}) are added as control variables. The regression is based on 16,604 weekly observations of the respective recovery rate. We include firm-fixed effects, quarterly time-fixed effects and an intercept (not reported). The standard-errors (given in parenthesis) are corrected for heteroscedasticity. The superscripts ***, ** and * denote significance at the 1%, 5% and 10% level.

	$\mu^{Sub} = 0$		$\mu^{Sub} = 24.6\%$	
	μ^{Sen}	μ^{Sen}	μ^{Sen}	μ^{Sen}
SupportProb	3.66***	2.81***	2.76***	2.12***
	(0.27)	(0.28)	(0.20)	(0.21)
SupportProb · Crisis		2.83***		2.14***
		(0.33)		(0.25)
Leverage	-10.68***	-10.72***	-8.05***	-8.08***
	(2.83)	(2.82)	(2.13)	(2.13)
QRatio	4.64***	4.33***	3.50***	3.27***
	(0.84)	(0.83)	(0.63)	(0.63)
Ln(total assets)	0.54*	0.41	0.41*	0.31
	(0.30)	(0.30)	(0.23)	(0.23)
r_{MSCI}	8.06***	8.15***	6.08***	6.15***
	(2.28)	(2.26)	(1.72)	(1.71)
Firm and quarterly FE	Y	Y	Y	Y
Obs.	16,604	16,604	16,604	16,604
$Adj.R^2$	70%	70%	70%	70%

Table 7: **Robustness of multivariate evidence on implied recovery rates:** the table shows the regression results for the senior unsecured recovery rate (ϕ^{Sen}) that is calculated assuming fixed recovery rates for the subordinate tier (see Norden and Weber (2012)). The two columns one the left assume a subordinate recovery rate of 0, the two columns on the right are based on a subordinate recovery rate of 24.6%, which refers to the mean realized recovery rate (excluding distressed exchanges) for the period 1982-2007 for financial companies as reported by Ou and Metz (2011). *SupportProb* is the transformed measure of the support likelihood based on the Fitch Support Rating. A dummy for the financial crisis (*Crisis* indicates the period from 08-03-2007 to 06-30-2009), *Leverage* (book value of liabilities / book value of assets), *QRatio* (market value of assets / book value of assets), the logarithm of the book value of total assets (*Ln*(*total assets*)) and the weekly return of the MSCI World Index (r_{MSCI}) are added as control variables. The regression is based on 16,604 weekly observations of the respective recovery rate. We include firm-fixed effects, quarterly time-fixed effects and an intercept (not reported). The standard-errors standard-errors (given in parenthesis) are corrected for heteroscedasticity. The superscripts ***, ** and * denote significance at the 1%, 5% and 10% level.

A Model formulas and the Rayleigh distribution

In order to estimate 2.4, we need to specify a probability distribution function $f(x)$ for the firm value at default. We transform the one-parametric Rayleigh distribution, which is defined on $[0, \infty)$, for this purpose. Since we normalize all claims and liability structure parameters by the value of all claims at default, the distribution has to encompass values on $(0, 1)$. The (non-transformed) probability density function $g(y)$ of the Rayleigh distribution is given by

$$g(y) = \frac{y}{\beta^2} e^{-\frac{1}{2}\left(\frac{y}{\beta}\right)^2}$$

for y, $\beta \geq 0$ We transform the distribution using the transformation theorem for densities

$$f(x) = \frac{g(t^{-1}(x))}{t'(t^{-1}(x))},$$

where $t(y) = 1 - e^{-y}$, $t^{-1}(\cdot)$ denotes the inverse function and $t'(\cdot)$ the derivative of $t(\cdot)$. Applying $t(y)$ to the Rayleigh distribution we obtain the probability density function

$$f(x) = \frac{\ln(1-x)}{\beta^2(x-1)} e^{\left(-\frac{1}{2}\left(\frac{\ln(1-x)}{\beta}\right)^2\right)} \qquad x \in [0,1], \beta > 0$$

Accordingly the expected firm recovery μ is

$$\mu = \beta e^{\frac{\beta^2}{2}} \sqrt{2\pi}(1 - \Phi(\beta)),$$

where $\Phi(\cdot)$ denotes the cumulative density function of the standard normal distribution. Figure 5 shows the transformed Rayleigh distribution for different choices of μ.

