The Effect of Rollover Risk on Default Risk: Evidence from Bank Financing

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This version: March 23, 2016

Abstract

We study the effect of rollover risk on the risk of default using a comprehensive database of U.S. industrial firms during 1986–2013 This article is the most thoroughgoing empirical research to date to support the existence of a rollover risk effect on the risk of default. A one standard deviation increase in the rollover risk variable leads to a 3.3% increase in default rates. We present evidence revealing the extent to which bank financing dependence affects the influence of rollover risk on default risk. Firms that depend on bank financing suffer the strongest rollover risk, especially during crisis in the credit market, and if they experience declining profitability and are of poor credit quality.

Keywords: Rollover Risk, Default Risk, Credit Risk, Bank Borrowing Dependence

JEL classification: G00; G18; G21; G32; G33

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1. Introduction

Rollover (refinancing) risk arises when a firm faces difficulties trying to roll over its maturing debt (Diamond (1991)), or needs to refinance debt affected by a high liquidity premium (He and Xiong (2012)).[1] The 2007–2009 crisis highlights that rollover risk interact with default risk through the deterioration in debt market liquidity that caused severe financing difficulties for many firms, which had negative impacts on the rollover of maturing debt, thus exacerbating many firms' default risk.

Recent theoretical literature also argues that rollover risk could be a source of credit risk, because it increases the possibility of a run on the firm (Morris and Shin (2009)) and sharpens conflicts of interest between shareholders and debt holders (He and Xiong (2012)). Therefore, equity holders declare the firm insolvent when the value of the assets of the firm is higher than would be in the standard situation. Forte and Peña (2011) offer the theoretical result that debt refinancing generates systematic rating downgrades, unless a minimum value of firm value growth exists.

The key implication of these theoretical models is that rollover risk tends to increase default risk, which we refer to as the rollover risk effect (RRE). Empirical evidence on RRE is in its early stage; as far as we know, only one published article by Gopalan, Song, and Yerramilli (2014) documents that firms that experience large increases in rollover risks likely suffer a strong deterioration in their credit quality.[2]

However, extant studies reveal a limited perspective of the impact of the rollover risk effect, because their samples are limited, restricted to firms with credit ratings,

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[1] Diamond (1991) shows that firms may struggle to roll over maturing debt, especially if the refinancing coincides with deterioration in the firm's fundamentals or credit market conditions.

[2] Chen, Xu, and Yang (2012), Hu (2010), and Valenzuela (2011) have working papers pertaining to this topic.

bond prices, or credit default swap spreads. To gain a comprehensive perspective, we consider important to study also other firms that previous research has neglected so far. In particular, unrated firms that represent a large proportion of U.S. firms (almost 67% according to our sample) are completely ignored by previous studies.[3]

This paper investigates the impact of rollover risk on default risk, by asking two questions: (1) Do firms with high rollover risk experience greater default probabilities than otherwise comparable firms that do not face rollover risk?, and (2) Do financing sources matter in the interaction between rollover risk and default risk?

In particular, we ask whether bank-dependent firms suffer greater rollover risk than otherwise similar firms that do not rely on bank financing. Firms that depend on bank financing tend to face more difficulties in long-term borrowing, have lower debt capacity, and suffer greater liquidity risk (Carey, Prowse, Rea, and Udell (1993); Diamond (1991); Lemmon and Zender (2010); Mian and Santos (2011)). All these attributes suggest that bank-dependent firms may have higher rollover risk, which in turn indicates higher default risk.

To test our hypotheses, we investigate non-financial firms in the U.S. market in the period from 1986 to 2013. We employ a panel data regression, where the dependent variable is the default risk, and the key explanatory variable is the rollover variable—the amount of the firm's long-term debt outstanding at the end of year $t-1$, due for repayment in year t. Several recent papers suggest that this rollover variable has lower correlation with firms' current risk factors. Thus, it is less affected by possible endogeneity concerns (see the discussion in Section 3.1.2) as compared with

[3] As we discuss in Section 3.2, our sample contains approximately 67% of firm-year observations of bank-dependent firms, and 33% of firm-year observations of firms that do not depend on bank financing.

other proxies for rollover risk, making this variable particularly suitable to be used in examining the rollover risk effect on credit risk (see e.g., Almeida, Campello, Laranjeira, and Weisbenner (2012); Gopalan et al. (2014)).

Our proxy for default risk is the expected default frequency (EDF), based on Merton's (1974) model. The EDF is a continuous, absolute measure of default risk that changes over the course of the credit cycle, reflecting changes in the level of default risk, which is exactly what we seek to capture in this study.[4] Furthermore, the computation of the EDF measure only requires publicly available information (stock price and accounting information), allowing us to gauge default risk for as many firms as possible.

We find that the empirical evidence strongly supports the rollover risk effect, in that it exacerbates default risk, consistent with our hypotheses. In particular, we show that, in the full sample, a one standard deviation increase in the rollover variable leads to a significant 3.3% increase in default rates after controlling for a comprehensive list of default risk factors. Furthermore, we examine whether the impact of the RRE is different depending on the financing sources of the firm. We find that a one standard deviation increase in the rollover variable leads to a significant 3.2% increase in the default rates of bank-dependent firms. However, this impact is lower (0.8%) and non-significant for non-bank-dependent firms.

Next, we test several alternative theories on the RRE related to the overall credit market condition, and firms' fundamental factors on profitability and credit quality. We find that the effect of the RRE is stronger during recessions, in years with increased spread yields of Baa-rated bonds relative to Aaa-rated bonds, for firms with

[4] Credit ratings can only reflect "relative" rankings of credit risk across firms at each time (see the discussion by Hovakimian, Kayhan, and Titman (2012)).

declining profitability, and for firms with relatively poor credit quality. The economic impact is substantial; in that, a one standard deviation increases in the rollover variable causes a 13.3% increase in the default rates during recessions, 12.3% when a firm experiences a declining profitability, and 10.4% for firms with poor credit quality. Interestingly, we find that for firms that have positive operating performance or good credit quality, the rollover variable significantly *decreases* default rates. This result suggests that the maturing debts, by themselves, do not cause refinancing risks. The risk only appears when the firm is already in trouble. This is consistent with the Diamond's (1991) theory that the maturing debt exposes a firm to refinancing risk only if the revealed information is negative, whereas debt's interest rate is likely to be reduced at refinancing as positive information is revealed.

We repeat this analysis for bank-dependent firms and non-bank-dependent firms separately. We find a similar pattern for bank-dependent firms as the one find in the baseline case. On the other hand, for non-bank-dependent firms, our results suggest that crises in the credit market do not drive the RRE. Only firms' fundamental factors seem likely to affect the RRE. Noticeably, we find that the impact of rollover variable in the case of firms with poor credit quality is quite substantial. A one standard deviation increase in the rollover risk variable leads a 17.7% increase in the default rates. Therefore, our results suggest that rollover risk is particularly serious for non-bank-dependent firms that have relatively low credit quality.

We conduct several robustness tests. First, we identify the level of bank dependence by examining the usage of a firm's bank debts relative to its total assets as alternative bank-dependent proxy, for which we identify unrated firms as bank-dependent firms in the baseline analysis. Second, we adopt an alternative proxy for measuring rollover risk—the ratio of debt maturing in more than three years to total assets value. Third, we repeat the baseline regressions with alternative sets of control variables. Overall results are systematically consistent with the baseline analysis, and thus provide further support to our arguments.

Our study adds to extant literature in several ways. First, we contribute to literature on both debt maturity and credit risk, by providing empirical validation of the theoretical prediction that rollover risk, arising from a firm's debt maturity structure, increases the firm's overall credit risk (e.g., He and Xiong (2012); Morris and Shin (2009)). Compared with most previous studies of the RRE that use restricted samples (e.g., Gopalan et al. (2014)), we provide more comprehensive empirical evidence, by including all levered firms in the U.S. market.

Second, this article complements several recent studies that exploit the global crisis of 2007–2009 to highlight its adverse impact on real-economy firms (e.g., Almeida et al. (2012); Duchin, Ozbas, and Sensoy (2010)).[5] The key contribution of our study is that whereas other articles examine the effect of rollover risk on the investment decisions of the firms, we investigate the impact of rollover risk on a firm's default risk and conclude that rollover risk likely exacerbates default risk.

Third, Chiu et al. (2015) study the mechanism by which a financial crisis affects the default risk of real-economy levered firms, using the 2007–2009 crisis as a natural experiment, and find that firms that depend strongly on bank financing tend to suffer higher increases in default risk than other, similar firms with no dependence on bank financing. However, they do not explore the economic reasons for these results. We

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[5] Almeida et al. (2012) show that firms for which a larger proportion of their long-term debt matured right after August 2007 experience larger drops in their real investment rates. Duchin et al. (2010) find that the decline in corporate investment following the global crisis is more pronounced among firms that had more net short-term debt.

instead provide new evidence that rollover risk constitutes an economic factor that helps explain why bank-dependent firms suffer higher default risks than non-bank-dependent firms.

The results in turn have important implications for academics and policy makers alike. For academics, our findings suggest a potential means to improve current credit risk models, namely, through a better understanding of the interaction between default risk and rollover risk (which relates closely to liquidity risk). Furthermore, we show that it is important to account for financing sources when assessing the interaction between rollover risk and default risk, because a firm's borrowing channel largely determines how rollover risk affects default risk. For policy makers, responsible for stabilizing economic situations, our results suggest a way to reduce the default risk of industrial firms, namely, by giving them incentives to adjust their debt maturity structure and thus minimize the impact of rollover risk.

The remainder of this article proceeds as follows: We present related literature and our hypotheses in Section 2. Section 3 contains the main variables for our study and the data. In Section 4, we discuss the empirical results, and in Section 5, we conclude with some discussion on the results of this study and suggestions for further research.

2. Literature Review and Hypothesis Development

In this section, we outline both theoretical and empirical research into the effect of the rollover risk on default risk and discuss the potential impact of a reliance on bank borrowing.

2.1. Rollover Risk Effect on Default Risk

2.1.1. Theoretical Background

Some recent studies propose theoretical models in which rollover (refinancing) risk increases default risk. Morris and Shin (2009) incorporate insights from bank-run literature (Diamond and Dybvig (1983)) into a stylized model and examine the interaction, showing that a negative fundamental shock can increase the probability that short-term debt holders decide not to refinance, which then increases the bank’s default probability.

He and Xiong (2012) apply Myers’s (1977) notions to Leland and Toft’s (1996) model and find that when debt market liquidity deteriorates, firms face rollover losses if they issue new bonds to replace maturing bonds. To avoid default, equity holders must bear rollover losses. The intrinsic conflict of interest between debt and equity holders may force equity holders to choose a higher fundamental firm value as a default barrier. In the presence of refinancing risk, a firm has a lower probability of survival. Forte and Peña (2011) also investigate the long-run effects of refinancing and find that debt refinancing increases default risk and systematic rating downgrades, unless some minimum level of firm value growth occurs. Deviations from this growth path imply asymmetric results: Lower firm value growth generates downgrades, and higher firm value growth generates upgrades. However, downgrades tend to be greater in absolute terms.

A key implication of these theoretical contributions is that the amount of firm’s debt that is maturing in the short term increases the firm’s overall default probability, beyond traditional default risk factors, causing the RRE we define herein.

2.1.2. Empirical Evidence

Some recent empirical evidence indicates the existence of a RRE. Gopalan et al. (2014) find that firms with greater exposure to rollover risk have poorer credit ratings. The RRE also is stronger among firms with speculative grade ratings and declining profitability, as well as during economic recessions. According to Chen et al. (2012), a bigger drop in the maturity of debt led to larger increases in credit spreads during the 2007–2009 crisis. This maturity effect on credit spreads is more pronounced for firms with high leverage or high systematic risk. Valenzuela (2011) finds an interaction between liquidity and default premiums, whereby debt market illiquidity increases firms' corporate bond spreads through rollover risk.

Our first hypothesis follows directly from these theoretical predictions and empirical evidence:

Hypothesis 1: *Firms with high exposure to rollover risk have higher default risk than firms without such exposure.*

Extant empirical studies that use particular proxies for default risk, usually study a restricted sample that does not cover all firms. For example, they use credit ratings, corporate bond spreads, or credit default swap spreads, making samples limited to large or less risky firms. We argue though that it is important to study all firms, especially those that have not been widely considered thus far. In particular, unrated firms that represent a quite large proportion of U.S. firms (almost 67% in our sample, as described in Section 3) are completely ignored in the previous studies. Due to these considerations, we employ a general default risk measure (EDF) and study a comprehensive sample, which should lead to conclusions that are more reliable than those from other published studies.

2.2. Impacts of Financing Sources on the RRE

The RRE is notable with regard to the potential role of alternative financing sources. To address this insufficiently explored issue, we particularly investigate whether the reliance on bank borrowing drives the RRE.

Carey et al. (1993) show that bank-dependent firms are more likely have trouble of finding long-term debt financing, because bank debts have shorter average maturities than publicly traded debt. Lemmon and Zender (2010) also note that unrated firms (typically classified as bank-dependent firms) tend to exhibit a lower debt capacity, possess a lower collateral value of assets, and suffer higher borrowing costs due to financial distress. These factors suggest unrated firms potentially are more exposed to rollover risk. Finally, Barclay and Smith (1995) find that a firm's debt maturity correlates negatively with credit risk for unrated firms, but positively for rated firms. Their findings suggest that higher short-term debt (i.e., higher rollover risk) thus might lead to a higher credit risk for bank-dependent firms as compared with firms that do not rely on bank borrowing. Thus our second hypothesis is:

Hypothesis 2: *The RRE is stronger for bank-dependent firms than for firms that do not depend on bank borrowing.*

3. Variables and Data

3.1. Variables

In this section we explain the measure we used to proxy for default risk, the construction of rollover risk as our main explanatory variable, and the characteristics of the control variables we employ in the corresponding regression.

3.1.1. Default Risk Variable

To examine RRE for all levered firms and obtain as large sample as possible, we are restricted from using some commonly employed proxies for default risk. That is, we need default risk measures that are flexible enough to quantify default risk for firms across the entire market. We compute the expected default frequency (EDF) on the basis of the Merton (1974) model, as the baseline measure of default risk; it has been used widely to indicate default risk for non-financial corporations (see Bharath and Shumway (2008); Chava and Purnanandam (2010); Hovakimian et al. (2012)). We adopted Moody's well-known KMV approach to measure EDF, which can be defined as:

$$EDF = N\left(-\left(\frac{\log\left(V/B\right)+\left(\mu-\sigma_V^2/2\right)T}{\sigma_V\sqrt{T}}\right)\right) = N\left(-DD\right), \tag{1}$$

where $N(.)$ is the cumulative distribution function for a standard normal distribution, V is a firm's total asset value, B represents a firm's face value of debt, σ_V is the volatility of the firm's asset return, μ offers an estimate of the expected long-run return of a firm's asset return, and T indicates the maturity of a firm's debt.

The EDF measure is a statistical prediction of default over some specified time horizon; we calculate the one-year default probability. In addition, we implement an estimate based on a one-year rolling window, updated monthly, to obtain time-series

EDF data. We explain the details of the estimation procedure in Appendix A.

Using EDF provides several advantages. Unlike credit ratings, which measure the *relative* probability of default at a fixed number of discrete levels, EDF is a continuous, *absolute* measure that changes over the course of the credit cycle (see Hovakimian et al. (2012)).[6] When the aim is to capture time-series dimension of default risk, EDF is a more appropriate measure of default risk than credit ratings.[7] In addition, computing EDF only requires stock price and accounting information, both of which are publicly available, so we can measure default risk for many, rather than a restricted group of firms.

3.1.2. Rollover Risk Variable

We use the proportion of long-term debt that matures every year to gauge the impact of rollover risk by following several recent papers (e.g., Almeida et al. (2012) Gopalan et al. (2014)). This variable has at least two advantages. First, long-term debt payable during the year should depend on the firm's previous long-term debt maturity decisions but be less correlated with the firm's current risk characteristics or credit quality. Second, this measure is largely free of the potential endogeneity that affects other measures of refinancing risk (e.g., short-term debt).

The rollover risk variable is defined as $(LT)_{-1,t-1}$: the amount of a firm's long-term debt outstanding at the end of year $t - 1$ due for repayment in year t (i.e.,

[6] Hovakimian et al. (2012) posit that ratings reflect relative rankings of credit risk at each point in time, without reference to an explicit time horizon; though credit ratings provide an ordinal ranking of default risk across firms, depending on the business cycle, mapping between ratings and short-run default probabilities may change.