Substituting $\theta_1^* = \theta_0 + \frac{\theta_1}{1-v}$, the instrument-specific recovery rate for the medium seniority tier μ^{Sen} is then

$$\mu^{Sen} = E_{t_0}^Q(\phi^{(1)} \,|\, \mathbf{1}_{\{\tau \leq T\}} = 1) = [\int_0^1 \phi^{(1)}(x,\theta,v)\, f(x)\, dx] =$$

$$\int_0^{\theta_0} 0 \cdot f(x)\, dx + \int_{\theta_0}^{\theta_1^*} \frac{x-\theta_0}{\theta_1} \cdot (1-v) \cdot f(x)\, dx + \int_{\theta_1^*}^1 1 \cdot f(x)\, dx =$$

$$\int_{\theta_0}^{\theta_1^*} \frac{x-\theta_0}{\theta_1} \cdot (1-v) \cdot \frac{\ln(1-x)}{\beta^2(x-1)} e^{\left(-\frac{1}{2}\left(\frac{\ln(1-x)}{\beta}\right)^2\right)} dx + \int_{\theta_1^*}^1 \frac{\ln(1-x)}{\beta^2(x-1)} e^{\left(-\frac{1}{2}\left(\frac{\ln(1-x)}{\beta}\right)^2\right)} dx =$$

$$\frac{\sqrt{2\pi} e^{\frac{\beta^2}{2}} \beta}{\theta_1} (1-v) \left(\Phi\left(\beta - \frac{ln(1-\theta_1^*)}{\beta}\right) - \Phi\left(\beta - \frac{ln(1-\theta_0)}{\beta}\right)\right).$$

The instrument-specific recovery rate for the least senior tier μ^{Sub} is

$$\mu^{Sub} = E_{t_0}^Q(\phi^{(2)} \,|\, \mathbf{1}_{\{\tau \leq T\}} = 1) = [\int_0^1 \phi^{(2)}(x,\theta,v)\, f(x)\, dx] =$$

$$\int_0^{\theta_0} 0 \cdot f(x)\, dx + \int_{\theta_0}^{\theta_1^*} \frac{x-\theta_0}{\theta_2} \cdot v \cdot f(x)\, dx + \int_{\theta_1^*}^1 \frac{x-(\theta_0+\theta_1)}{\theta_2} \cdot f(x)\, dx =$$

$$\int_{\theta_0}^{\theta_1^*} \frac{x-\theta_0}{\theta_2} \cdot v \cdot \frac{\ln(1-x)}{\beta^2(x-1)} e^{\left(-\frac{1}{2}\left(\frac{\ln(1-x)}{\beta}\right)^2\right)} dx + \int_{\theta_1^*}^1 \frac{x-(\theta_0+\theta_1)}{\theta_2} \cdot \frac{\ln(1-x)}{\beta^2(x-1)} e^{\left(-\frac{1}{2}\left(\frac{\ln(1-x)}{\beta}\right)^2\right)} dx =$$

$$\frac{\sqrt{2\pi} e^{\frac{\beta^2}{2}} \beta}{\theta_2} \left(v \cdot (\Phi\left(\beta - \frac{ln(1-\theta_1^*)}{\beta}\right) - \Phi\left(\beta - \frac{ln(1-\theta_0)}{\beta}\right)) + 1 - \Phi\left(\beta - \frac{ln(1-\theta_1^*)}{\beta}\right)\right).$$

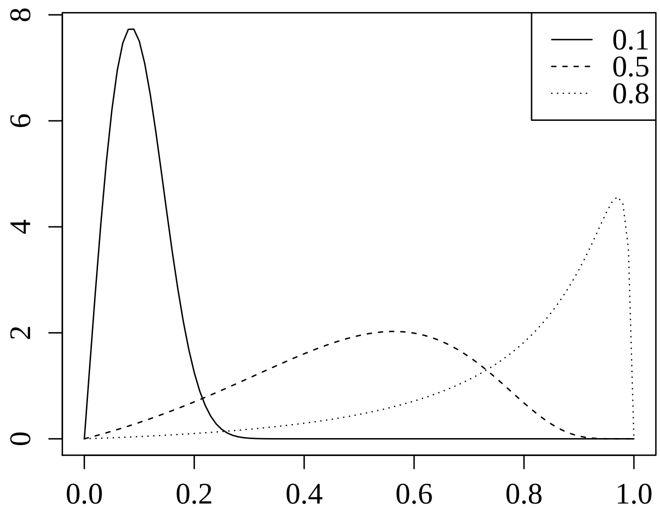

Figure 5: **Transformed Rayleigh probability density function:** the figure shows the probability density function for the transformed Rayleigh distribution for different means (0.1, 0.5 and 0.8).