[7] Gopalan et al. (2014) use credit ratings, and as far as we know, we are the first study using EDF to examine the RRE.

COMPUSTAT item *dd1* in year $t - 1$), scaled by the book value of total assets. A positive value of $(LT)_{-1,t-1}$ implies that a firm's exposure to rollover risk increases in year t.

3.1.3. Control Variables

We control for several relevant firm characteristics that may affect a firm's default risk in our empirical model. They are: (1) *Cash*, the ratio of cash holdings to total assets; (2) *MTB*, the ratio of the market value of total asset to book value of total assets, which represents growth opportunities; (3) *Idiovol*, measured using a standard deviation of excess equity returns, which represents operating risk; (4) *Tangibility*; (5) *Size*, measured using the logarithm of total assets; (6) *R&D*, the ratio of research and development expenditures to the book value of total assets; (7) *Tax*, the ratio of tax expenditures to the book value of total assets; (8) *Profitability*, the ratio of operating income to sales; (9) *Leverage*, the ratio of total debt to total assets; (10) *IntCov*, represents interest coverage. The detailed definitions of these variables are provided in Appendix B.

Regarding their economic rationale, *Cash* reflects a firm's ability to pay its debt obligations, so we expect this variable to exhibit a negative sign in the corresponding regression. *MTB* reflects growth opportunities and should be negatively correlated with default probability, in that it represents additional value (over and above book value) that debt holders can access in the event of a default. The *Idiovol* variable implies the probability that a firm's asset value is below the default boundary; the higher volatility, the higher the uncertainty, and therefore the higher the default probability. *Tangibility* should have a negative effect on default probability, because tangible assets lose less of their value in default than do intangible assets. *Size* is relevant because larger firms are more diversified, which reduces operating risks, so they should face less default risk than smaller firms. The *R&D* expenses proxy for the firm's brand equity and intellectual capital and are intangible. Intangible assets tend to lose more value than tangible assets in the event of default (Hale and Santos (2010)), so we expect a positive sign. *Tax* is negatively associated with default probability (Hovakimian et el. (2012)), because firms with higher tax rates tend to choose more conservative capital structures. For *Profitability*, we note that a profitable firm should be less likely to default; the expected sign is negative. We include *Leverage* because higher leverage implies a greater chance that the firm files for bankruptcy; we expect a positive sign associated with this variable in the corresponding regression. Finally, *IntCov* is a ratio used to assess how easily a firm can pay interest on its outstanding debt. When this ratio is lower, the firm is more burdened by debt expenses, so its chances of failure increase, suggesting an expected negative sign in the regression.

3.2. Databases and Descriptive Statistics

We investigate public firms in the U.S. market over the period from 1986 to 2013.[8] Financial statement data come from COMPUSTAT, and the stock return data are from the Center for Research Security Prices (CRSP). We exclude financial firms (standard industrial classification [SIC] codes 6000–6999), utilities (SIC codes 4900–4999), and quasi-public firms (SIC codes over 8999), whose capital structure decisions can be subject to regulation. In addition, we include only those firms whose total debt represents at least 5% of their assets (Chen et al. (2012)), to avoid

[8] We chose 1986 as the initial year, because COMPUSTAT started to cover credit ratings in that year. Furthermore, our sample includes all firms during this period; thus, there is no survivorship bias.

inappropriately contrasting firms that can issue long-term debt with ones that cannot. To minimize the effects of outliers on the results, all variables are winsorized at the 1st and 99th percentiles (e.g., values exceeding the 99th percentile are set equal to the 99th percentile). The final sample size featured is 67,609 firm-year observations, representing 10,479 firms.

To investigate whether the RRE is more pronounced for bank-dependent firms, we first need to identify borrowers that depend on their lenders. We use the S&P long-term issuer level rating, extracted from COMPUSTAT,[9] to identify a firm as either bank-dependent firms (BD firms) or non-bank-dependent firms (Non-BD firms). The prior literature similarly uses rating information to discriminate between BD and Non-BD firms (e.g., Chava and Purnanandam (2011)), because firms that do not have ratings likely lack an access to public debt markets, and depend on bank loan borrowing. Our final sample contains BD firms with 45,529 firm-year observations (approximately 67% of the full sample) and Non-BD firms with 22,080 firm-year observations (approximately 33% of the full sample).

In Table 1, we present the summary statistics for the variables, including $(LT)_{-1,t-1}$, the EDF, and relevant firm characteristics used as regressors in our empirical model. In terms of the full sample (Panel A), the mean EDF value is about 0.117, and its median value is 0.001, indicating that its distribution is very right skewed, and almost half of the firms are less likely to default, according to the very low median value. The mean (median) for $(LT)_{-1,t-1}$ is 0.029 (0.012); an interquartile range of 0.03 implies wide variation in this debt maturity measure across firms. We also present the

[9] The COMPUSTAT data item for credit rating is SPLTICRM, defined as the S&P's current opinion of the issuer's overall creditworthiness, beyond its ability to repay individual obligations; this measure focuses on the obligor's capacity and willingness to meet its long-term financial commitments.

firm characteristics for BD and Non-BD subsamples separately in Panel B.

Regarding our key variable $(LT)_{-1,t-1}$, we find average levels of 0.034 for BD firms and 0.018 for Non-BD firms. The median value shows a similar pattern, namely, 0.015 for BD firms and 0.008 for Non-BD firms, suggesting that BD firms experience more rollover risk. The EDF is approximately 13.7% for BD firms and 7.7% for Non-BD firms, indicating that BD firms are generally more likely to default.[10] Furthermore, BD firms tend to be smaller and less profitable, and they have lower asset tangibility, tax rates, leverage, and interest coverage; in contrast, they have higher cash holdings, market-to-book ratios, idiosyncratic volatility, and R&D expenditures. These differences are statistically significant at the 1% level (except for *MTB*) and generally consistent with our expectations (see also Chava and Purnanandam (2011); Hovakimian et al. (2012)).[11]

[Insert Table 1 Here]

3.3. Correlation Matrix

Table 2 contains the correlation matrix of the variables. The correlation between $(LT)_{-1,t-1}$ and EDF is 0.16, at a 1% significance level, consistent with our prediction that higher rollover risk would lead to higher default risk. The signs of the

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[10] Hovakimian et al. (2012) find that the average one-year default probability is about 5% for unrated firms and 1.6% for rated firms—lower than in our sample. A possible explanation of this difference is that our sample covers three years (2009, 2010, 2011) that do not appear in their sample and that are particularly turbulent, which likely leads to higher default probabilities.

[11] Chava and Purnanandam (2011) show that BD firms have lower leverage and profitability but higher default risk, market to book, and equity volatility. Hovakimian et al. (2012) find similar results and also show that BD firms have lower tangibility, size, and Tax.

correlations between EDF and the other factors are also as expected in general. That is, *Cash*, *MTB*, *Tangibility*, *Size*, *Tax*, *Profitability*, and *IntCov* relate negatively to EDF, whereas *Idiovol* and *Leverage* relates positively to it. However, the relation between EDF and R&D presents a negative sign, which is against the expectation of a positive association.

[Insert Table 2 Here]

4. Empirical Results

We present the results in four sections, focusing on (1) the results of testing the effect of rollover risk on default risk, in the baseline case; (2) the test of the hypothesis that bank borrowing dependence strengthens the rollover risk effect; (3) the extent to which rollover risk effect related the overall credit market condition, a firm's fundamental factors on profitability and credit quality; and (4) several robustness checks.

4.1. Baseline Results on the Rollover Risk Effect

We employ a fixed effect regression to examine the research questions at hand. That is,

$$\begin{aligned} EDF_{i,t} &= \alpha + \beta_1 (LT) - 1_{i,t-1} + \beta_2 Cash_{i,t-1} + \beta_3 MTB_{i,t-1} + \beta_4 Idiovol_{i,t-1} \\ &+ \beta_5 Tangibility_{i,t-1} + \beta_6 Size_{j,t=1} + \beta_7 R\&D_{i,t} + \beta_8 Tax_{i,t-1} \\ &+ \beta_9 Profitibil\,ity_{i,t-1} + \beta_{10} Leverage_{i,t-1} + \beta_{11} IntCov_{i,t-1} \\ &+ \text{Year FE} + \text{Firm FE} + \varepsilon_{i,t} \end{aligned} \tag{2}$$

where the dependent variable, $EDF_{i,t}$, represents the firm *i*'s expected default frequency in year *t*. We control for ten relevant firm characteristics that may affect the firm's default risk, as we detail in Section 3.1.3. Furthermore, we include the year fixed effect to control for any macroeconomic variable, and the firm fixed effect to control for unobservable factors across firms that also affect default risk. The standard errors are robust to heteroscedasticity and autocorrelation, clustered at the firm level.