B Capital IQ items used to calculate the debt structure

Capital IQ item	Description
	Priority class
AP	Accounts payable
INC_TAX_PAY_CURRENT	Current income taxes payable
DEF_TAX_LIAB_LT	Deferred tax liabilities non-current
CAPITAL_LEASES_TOTAL	Outstanding balance for capital leases
SECURED_DEBT	Secured debt
TOTAL_DEPOSITS	Total deposits
INS_ANNUITY_LIAB	Insurance and annuity liabilities
	Senior unsecured class
SR_UNSECURED_BONDS_NOTES	Senior unsecured bonds and notes
	Subordinate class
TOTAL_SUB_DEBT	Total subordinate debt

Table 8: **Capital IQ items:** this table shows the Capital IQ items that we used to calculate the debt structure of our sample companies and the respective seniority classes.

C Fitch Support Rating

Support Rating	Fitch description	Support Prob.
1	A bank for which there is an extremely high probability of external support. The potential provider of support is very highly rated in its own right and has a very high propensity to support the bank in question. This probability of support indicates a minimum Long-Term Rating floor of 'A-'.	1
2	A bank for which there is a high probability of external support. The potential provider of support is highly rated in its own right and has a high propensity to provide support to the bank in question. This probability of support indicates a minimum Long-Term Rating floor of 'BBB-'.	0.9
3	A bank for which there is a moderate probability of support because of uncertainties about the ability or propensity of the potential provider of support to do so. This probability of support indicates a minimum Long-Term Rating floor of 'BB-'.	0.5
4	A bank for which there is a limited probability of support because of significant uncertainties about the ability or propensity of any possible provider of support to do so. This probability of support indicates a minimum Long-Term Rating floor of 'B'.	0.25
5	A bank for which there is a possibility of external support, but it cannot be relied upon. This may be due to a lack of propensity to provide support or to very weak financial ability to do so. This probability of support indicates a Long-Term Rating floor no higher than 'B-' and in many cases, no floor at all.	0

Table 9: **Fitch Support Rating and associated support probabilities:** this table shows the different scales of the Support Rating by Fitch and their definitions (cited from Fitch (2013)). The assignment of different probabilities to each of the rating categories follows Gropp et al. (2010).

D Realized default events with senior unsecured and subordinate creditors

We combine data from the annual Moody's default review (see e.g. Ou et al. (2013)) for the years 2008-2012 and collect all available recovery rates from CDS auctions where information on senior unsecured and subordinate creditors is available.[16] Thereof, we select those where senior unsecured creditors receive a payment. We exclude one case where the senior unsecured recovery rate is smaller than 0.1% as well as the defaults of Fannie Mae and Freedie Mac as the senior unsecured and subordinate recovery rates are almost one. If a senior unsecured and a subordinate recovery rate is available in both datasets for a specific default, we use the data from the CDS auction. We also exclude one subsidiary observation where the holding company defaulted as well. If more than one credit tier is available in the CDS auction, we choose the 'B2' tier as the most representative and do not include the other tiers. Table 10 provides an overview of the resulting 26 cases.

E Recovery rate estimates per company

See Table 11 and 12.

[16]CDS auction results are available at www.creditfixings.com.

Default year	Company	μ_{real}^{Sen}	μ_{real}^{Sub}	$\mu_{real}^{Sub}/\mu_{real}^{Sen}$	Source
2005	Collins & Aikman Products	43.63	6.38	14.61	CDS auction
2006	Dura Operating	24.13	3.50	14.51	CDS auction
2008	Glitnir banki hf.	3.00	0.13	4.17	CDS auction
2008	Hawaiian Telcom Communications	6.25	0.50	8.00	Moody's
2008	Kaupthing banki hf.	6.63	2.38	35.85	CDS auction
2008	Landsbanki Islands hf	1.25	0.13	10.00	CDS auction
2008	Lehman Brothers Holdings	9.32	0.13	1.39	Moody's
2008	Pilgrim's Pride Corporation	25.00	5.50	22.00	Moody's
2008	Tousa	53.00	8.50	16.04	Moody's
2008	Vertis	46.00	12.13	26.37	Moody's
2008	Washington Mutual	57.00	18.00	31.58	Moody's
2009	Aleris International	0.30	0.10	33.33	Moody's
2009	Bradford & Bingley	94.63	5.00	5.28	CDS auction
2009	Cooper Standard Automotive	22.50	6.00	26.67	Moody's
2009	Dex Media West	68.00	14.00	20.59	Moody's
2009	Georgia Gulf Corporation	36.10	9.80	27.15	Moody's
2009	Simmons Company	8.00	15.00	187.50	Moody's
2009	Station Casinos	33.40	2.80	8.38	Moody's
2009	Thornburg Mortgage	1.90	0.80	42.11	Moody's
2010	Anglo Irish Bank	76.00	18.25	24.01	CDS auction
2011	Allied Irish Bks	70.13	10.38	14.80	CDS auction
2011	Irish Life and Permanent	71.00	21.38	30.11	CDS auction
2011	The Gov. and Comp. of the Bank of Ireland	76.63	35.63	46.49	CDS auction
2012	Banco Cruzeiro do Sul	15.87	13.50	85.09	Moody's
2012	BTA Bank	26.25	6.25	23.81	Moody's
2012	Hawker Beechcraft Acquisition Comp.	15.00	0.50	3.33	Moody's

Table 10: **Default events with seniority violations**: the table shows 26 default events with recovery rates for senior unsecured (μ_{real}^{Sen}) and subordinate creditors (μ_{real}^{Sub}) of companies where seniority violations occur. The data is based on recovery rates as reported by the annual Moody's default review and CDS auctions. All values are given in percent.

COMPANY NAME (COUNTRY)		$\bar{\mu}^{Firm}$	$\bar{\mu}^{Sen}$	$\bar{\mu}^{Sub}$	COMPANY NAME (COUNTRY)		$\bar{\mu}^{Firm}$	$\bar{\mu}^{Sen}$	$\bar{\mu}^{Sub}$
AMKOR TECHNOLOGY	US	39.34	32.66	7.91	LEHMAN BROTHERS HOLD.	US	69.23	22.69	5.24
BANK OF AMERICA CORP.	US	82.81	34.40	14.89	MGM MIRAGE	US	47.68	28.31	6.86
BANK ONE CORP.	US	85.88	46.09	24.92	MORGAN STANLEY	US	66.79	21.08	4.83
BE AEROSPACE	US	26.44	41.46	11.92	NAVISTAR INT. CORP.	US	53.65	19.05	4.37
BEST BUY CO.	US	67.32	6.79	1.80	OFFICE DEPOT	US	57.82	14.97	5.18
BOYD GAMING CORP.	US	48.42	5.16	1.45	OMNICARE	US	26.18	7.25	1.69
CITIGROUP INC.	US	76.49	30.56	7.79	PERKINELMER	US	49.18	28.83	9.97
DISH NETWORK CORP.	US	34.56	21.65	4.96	SANMINA-SCI CORP.	US	41.73	19.06	4.66
FEDERAL NATIONAL MORTGAGE AS.	US	57.99	58.69	13.82	SUNTRUST BANKS	US	92.18	62.51	45.11
HEALTH MANAGEMENT ASSOCIATES	US	50.99	15.83	5.86	TENNECO	US	77.00	55.93	31.42
HEALTHSOUTH CORP.	US	36.65	40.93	9.39	THE GOLDMAN SACHS GROUP	US	78.20	30.45	13.33
INTEL CORP.	US	51.22	26.09	11.66	THE TJX COMPANIES	US	72.98	52.89	27.08
IRON MOUNTAIN	US	25.92	7.03	1.76	U.S. BANCORP	US	83.16	38.19	21.33
KB HOME	US	33.28	16.08	3.82	UNITED RENTALS	US	46.70	37.91	9.57
KEYCORP	US	72.93	18.63	5.13	VINTAGE PETROLEUM	US	37.08	32.70	7.55
KOHL'S CORP.	US	36.15	8.48	2.02	WASHINGTON MUTUAL	US	82.97	26.05	10.32
L-3 COMMUNICATIONS CORP.	US	16.20	11.41	2.65	WELLS FARGO & COMPANY	US	78.84	33.04	10.60

Table 11: **Recovery rate estimates for companies located in the United States**: this table shows the means of the firm- ($\bar{\mu}^{Firm}$), senior unsecured ($\bar{\mu}^{Sen}$) and subordinate ($\bar{\mu}^{Sub}$) recovery rate estimates for all sample companies, which are located in the United States. Recovery rates are given in percent.