The baseline results are presented in Table 3. The variable of interest for our study is $(LT)_{-1,t-1}$, that is, the long-term debt that matures in a year. Column 1 reports the estimators without control variables and shows that the estimated coefficient of $(LT)_{-1,t-1}$ is positive and significantly different from zero at the 1% significance level, consistent with Hypothesis 1. The coefficient of 0.202 implies that a one standard deviation increase in $(LT)_{-1,t-1}$ leads to a 11.4% increase in default rates.[12] Thus, the effect of rollover risk on default risk is not only statistically but also economically significant.

It is important to check whether the RRE remains after accounting for other default risk factors. We find that the estimated coefficient of $(LT)_{-1,t-1}$ retains its statistical significance (see Column 2). The coefficient of 0.058 implies that a one standard deviation increase in $(LT)_{-1,t-1}$ leads to a 3.3% increase in default rates.

Regarding the influence of the control variables on EDF, the results are largely consistent with our expectations: *Cash*, *Market to book*, *Tangibility*, *Tax*, and *Profitability*, relate significantly negatively to EDF, whereas *Idiovol*, *R&D*, and *leverage* relate significantly positively to it. However, the estimated coefficients on the two variables (*Size* and *IntCov*) are not consistent with our expectations. This may be due to multicollinearity problem among explanatory variables. For that, we

[12] The economic impact is computed as follows. We multiply a one standard deviation of $(LT)_{-1,t-1}$, (which is 0.066 as shown in Table 1), with the estimated coefficient of $(LT)_{-1,t-1}$ (0.202 in this case), and then divide the previous computed number by the unconditional mean value of the EDF (0.117 as shown in Table 1). That is, $0.202 \times 0.066 = 0.0133$; and $0.0133/0.117 = 11.395\%$.

examine several regressions with different sets of control variables as robustness test provided in Section 4.4.3.

[Insert Table 3 Here]

4.2. Does the Bank Borrowing Dependence Matter?

This section tests whether firms that are bank-dependent are likely to experience a larger effect of the rollover risk on the default risk (see Hypothesis 2). To do this, we run the baseline regression on the two subsamples that contain BD firms and Non-BD respectively, and compare their estimated coefficients of $(LT)_{-1,t-1}$.

Columns 3−4 (Columns 5−6) of Table 3 contain the results for BD (Non-BD) firms. We find a significant coefficient of $(LT)_{-1,i,t-1}$ for both types of firms in the regression without control variables, but this is not case when control variables are included. The coefficient is only positively significant for BD firms (Column 4), but not for Non-BD firms (Column6). Therefore, firms that experience growth in their long-term debt maturing in the coming year suffer higher default rates, though this effect is only significant for BD firms, consistent with our Hypothesis 2.

In particular, without taking into account of control variables, for BD firms, given the average value of 0.137 for EDF of BD firms (see Table 1), this result indicates that a one standard deviation increase in $(LT)_{-1,t-1}$ leads to a 11.2% increase in default rates, whereas it is only 6.3% for Non-BD firms. After controlling for other default risk factors, the economic impact remains substantial for BD firms; in that, a firm on average experiences a significant 3.2% increase in default rates when a one standard deviation increase in $(LT)_{-1,t-1}$. On the contrary, a one standard deviation increase in $(LT)_{-1,t-1}$ only raises a Non-BD firm’s default rate by a (non-significant) 0.8%.

Overall, our results suggest that rollover risk effect has different impacts on firms according to their dependence on bank borrowing. The RRE is of material importance for BD firms, but not Non-BD firms. We should address that the above results constitute evidence about the lower limit of the effect of rollover risk on credit risk. If we consider short-term debt likely amplify this effect, the RRE is probably even stronger for BD firms. This is because BD firms typically use more short-term debt than do Non-BD firms.[13]

4.3. Further Tests

To provide more insights on the relationship between debt maturity structure and firm default risk, we perform a number of cross-sectional tests on the basis of the credit market condition and a firm's fundamental factors on the profitability and the credit quality.

4.3.1. Credit Market Crises

Theory suggests that rollover risk deteriorates default risk especially in times of credit crunch. He and Xiong's (2012) theoretical model demonstrates that debt market frictions trigger the emergence of the RRE. Gopalan et al. (2014) also provide empirical evidence suggesting that the RRE exists during both recessionary and normal periods, but the effect is stronger in the former case. Thus, a rollover risk effect should exist all the time but be stronger during economic downturns, which

[13] The reason not to use short-term debt measures is the potential for endogeneity. The amount of short-term debt outstanding likely relates to the default risk (e.g., Almeida et al. (2012)).

usually coincide with distressed credit markets.

To test this prediction, we replace $(LT)_{-1,t-1}$ in the baseline regression with two interaction terms: $(LT)_{-1,t-1}$ x *Recession* and $(LT)_{-1,t-1}$ x (1−*Recession*), where *Recession* is a dummy variable that identifies years classified by the NBER as recessionary: 1990, 1991, 2001, 2002, 2008, and 2009. The result is reported in Panel A of Table 4. We find that although $(LT)_{-1,t-1}$ is positively associated with EDF both during recessions and expansions, the coefficient is only significant for $(LT)_{-1,t-1}$ x *Recession*. The magnitude of the effect is higher during recessions: as can be seen from the row titled Δ*Coef.*, the coefficients on the two interaction terms are significantly different from each other. In terms of economic impacts, we find that a one standard deviation increase in $(LT)_{-1,t-1}$, the EDF increases by 13.3% during periods of recessions, whereas only 0.4% in normal times.

In addition to recessions, we also use the spread between yields on Baa- and Aaa-rated corporate bonds, to test this prediction. This indicator is widely used to represent a default-risk or credit-risk factor (e.g., Gatev, Schuermann, and Strahan (2009)).[14] We define a dummy variable *Spread* that equals to 1 if the spread increases, and otherwise 0. Thus, *Spread* indicates a poor credit market.

We replace *Recession* in Column 1 with *Spread*, re-run regressions and report results in Column 2. We find that although $(LT)_{-1,t-1}$ is positively associated with EDF irrespective the overall level of credit risk, but the coefficient is only significant for $(LT)_{-1,t-1}$ x *Spread*. Also, the magnitude of the effect is much greater in times of spread increases: as can be seen from the row titled Δ*Coef.*, the coefficients on the two interaction terms are significantly different from each other at 1% significance level. In terms of economic impacts, we find that a one standard deviation increase in

[14] Data for the yields are taken from the statistical release published by the Federal Reserve Board.

$(LT)_{-1,t-1}$, the EDF increases by 6% in times of credit crunch, whereas only 1% when the credit market is improved.

In summary, consistent with extant theories, we find that the impact of RRE is stronger when the credit market is in crisis.

[Insert Table 4 Here]

4.3.2. Decline in Profitability

The RRE also likely relates to a firm's fundamental factors, in addition to transitory credit market conditions. Theory suggests that rollover risk should be more pronounced for firms with declining profitability. We test this prediction by estimating the Equation (2) after replacing $(LT)_{-1,t-1}$ with $(LT)_{-1,t-1}$ x *Decline* and $(LT)_{-1,t-1}$ x (1−*Decline*), where *Decline* is a dummy variable that identifies firms that experience a decline in profitability (measured using Operating income divided by Sales) during the years as compared to the previous year. Consistent with theory, we find that the coefficient on $(LT)_{-1,t-1}$ x *Decline* is positively significant, and is significantly larger than that on $(LT)_{-1,t-1}$ x (1−*Decline*), : as can be seen from the row titled Δ*Coef*. (see Column 3). Interestingly, we find that the coefficient along with $(LT)_{,t-1}$ x (1−*Decline*) is significantly negative, suggesting that the maturing debts themselves are not necessary conditions of causing refinancing risks, but only when firms face negative operating performance. This is consistent with the Diamond's (1991) theory that the maturing debt exposes a firm to refinancing risk only if the revealed information is negative, which lenders might not refinance—thus, forcing a firm into premature liquidation. On the other hand, debt's interest rate is likely to be reduced at refinancing as positive information is revealed.