COMPANY NAME (COUNTRY)		$\bar{\mu}^{Firm}$	$\bar{\mu}^{Sen}$	$\bar{\mu}^{Sub}$	COMPANY NAME (COUNTRY)		$\bar{\mu}^{Firm}$	$\bar{\mu}^{Sen}$	$\bar{\mu}^{Sub}$
ERSTE BANK D. OESTER. SPARK.	AT	85.30	53.08	23.69	EFG EUROBANK ERGASIAS	GR	86.76	41.59	13.35
CREDIT SUISSE GROUP	CH	81.31	37.51	12.61	ALLIED IRISH BANKS	IE	88.20	54.15	23.79
ALLIANZ	DE	87.85	51.68	23.77	IRISH LIFE & PERMANENT	IE	89.29	68.47	39.06
COMMERZBANK	DE	81.24	63.16	28.27	GLITNIR BANKI HF.	IS	78.24	34.42	12.60
DEUTSCHE BANK	DE	82.88	45.45	13.78	BANCA INTESA	IT	80.95	53.64	20.79
HANNOVER RUECKVER.	DE	95.73	64.68	52.44	BANCA LOMBARDA E PIEMONTESE	IT	77.35	50.91	14.70
INFINEON TECHNOLOGIES	DE	31.19	10.05	3.11	BANCA MONTE DEI PASCHI DI SIENA	IT	81.15	53.98	18.94
DANSKE BANK A/S	DK	83.73	49.09	17.84	BANCA POPOLARE DI LODI	IT	68.15	43.77	10.79
BANCO BILBAO VIZCAYA ARG.	ES	88.66	58.56	33.31	BANCA POPOLARE DI MILANO	IT	82.33	51.30	21.55
BANCO DE SABADELL	ES	86.72	54.19	27.47	BANCHE POPOLARI UNITE	IT	77.32	52.00	14.24
BANCO POPULAR ESPANOL	ES	88.47	52.61	24.95	BANCO POPOLARE DI VER. E NOV.	IT	79.01	45.36	11.65
BANCO SANTANDER CENTR. H.	ES	83.65	51.41	22.49	CAPITALIA	IT	76.96	45.59	12.85
BANKINTER	ES	86.57	50.37	20.47	SANPAOLO IMI	IT	80.10	49.12	12.56
AXA	FR	93.53	64.92	49.92	UNICREDITO ITALIANO	IT	87.90	57.03	30.77
BNP PARIBAS	FR	91.66	66.54	44.92	UNIPOL GRUPPO FINANZIARIO	IT	88.72	52.04	35.94
CREDIT AGRICOLE	FR	81.42	51.05	19.36	AEGON	NL	91.32	33.46	13.45
NATEXIS BANQUES POP.	FR	88.44	59.46	35.68	ING GROEP	NL	82.58	43.64	21.40
SCOR	FR	94.00	70.19	55.56	KONINKLIJKE AHOLD	NL	67.40	40.60	9.82
SOCIETE GENERALE	FR	95.10	70.05	56.81	KONINKLIJKE KPN	NL	25.31	9.58	2.20
AVIVA	GB	95.77	70.57	59.52	WOLTERS KLUWER	NL	25.76	9.15	2.09
BARCLAYS	GB	91.10	53.31	33.63	DNB NOR ASA	NO	74.77	47.57	12.29
HSBC HOLDINGS	GB	87.88	55.35	29.82	BANCO BPI	PT	82.54	46.93	16.02
LEGAL & GENERAL GROUP	GB	92.53	57.70	41.86	BANCO COMERCIAL PORTUGUES	PT	77.85	44.25	12.24
LLOYDS BANKING GROUP	GB	92.59	69.55	50.65	BANCO ESPIRITO SANTO	PT	80.16	46.64	17.29
MAN GROUP	GB	43.58	43.62	10.17	FORENINGSSPARBANKEN	SE	66.61	43.18	10.14
OLD MUTUAL	GB	93.56	58.53	43.66	NORDEA BANK	SE	81.30	45.94	14.12
PRUDENTIAL	GB	93.85	57.35	43.35	SKANDINAVISKA ENSKILDA B.	SE	80.32	46.73	14.16
ROYAL & SUN AL. INS. GROUP	GB	94.99	61.87	50.77	SVENSKA HANDELSBANKEN	SE	62.67	43.72	10.11
STANDARD CHARTERED BANK	GB	92.95	69.21	51.85					

Table 12: **Recovery rate estimates for European companies**: this table shows the means of the firm- ($\bar{\mu}^{Firm}$), senior unsecured ($\bar{\mu}^{Sen}$) and subordinate ($\bar{\mu}^{Sub}$) recovery rate estimates for all European sample companies. Recovery rates are given in percent.