In terms of economic impacts, we find that a one standard deviation increase in $(LT)_{-1,t-1}$, the EDF increases by 12.3% when firms face the year-on-year decline in the profitability, whereas the EDF decreases by 7.4% when firms have the year-on-year increase in the profitability. Overall the results suggest that $(LT)_{-1,t-1}$ is associated with more severe default rates increase for firms that experience a decline profitability.

4.3.3. Credit Quality

Theory also suggests that the RRE should be stronger for poor credit quality firms, because they should find it more difficult to extend the maturity of their debts. For example, Diamond (1991) argues that low credit quality firms that face greater liquidity risk may demand longer-term debt to reduce this risk but cannot find lenders willing to supply it at reasonable cost. In contrast, higher credit quality firms likely bear lower liquidity risk and can borrow over the longer term if liquidity risk concerns arise. Mian and Santos (2011) show that only creditworthy firms can choose to refinance at a lower rate if their cost of capital rises; lower credit quality firms instead have minimal access to new capital at a reasonable cost, such that they incur substantial rollover losses. He and Milbradt (2014) point out that investors will require high interest rates for bearing the long-term credit risk of high-default risk firms. These high rates might then cause a firm to choose very high-risk projects, leading higher default rates.

To test this prediction, we create a dummy variable, denoted *Bad* to identify a poor credit quality firm. According to the sample median EDF value, we consider the high EDF group represents bad credit quality, whereas the low EDF group constitutes the good credit quality. We implement the baseline regression (Equation 2) after substituting $(LT)_{-1,t-1}$ with $(LT)_{-1,t-1}$ x *Bad* and $(LT)_{-1,t-1}$ x (1−*Bad*), and present the results in Column 4. We find that only the estimated coefficient of $(LT)_{-1,t-1}$ x *Bad* is positively associated with EDF, indicating that firms in the bad credit quality group experience higher RRE. Notably, the coefficient of $(LT)_{-1,t-1}$ x (1−*Bad*) is significantly negative at the 1% level, suggesting that when a firm with a good credit quality that tries to refinance maturing debts, the default risk is reduced. This result is inconsistent with the evidence documented in Gopolan et al. (2014), for which they show that good credit quality firms also suffer the RRE, though the effect is negligible.[15]

Furthermore, our findings also show that the coefficients on the two interaction terms are significantly different from each other (see the row titled Δ*Coef.*) at 1% significance level. In terms of economic impacts, we find that a one standard deviation increase in $(LT)_{-1,t-1}$, the EDF increases by 10.4% for firms with bad credit quality, whereas the EDF decreases by 37.2% for firms with good credit quality.

Overall, we find that the positive correlation between $(LT)_{-1,t-1}$ and EDF is stronger during distressed credit market, and for firms that experience a year-on-year decline in operating profitability, and have bad credit qualities.

4.3.4. BD versus Non-BD Firms

We also examine whether bank dependence has differential impacts on the above analysis. To do that, we re-estimate all regressions in Panel A of Table 4 but use the two subsamples that contain BD firm and Non-BD firms separately, and report results in Panel B and C of Table 4 respectively. For BD group, we find that the results are

[15] We should address again that their study only considers firms that have ratings, whereas our study include all firms.

systematically consistent with the results based on the entire sample. That is, firms suffer RRE significantly during recessions, in times of high credit risks, for firms with decline in profitability and firms with poor credit quality. The economic impact is also substantial. Our results shows that a one standard deviation increase in $(LT)_{-1,t-1}$, the EDF increases by 14.4% during recessions, by 6.4% when the overall credit risk increases, by 11.6% when firms face the year-on-year decline in the profitability, by 8.8% for firms with bad credit quality.

However, for Non-BD group, we find that credit market condition has marginal effect on the RRE, because we do not find significant coefficients on any variables interacted with *Recession* or *Spread*. On the other hand, we find that a firm's fundamental factors still drive the RRE; in that the estimated coefficients of $(LT)_{-1,t-1}$ x *Decline* and $(LT)_{-1,t-1}$ x *Bad* are presenting positively significant signs.

In terms of economic impact, a one standard deviation increase in $(LT)_{-1,t-1}$, the EDF increases by 12% when firms face the year-on-year decline in the profitability, and by 17.7% for firms with bad credit quality—this magnitude is twice as large as it has shown in the case of BD firms. Therefore, our results strongly suggest that firms' credit quality is a very important factor that induces the increase of default risk through the channel of rolling over the maturing debts for rated firms.

In summary, the RRE is relevant for firms that depend on banks for their financing needs. The effect is stronger for BD firms with negative profitability and having poor credit quality and during distressed credit markets. However the overall credit market condition does not induce different effects for Non-BD firms.

4.4. Robustness Tests

We conduct several robustness checks. First we use an alternative method to identify the level of bank dependence. Second, we use an alternative proxy for rollover risk. Third, we re-examine the RRE on regressions with different sets of control variables.

4.4.1. Capital IQ-Based Sample Analysis

For robustness, we conduct additional tests to strengthen our findings from the baseline analysis on bank dependence by using the information (firm-level debt structure variable information) provided in the Capital IQ database to discriminate BD firms from Non-BD firms. Because coverage by Capital IQ is comprehensive only from 2002 onwards, the Capital IQ-based sample spans from 2002 to 2013. We further remove observations with missing values in the database of Capital IQ**.** The sample size is reduced to 16,340 firm-year observations, which covers 24% (= 16,340 / 67,609) of the firms selected in the main analysis.[16]

In particular, we give a new definition for bank dependence based on the bank debt-to-total assets ratio. In this analysis, the BD group is the one that contains firms having a bank debt-to-total assets ratio in the top 33%, 25%, 20%, or 10% among of firms and the Non-BD is the group that contains the remainder of the identified BD subject. The bank debt-to-total assets ratio is measured by using bank debt—the sum of term loans and revolving credit divided by total assets.

Table 5 reports the estimation results on Equation (2) after using the Capital IQ-based identification scheme and for BD group and Non-BD group respectively. We

[16] The detailed procedure of building the Capital IQ-based sample can be referred to Chiu et al. (2015).

find that the coefficient of $(LT)_{-1,t-1}$ is positive and significant for BD firms across different criteria of the bank debt to total asset ratio through the top 33%, 25%, 20%, and 10%, whereas the coefficients are consistently not significant across all Non-BD subsample. Overall, the Capital IQ-based analysis provides further evidence supporting that the rollover risk effect is more pronounced for firms that rely on bank financing.

[Insert Table 5 Here]

4.4.2. Alternative Rollover Risk Proxy

Following existing studies (e.g., Barclay and Smith (1995), Chen et al. (2012)), we construct the measure of debt maturity using the long-term debt share, which is the percentage of total debt that matures in more than 3 years (*ldebt*3*y*). By construction, the *ldebt*3*y* is conversely related to the benchmark measure of $(LT)_{-1,t-1}$. Therefore, if the RRE exists, we should find the estimated coefficient is negative, instead of positive, which indicates that *ldebt*3*y* reduces EDF.

We replace $(LT)_{-1,t-1}$ with *ldebt*3*y* and re-examine the regression specifications in Table 3 (control variables included), with the results reported in Columns 1−3 of Table 6. The result for the entire sample (Column 1) shows the negatively significant coefficient of *ldebt*3*y*, which confirms a rollover risk effect on default risk. Columns 2 and 3 of Table 6 provide the regression results, with *ldebt*3*y* as the main independent variable for BD and Non-BD firms respectively. After taking into account of control variables, the coefficient of *ldebt*3*y* is negative and significant at the 1% level only for BD firms (Column 2), but it is barely significant for the Non-BD firms (Column 3). In terms of economic impacts, we find that a one standard deviation increase in *ldebt*3*y*, the EDF decreases by 2.88% in the case of all firms, and by 2.91% for BD firms, but only 0.43% for Non-BD firms. Overall, these results are consistent with our findings using $(LT)_{-1,t-1}$ as the proxy for rollover risk, and further support Hypothesis 1 and 2.

[Insert Table 6 Here]

4.4.3. Control Variables

In the baseline regression (Equation 2), we include many firm risk characteristics as control variables. Because these variables may be correlated with each other, a multicollinearity problem may appear. To mitigate this concern, we re-examine the RRE based on several regressions with different sets of control variables. We start with the regression with two explanatory variables of $(LT)_{-1,t-1}$ and *Cash*, and include one more control variable every time for every new model specification. The results are presented in Columns 1−10 of Table 7. We find that $(LT)_{-1,t-1}$ is positively significant in all model specifications. Overall, these results are consistent with main analysis, and further support the existence of the RRE.

[Insert Table 7 Here]

5. Conclusion

Understanding which economic factors explain a firm's credit quality is of paramount importance. The seminal work of Merton's (1974) model signaled the firm's debt structure and the value of its assets as two fundamental variables for explaining a firm's credit quality. We pay particular attention to one aspect of the debt structure, namely, refinancing or rollover risk, which theory has predicted should be an important variable, and we consider the extent to which this risk has material importance.

To this end, we examine the impact on default risk that arises from rollover risk in the U.S. context, from 1986 to 2013. Our results support the notion that this risk is significant, though not for all firms. Only firms that depend on banks for their refinancing needs suffer increases in their credit risk caused by rollover risk. This increase is higher during recessions and credit crunches, and is stronger for firms that have declining profitability or low credit quality. However, firms that do not depend on bank financing do not suffer rollover risk in times of crises in the credit markets.

Some evidence suggests the bond market is aware of the possible impact of refinancing risk on credit quality (Gopalan et al. (2014)). Therefore, an obvious extension of our work would be investigate the extent to which banks recognize the importance of the rollover risk effect, such that they adjust the terms and conditions of loans dedicated to refinancing existing debt.

Acknowledges

We thank José Antonio Clemente-Almendros at the XXII Finance Forum (2014) in Zaragoza (Spain), Claus Schmitt at the 18th SGF in Zurich (Switzerland), Baheo Kim at the 2015 Asian FMA in Seoul (South Korea), and participants at the 2015 FEBS in Nantes (France) and the above listed conferences for useful comments.

Appendix A

Estimating Expected Default Frequency and Distance-to-Default

Moody's KMV model is closely related to the Black and Scholes (1973) model: The basic idea is that equity can be viewed as a call option, for which the underlying asset is a firm's asset value and the strike price is equal to the face value of a firm's debt. A firm's market value of assets is assumed to follow a geometric Brownian motion, of the form:

$$dV = \mu V dt + \sigma_V V dZ, \qquad \text{(A1)}$$

where V is the total value of a firm, μ indicates the expected continuously compounded return of V, σ_V represents the volatility of a firm's value, and dZ is a standard Brownian motion. With these assumptions and a Black and Scholes (1973) model, we can express a firm's market value of equity V_E as a function of its total value,

$$V_E = VN(d_1) - Be^{-rT} N(d_2), \qquad \text{(A2)}$$

where

$$d_1 = \frac{\ln(V/B) + (r + 0.5\sigma_V^2)T}{\sigma_V \sqrt{T}}, \quad d_2 = d_1 - \sigma_V \sqrt{T} ,$$

B is the face value of a firm's debt, r is the risk-free rate, T is the forecast horizon, and $N(.)$ is the cumulative standard normal distribution.

In our exercise, we compute V_E as the product of a firm's outstanding shares and its current stock price, assume T equals one year, and treat B as the debt in current liabilities plus half of the long-term debt, consistent with prior applications. The two remaining variables in the Black-Scholes equation—the total asset value of the firm V and the volatility of the firm value σ_V—are estimated with an iterative procedure, following the method proposed by Vassalou and Xing (2004). Initially, we estimate σ_V

as the annualized standard deviation of a firm's asset returns, using daily data about the summation of the market value of equity and the face value of debt over the past year. This method provides an initial estimate of σ_V, and together with the market value of equity and other inputs, Equation A2 indicates the daily values of V. Using these estimated values of V, we generate new estimates of σ_V with the implied log returns on assets. The new estimate of σ_V enters the next iteration, until the difference in values of σ_V across two consecutive iterations is less than 10^{-3}. Then we take the final estimated σ_V and its implied V. We compute the drift μ by calculating the mean value of log-returns of V. With these estimated values, the DD can be calculated according to Equation 1.

Appendix B

Variable Definitions

- *Bad* is a dummy variable that identifies firms having lower EDF value than the median EDF value among all firms.
- *Cash* is the ratio of the book value of cash and marketable securities (COMPUSTAT item che) to the book value of total assets (COMPUSTAT item at).
- *Decline* is a dummy variable that identifies firms having a decline in *Profitability* during the years as compared to the previous year.
- *Idiovol* represents idiosyncratic risk and is the standard deviation of daily excess returns relative to the CRSP value-weighted index for each firm's equity in a year.
- *IntCov* represents the interest coverage, and is the ratio of operating income after depreciation (COMPUSTAT items oiadp+ xint) to the total interest expenditure (COMPUSTAT item xint).
- *Leverage* is the ratio of total debt (COMPUSTAT items dlc + dltt) to total assets.

- *MTB* is the ratio of the market value of total assets to the book value of total assets. We calculate the market value of total assets as the sum of the book value of total assets and the market value of equity, less the book value of equity.
- *Profitability* is the ratio of operating income after depreciation (COMPUSTAT item oiadp) to total sales (COMPUSTAT item sale).
- *Recession* is a dummy variable that identifies years classified by the NBER.
- *R&D* is the ratio of research and development expenditures (COMPUSTAT item xrd) to the book value of total assets (COMPUSTAT item at). We replace missing values of xrd with zeros.
- *Size* is the natural logarithm of the book value of total assets (COMPUSTAT item at).
- *Spread* is a dummy variable that equals to 1 if the spread between yields on Baa- and Aaa-rated corporate bonds increases.
- *Tangibility* is the ratio of book value of property, plants, and equipment (COMPUSTAT item ppent) to the book value of total assets (COMPUSTAT item at).
- *Tax* is the ratio of tax expenditure (COMPUSTAT item txt) to the book value of total assets (COMPUSTAT item at).
- *ldebt3y* is the ratio of debt that matures in more than 3 years (COMPUSTAT item dltt-dd2-dd3) to total debt (COMPUSTAT item *dlc+ dltt*).

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Table 1. Summary statistics

The summary statistics refer to the sample of 67,609 firm-year observations from 1986 to 2013. Firms are identified as either bank dependent (BD) with 45,529 firm-year observations or Non-bank-dependent (Non-BD) with 22,080 firm-year observations. EDF is the expected default probability; they are measured according to Merton's model. $(LT)\text{-}1_{,t-1}$ is the amount of a firm's long-term debt outstanding at the end of year $t-1$ that is due for repayment in year t, scaled by the current book value of total assets. We control for many default risk factors: *Cash*, *MTB Idiovol*, *Tangibility*, *Size*, *R&D*, *Tax*, *Profitability*, *Leverage*, and *IntCov* (see details in Appendix B). The statistically significant differences between the characteristics of BD and Non-BD firms are at the 1% level, as indicated by ***.

Panel A: All Firms

Variable	Mean	Std. Dev.	25^{th} percentile	Median	75^{th} percentile	Interquartile
EDF	0.117	0.232	0.000	0.001	0.100	0.100
LT-$1_{,t-1}$	0.029	0.066	0.002	0.012	0.032	0.030
Cash	0.103	0.134	0.017	0.051	0.133	0.116
MTB	1.416	1.360	0.681	0.995	1.601	0.921
Idiovol	0.038	0.026	0.020	0.030	0.047	0.026
Tangibility	0.342	0.237	0.151	0.289	0.499	0.347
Size	5.608	2.283	3.909	5.562	7.209	3.300
R&D	0.027	0.061	0.000	0.000	0.025	0.025
Tax	0.019	0.030	0.000	0.014	0.035	0.035
Profitability	-0.084	0.868	0.013	0.063	0.118	0.105
Leverage	0.317	0.190	0.174	0.284	0.418	0.244
IntCov	4.746	15.342	1.515	3.750	7.756	6.241
Idebt3y	0.537	0.333	0.247	0.590	0.828	0.581

Panel B: BD Firms versus Non-BD Firms

	Bank-Dependent Firms			Non-Bank-Dependent Firms			Difference
Variable	Mean	Median	Std. Dev.	Mean	Median	Std. Dev.	of means
EDF	0.137	0.004	0.247	0.077	0.000	0.193	0.060***
LT-$1_{,t-1}$	0.034	0.015	0.077	0.018	0.008	0.033	0.016***
Cash	0.114	0.055	0.146	0.081	0.045	0.100	0.033***
MTB	1.474	0.988	1.484	1.296	1.008	1.048	0.178
Idiovol	0.044	0.036	0.028	0.025	0.021	0.014	0.019***
Tangibility	0.327	0.270	0.237	0.374	0.332	0.236	-0.048***
Size	4.593	4.554	1.840	7.702	7.618	1.572	-3.109***
R&D	0.033	0.000	0.071	0.015	0.000	0.032	0.018***
Tax	0.017	0.011	0.031	0.022	0.020	0.028	-0.005***
Profitability	-0.162	0.048	1.021	0.079	0.092	0.343	-0.241***
Leverage	0.299	0.263	0.188	0.353	0.320	0.187	-0.054***
IntCov	3.776	3.351	17.445	6.748	4.401	9.343	-2.972***
Idebt3y	0.454	0.458	0.338	0.706	0.760	0.249	-0.252***

Table 2. Correlation matrix

The table presents the correlation matrix for the variables used in the empirical model based on the sample of 67,609 COMPUSTAT firm-year observations from 1986 to 2013. EDF is the expected default probability measured according to Merton's model. $(LT)_{-1,t-1}$ is the amount of a firm's long-term debt outstanding at the end of year $t-1$ that is due for repayment in year t, scaled by the current book value of total assets. Other relevant default risk factors are: *Cash*, *MTB*, *Idiovol*, *Tangibility*, *Size*, *R&D*, *Tax*, *Profitability*, *Leverage*, and *IntCov*.

	EDF	$(LT)_{-1,t-1}$	*Cash*	*MTB*	*Idiovol*	*Tangibility*	*Size*	*R&D*	*Tax*	*Profitability*	*Leverage*	*IntCov*
$(LT)_{-1,t-1}$	0.16											
Cash	-0.03	-0.02										
MTB	-0.19	0.04	0.28									
Idiovol	0.55	0.20	0.07	0.00								
Tangibility	-0.02	0.02	-0.27	-0.10	-0.06							
Size	-0.17	-0.14	-0.12	-0.19	-0.54	0.12						
R&D	-0.01	0.02	0.43	0.33	0.16	-0.24	-0.18					
Tax	-0.23	-0.10	-0.01	0.15	-0.31	-0.04	0.16	-0.10				
Profitability	-0.11	-0.08	-0.32	-0.23	-0.25	0.05	0.23	-0.40	0.18			
Leverage	0.25	0.24	-0.15	-0.01	0.14	0.15	0.03	-0.10	-0.24	-0.03		
IntCov	-0.18	-0.08	-0.13	-0.01	-0.32	0.00	0.25	-0.29	0.46	0.43	-0.17	
ldebt3y	-0.12	-0.24	0.00	-0.04	-0.26	0.17	0.35	-0.10	0.05	0.07	0.19	0.06

Table 3. Rollover risk effect on default risk

This table reports the results of regressions aimed at understanding the impact of the rollover risk on the default probability. The dependent variable is EDF, the expected default frequency, based on Merton's model. The main independent variable is $(LT)\text{-}1_{,t\text{-}1}$, the long-term debt outstanding at the end of year t – 1 that is due for repayment in year t. Columns 3−4 reports the results based on using the entire sample, while Columns 3−4 and 5−6 present the results for the subsamples that contain BD firms and Non-BD firms respectively. Control variables are: *Cash*, *MTB*, *Idiovol*, *Tangibility*, *Size*, *R&D*, *Tax*, *Profitability*, *Leverage*, and *IntCov*, and all specifications include the firm fixed effect and the time fixed effect. The standard errors (in parenthesis) are robust to heteroscedasticity and autocorrelation and are clustered at the firm level. ***Significant at 1%. **Significant at 5%. *Significant at 10%.

	All Firms		BD Firms		Non-BD Firms	
Variables	(1)	(2)	(3)	(4)	(5)	(6)
$(LT)\text{-}1_{,t\text{-}1}$	0.202 ***	0.058 **	0.199 ***	0.057 **	0.144 **	0.018
	(0.029)	(0.023)	(0.032)	(0.025)	(0.061)	(0.055)
$Cash_{t\text{-}1}$		-0.015		-0.031 ***		0.035 *
		(0.010)		(0.012)		(0.021)
$MTB_{t\text{-}1}$		-0.018 ***		-0.020 ***		-0.013 ***
		(0.001)		(0.001)		(0.002)
$Idiovol_{t\text{-}1}$		3.974 ***		3.690 ***		5.095 ***
		(0.072)		(0.077)		(0.226)
$Tangibility_{t\text{-}1}$		-0.028 **		-0.042 ***		-0.007
		(0.012)		(0.014)		(0.021)
$Size_{t\text{-}1}$		0.037 ***		0.040 ***		0.041 ***
		(0.002)		(0.003)		(0.003)
$R\&D_{t\text{-}1}$		0.088 ***		0.104 ***		-0.011
		(0.034)		(0.037)		(0.079)
$Tax_{t\text{-}1}$		-0.063 *		-0.086 **		0.030
		(0.033)		(0.041)		(0.058)
$Profitability_{t\text{-}1}$		-0.005 ***		-0.005 **		0.004
		(0.002)		(0.002)		(0.006)
$Leverage_{t\text{-}1}$		0.117 ***		0.132 ***		0.067 ***
		(0.008)		(0.010)		(0.016)
$IntCov_{t\text{-}1}$		0.000 **		0.000		0.000 *
		(0.000)		(0.000)		(0.000)
Constant	0.035 ***	-0.237 ***	0.039 ***	-0.211 ***	0.031 ***	-0.334 ***
	(0.005)	(0.012)	(0.006)	(0.013)	(0.007)	(0.028)
Obs.	67609	67609	45529	45529	22080	22080
R^2	0.0483	0.2968	0.0463	0.3422	0.0601	0.2518
Firm Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes

Table 4. Rollover risk effect on default risk conditional on the credit market condition, the declining profitability, and credit quality

This table reports the results of regressions to test whether the rollover risk effect is conditional on the state of the economy, a firm's characteristics on the declining profitability and credit quality. Panel A presents results for the entire sample. Panel B and C present results for the subsample that contains BD firms and Non-BD firms respectively. The dependent variable is EDF, the expected default frequency, measured with Merton's model. The main independent variable is $(LT)_{-1,t-1}$, the long-term debt outstanding at the end of year t – 1 that is due for repayment in year t. The *Recession* is a dummy variable that identifies years classified by the NBER. The *Spread* is a dummy variable that equals to 1 if the spread between yields on Baa- and Aaa-rated corporate bonds increases. The *Decline* is a dummy variable that identifies firms having a decline in profitability during the years as compared to the previous year. The *Bad* is a dummy variable that identifies firms having lower EDF value than the median EDF value among all firms. Results of the tests of the differences between coefficients on the interaction terms in columns 1−4 are presented in the row titled Δ*Coef* in each panel. All model specifications include control variables of *Cash*, *MTB*, *Idiovol*, *Tangibility*, *Size*, *R&D*, *Tax*, *Profitability*, *Leverage*, and *IntCov*. The standard errors (in parenthesis) are robust to heteroscedasticity and autocorrelation and are clustered at the firm level. ***Significant at 1%. **Significant at 5%. *Significant at 10%.

Panel A: All Firms				
Variables	(1)	(2)	(3)	(4)
$(LT)_{-1,t-1}$ x *Recession*	0.235 ***			
	(0.039)			
$(LT)_{-1,t-1}$ x (1−*Recession*)	0.007			
	(0.022)			
$(LT)_{-1,t-1}$ x *Spread*		0.106 ***		
		(0.028)		
$(LT)_{-1,t-1}$ x (1−*Spread*)		0.024		
		(0.025)		
$(LT)_{-1,t-1}$ x *Decline*			0.217 ***	
			(0.023)	
$(LT)_{-1,t-1}$ x (1−*Decline*)			-0.130 ***	
			(0.024)	
$(LT)_{-1,t-1}$ x *Bad*				0.184 ***
				(0.031)
$(LT)_{-1,t-1}$ x (1− *Bad*)				-0.658 ***
				(0.034)
Constant	Yes	Yes	Yes	Yes
Δ*Coef.*	0.228 ***	0.082 ***	0.347 ***	0.843 ***
	(0.041)	(0.031)	(0.030)	(0.041)
Control Variables	Yes	Yes	Yes	Yes
Obs.	67609	67609	67609	67609
R^2	0.2969	0.2968	0.3051	0.3223
Firm Fixed Effect	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes

Panel B: Bank-Dependent Firms				
Variables	(1)	(2)	(3)	(4)
$(LT)_{-1,t-1}$ x *Recession*	0.257 ***			
	(0.047)			
$(LT)_{-1,t-1}$ x (1−*Recession*)	0.002			

	(0.024)			
$(LT)_{-1,t-1}$ x *Spread*		0.113 ***		
		(0.030)		
$(LT)_{-1,t-1}$ x (1−*Spread*)		0.018		
		(0.027)		
$(LT)_{-1,t-1}$ x *Decline*			0.207 ***	
			(0.024)	
$(LT)_{-1,t-1}$ x (1−*Decline*)			-0.136 ***	
			(0.027)	
$(LT)_{-1,t-1}$ x *Bad*				0.158 ***
				(0.031)
$(LT)_{-1,t-1}$ x (1− *Bad*)				-0.662 ***
				(0.040)
Constant	Yes	Yes	Yes	Yes
Δ*Coef.*	0.255 ***	0.095 ***	0.343 ***	0.819 ***
	(0.048)	(0.033)	(0.033)	(0.046)
Control Variables	Yes	Yes	Yes	Yes
Obs.	45529	45529	45529	45529
R^2	0.3425	0.3422	0.3509	0.3647
Firm Fixed Effect	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes

Panel C: Non-Bank-Dependent Firms

Variables	(1)	(2)	(3)	(4)
$(LT)_{-1,t-1}$ x *Recession*	0.002			
	(0.107)			
$(LT)_{-1,t-1}$ x (1−*Recession*)	0.025			
	(0.058)			
$(LT)_{-1,t-1}$ x *Spread*		-0.009		
		(0.077)		
$(LT)_{-1,t-1}$ x (1−*Spread*)		0.046		
		(0.064)		
$(LT)_{-1,t-1}$ x *Decline*			0.275 ***	
			(0.093)	
$(LT)_{-1,t-1}$ x (1−*Decline*)			-0.130 **	
			(0.053)	
$(LT)_{-1,t-1}$ x *Bad*				0.406 ***
				(0.101)
$(LT)_{-1,t-1}$ x (1− *Bad*)				-0.600 ***
				(0.061)
Constant	Yes	Yes	Yes	Yes
Δ*Coef.*	-0.023	-0.055	0.406 ***	1.006 ***
	(0.113)	(0.089)	(0.087)	(0.103)
Control Variables	Yes	Yes	Yes	Yes
Obs.	22080	22080	22080	22080
R^2	0.2518	0.2517	0.2551	0.2811
Firm Fixed Effect	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes

Table 5. Capital IQ-based sample analysis

This table reports the regression (Equation 2) analysis results using the Capital IQ-based sample that contains 16,340 firm-year observations and spans from 2002 to 2013. The BD group contains firms having bank debt-to-total assets in the top 33%, 25%, 20%, or 10% of firms and the Non-BD group contains the remainders of the identified BD subject. All model specifications include control variables, the firm fixed effect and the year fixed effect. The standard errors (in parenthesis) are robust to heteroscedasticity and autocorrelation and are clustered at the firm level. ***Significant at 1%. **Significant at 5%. *Significant at 10%.

Bank debt-to-total assets	Top 33%		Top 25%		Top 20%		Top10%	
	(1)		(2)		(3)		(4)	
	BD	Non-BD	BD	Non-BD	BD	Non-BD	BD	Non-BD
$(LT)_{-1,t-1}$	0.095*	0.039	0.122*	0.003	0.126*	-0.025	0.172*	-0.007
	(0.057)	(0.048)	(0.065)	(0.045)	(0.069)	(0.047)	(0.104)	(0.039)
Constant	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Control Variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	5,447	10,893	4,085	12,255	3,268	13,072	1,634	14,706
R^2	0.1372	0.1833	0.1341	0.1975	0.095	0.1941	0.1084	0.1748
Firm Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table 6. Alternative rollover risk measure

This table reports the results of regressions implemented in Table 3 after replacing $(LT)_{-1,t-1}$ with $(ldebt3y)_{,t-1}$, which is the percentage of debt that matures in more than 3 years to total debt. The dependent variable is EDF, the expected default frequency. Column 1 presents results for the entire sample, and Columns 2 and 3 present results for the subsamples that contain bank-dependent firms and non-bank-dependent firms respectively. All specifications include the firm fixed effect and the time fixed effect. The standard errors (in parenthesis) are robust to heteroscedasticity and autocorrelation and are clustered at the firm level. ***Significant at 1%. **Significant at 5%. *Significant at 10%.

	All Firms	BD Firms	Non-BD Firms
Variables	(1)	(2)	(3)
$(ldebt3y)_{,t-1}$	-0.010***	-0.012***	-0.001
	(0.003)	(0.004)	(0.005)
Constant	Yes	Yes	Yes
Control Variables	Yes	Yes	Yes
Obs.	67,927	45,672	22,255
R^2	0.2965	0.3432	0.2527
Firm Fixed Effect	Yes	Yes	Yes
Year Fixed Effect	Yes	Yes	Yes

Table 7. Different sets of control variables

The table reports the results from regressions with different sets of control variables. The dependent variable is EDF, the expected default frequency, and the main independent variable is $(LT)_{-1,t-1}$, the long-term debt outstanding at the end of year $t - 1$ that is due for repayment in year t. All specifications include the firm fixed effect and the time fixed effect. The standard errors (in parenthesis) are robust to heteroscedasticity and autocorrelation and are clustered at the firm level. ***Significant at 1%. **Significant at 5%. *Significant at 10%.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
$(LT)_{-1,t-1}$	0.197 ***	0.215 ***	0.093 ***	0.092 ***	0.105 ***	0.105 ***	0.103 ***	0.101 ***	0.058 **	0.058 **
	(0.029)	(0.027)	(0.023)	(0.023)	(0.023)	(0.023)	(0.023)	(0.023)	(0.023)	(0.023)
Cash	-0.123 ***	-0.091 ***	-0.047 ***	-0.056 ***	-0.032 ***	-0.031 ***	-0.028 ***	-0.031 ***	-0.014	-0.015
	(0.011)	(0.011)	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)
MTB		-0.030 ***	-0.024 ***	-0.024 ***	-0.017 ***	-0.017 ***	-0.017 ***	-0.017 ***	-0.018 ***	-0.018 ***
		-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	(0.001)	(0.001)
Idiovol			3.884 ***	3.889 ***	4.130 ***	4.123 ***	4.093 ***	4.085 ***	3.968 ***	3.974 ***
			(0.071)	(0.071)	(0.073)	(0.073)	(0.073)	(0.073)	(0.072)	(0.072)
Tangibility				-0.029 **	-0.017	-0.019	-0.019	-0.020 *	-0.027 **	-0.028 **
				(0.012)	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)
Size					0.040 ***	0.041 ***	0.041 ***	0.041 ***	0.038 ***	0.037 ***
					(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
R&D						0.113 ***	0.107 ***	0.090 ***	0.080 **	0.088 **
						(0.034)	(0.034)	(0.034)	(0.034)	(0.034)
Tax							-0.157 ***	-0.146 ***	-0.040	-0.063 *
							(0.032)	(0.032)	(0.032)	(0.033)
Profitability								-0.005 ***	-0.004 **	-0.005 ***
								(0.002)	(0.002)	(0.002)
Leverage									0.116 ***	0.117 ***
									(0.008)	(0.008)
IntCov										0.000 **
										(0.000)
Constant	0.050 ***	0.093 ***	-0.026 ***	-0.014 **	-0.223 ***	-0.228 ***	-0.223 ***	-0.223 ***	-0.237 ***	-0.237 ***
	(0.005)	(0.005)	(0.005)	(0.007)	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)
Obs.	67,609	67,609	67,609	67,609	67,609	67,609	67,609	67,609	67,609	67,609
R^2	0.0474	0.0825	0.3589	0.3581	0.2648	0.2607	0.2645	0.266	0.2959	0.2968
Firm Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes