Granularity of Corporate Debt: Theory and Tests*

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Abstract

This paper studies the granularity of corporate debt — the degree to which firms spread out their bonds' maturity dates across time. In the model, a firm's access to the bond market may be hindered temporarily, either because of a capital market freeze or because the firm becomes exposed to large risks. In such a setting, it is advantageous to diversify the debt roll-over across maturity dates. Using a large sample of corporate bond issuers during the 1991–2009 period, we find evidence that supports our theory's predictions in cross-sectional and time-series tests. In the cross-section, corporate debt structure is more granular and adjusts faster over time for larger and more mature firms, for firms with better investment opportunities, for firms with more tangible assets, for firms with higher leverage ratios, for firms with lower values of assets in place, and for firms with lower levels of current cash flows. In the time-series, we also document that firms actively engage in granularity management in the sense that newly issued corporate bond maturities are inversely related to pre-existing bond maturity profiles.

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1 Introduction

It is not well understood how firms decide on the number of bonds they issue and how they spread out their maturities. Clearly, if relative issue costs decrease and secondary market liquidity improves with issue size, one would expect firms to concentrate their debt in a single bond. However, even non-financial firms frequently have a large number of bonds outstanding, with different times to maturity. What are the frictions and tradeoffs that drive these decisions? In this paper we study the granularity structure of corporate debt, i.e. the degree to which companies spread out their bond maturity dates.

We build a two-period model where a firm has access to two investment projects which generate cash flows at time two and, to capture the dynamic nature of the problem, also a continuation value. The firm either issues a single bond which must be rolled over once to the final point in time or it issues two bonds, one short-term and one long-term bond. Both the short-term bond and the long-term bond also must be rolled over once to the final point in time. Thus, the single-bond firm (or firm S) must roll over its bond at *one* point in time whereas the two bonds of the multi-bond firm (or firm M) are rolled over at *two* points in time. The firm cannot pledge the cash flows from its projects. Instead, it can only pledge the collateral value of its projects and its final continuation value. To realize a project's collateral value, the project must be partially terminated before the final cash flow is realized and this is inefficient.

In normal times, the bonds can be rolled over and the risky project cash flows and the firm's continuation value are eventually realized. With some probability, however, the firm can loose its access to the bond market in any given period. The firm's inability to access the bond market may arise endogenously since it can become temporarily exposed to a large risk. If the firm enters this state of increased uncertainty, then its entire collateral value may drop to zero and the firm may seize to exist. We will refer to the realization of such a risk as a technology shock. Since bondholders observe when a firm is vulnerable to such a risk, they may not roll over the bond in this state and hence the market freezes endogenously.[1] Crucially, if a bond cannot be rolled over, then one or both projects must

[1] See, e.g., Acharya et al. (2011) for a market freeze that follows a drop in collateral. We note that there are

be partially liquidated to repay the bondholders.

Uncertainty about final cash flows is resolved gradually over time, so that the firm can observe whether the non-contractible cash flow component of a project will be high or low, even before it is realized. When bondholders request partial liquidation of a project, the firm therefore knows already its projects' cash flows if no technology shock occurs. Thus, if the firm only needs to partially liquidate one project, it will be able to retain the better project, i.e., the one with the (weakly) higher future payoff. By contrast, if firm S cannot roll over its single bond, then it must partially liquidate both projects. Intuitively, the model's trade-off is that firm M has a flexibility advantage over firm S, whereas firm S has a transaction cost advantage over firm M, since one larger issue faces lower floatation and illiquidity costs than two smaller issues.[2]

Based on this trade-off, we derive a number of testable implications, using the value differential between firm M and firm S as a gauge for the benefits of a more granular debt structure. In both versions of the model, the benefits of a more granular debt structure (i.e., being a multi- rather than a single-bond firm) increase with the probability of market freezes and with the value of the firm's investment opportunity set. Moreover, the solution of the model indicates that corporate debt structure should be more granular for larger and more mature firms, for firms with more tangible assets, for firms with higher leverage ratios, and for firms with lower levels of current cash flows.

To test the model's predictions, we construct a large panel data set that contains information on firms' granularity structure, leverage, maturity, and other characteristics (e.g., age, size, Tobin's Q, etc.) by merging data on public debt issues from Mergent's Fixed Investment Securities Database (FISD) with the Compustat database. For the 1991–2009 period, we obtain an unbalanced panel with 16,593 (9,288) firm-year observations by firms

many examples for a state of increased uncertainty to have material implications for a firm's ability to access financial markets that can lead to a market freeze for that firm: negative supply shocks due to firm-specific or market-wide tightening of credit, large legal battles or liability risks (e.g., in the oil industry as documented by Cutler and Summers (1988) or in the pharmaceutical industry), recall risks of car manufacturers (e.g., Toyota's malfunctioning gas pedal), challenges or disputes of patents, regulatory risks of energy companies (e.g., whether or not to exit nuclear power production after disasters such as Fukushima) or hedge funds (e.g., after the financial crisis), and impending natural catastrophes, such as oil spills whose exact consequences for businesses such as tourism are unknown for some time (see, e.g., Massa and Zhang (2011)).

[2]See, e.g., Longstaff et al. (2005) and Mahanti et al. (2008) for evidence on a positive relation between bond issue size and secondary market liquidity.

with at least one bond (two bonds) outstanding. We use these firm-level data on individual corporate bond issues to construct proxies for how dispersed firms' maturity structures are based on FISD data through time. For each firm, maturities of bonds are grouped into the nearest integer years and their fractions out of the total amount of bonds outstanding are used to compute the Herfindahl-Hirschman index of the firm's debt maturity profile each year. In particular, we consider two measures of granularity, the negative value and the inverse of the maturity profile's Herfindahl-Hirschman index.

Several novel results emerge. Consistent with the theory's predictions, we first find strong evidence that larger and more mature firms, firms with higher Tobin's Q, more levered firms, and firms with higher asset tangibility exhibit more granular debt structures. In contrast, debt granularity is negatively associated with profitability. Most of these firm characteristics have explanatory power even after controlling for industry-level or firm-level fixed effects, suggesting that firms condition on these variables in their granularity management over time. In a second series of cross-sectional tests, we establish that debt granularity over time moves towards target levels. In particular, speed-of-adjustment regressions reveal surprisingly high adjustment rates, ranging from 20% to 40% per year.[3]

Building on these cross-sectional results, we further examine whether firms consider pre-existing maturity profiles when they issue new bonds. To do so, we investigate whether discrepancies between a firm's pre-existing maturity profile and a benchmark maturity profile (defined based on industry and firm characteristics) support our model's prediction that there are benefits from being more granular. In other words, most firms should issue bonds to make their maturity profiles more granular relative to a benchmark maturity profile. We confirm this prediction in our sample of bond issuance using five two-year buckets for one- to ten-year bonds in addition to two ten-year buckets for ten- to thirty-year bonds. When a firm has a large fraction of bonds outstanding in any given maturity bucket relative to its benchmark group, then the firm is significantly less likely to issue bonds in those maturity buckets. For example, the probability of issuing nine- or ten-year maturity bonds is 77% lower if the firm has bonds outstanding in this maturity bucket. Moreover, comparison

[3] Both cross-sectional test results also hold for the subsample of firms with at least two bonds outstanding.

across all buckets in the profile, produces also reliable difference of issuance probabilities that suggest firms engage in granularity management by avoiding maturity towers. The results hold across all maturity buckets, is largely invariant to the definition of the benchmarks or buckets, and the economic significance of probabilities is also quite sizeable.

Our paper is related to recent literature that examines maturity structure in the presence of roll-over frictions.[4] By linking corporate bond credit risk and bond market liquidity risk, He and Xiong (2011) show that short-term debt exacerbates roll-over risk. He and Milbradt (2011) endogenize the feedback between secondary market liquidity risk and roll-over risk — reduced liquidity raises equity's rollover losses, leading to earlier endogenous default, which in turn worsens bond liquidity. These papers focus on single-bond firms' maturity choice. Similar to our multi-bond firm is the paper by Diamond and He (2011), which shows that maturing, risky short-term debt can lead to more debt overhang than non-maturing risky long-term. However, none of these papers examines the trade-offs faced by firms when diversifying debt roll-overs across maturity dates. In our setting, issuance of only long-term or only short-term debt may not be optimal. But a combination of short-term and long-term debt can better balance inefficiencies due to roll-over risk at different points in time.

Our paper is also related to recent empirical research. Almeida et al. (2011) document that firms with a greater fraction of long-term debt maturing at the onset of the 2007 financial crisis had more pronounced investment decline than otherwise similar firms.[5] In the context of U.S. Treasury bonds, Greenwood et al. (2010) argue that firms vary their debt maturity to act as macro liquidity providers by absorbing supply shocks due to changes in the maturity of Treasuries. Using syndicated loan data for U.S. firms, Mian and Santos (2011) find more active maturity management by credit worthy firms to avoid being exposed to liquidity risk. Finally, Rauh and Sufi (2010) and Colla et al. (2011) find that – relative to large, high credit quality firms – small, low rated firms have dispersed or multi-tiered debt structures, while small, unrated firms specialize in fewer types. Unlike these studies, we focus on testing cross-sectional and time-series implications for the granularity of corporate debt.[6]

[4]For earlier theories of maturity structure, see, e.g., Diamond (1991, 1993) and Flannery (1986, 1994).

[5]Similarly, Hu (2010) finds firms with more maturing long-term debt had larger increases in credit spreads.

[6]For empirical studies of debt maturity see, e.g., Barclay and Smith (1995), Guedes and Opler (1996), Stohs and Mauer (1996), and Johnson (2003).

The rest of the paper is organized as follows. Section 2 describes the model. Section 3 derives the model's solution and its testable implications. Section 4 presents data sources and summary statistics. Section 5 contains the empirical findings and Section 6 concludes.

2 Model

2.1 Technology

We consider an initially all equity financed firm with assets in place (or initial net worth), A, and two two-period investment projects, whose cash flows are realized in the last period. In particular, each project is available at time t_0 and requires a capital outlay, I. If both periods elapse without (partial) early liquidation and without a technology shock, then each project generates two uncorrelated random cash flows at time t_2 plus a certain continuation value $\bar{v}$ time t_2^+ . Each of the two random cash flows, $\widetilde{CF}_1$ and $\widetilde{CF}_2$, can take the realization c or $c+H$, with equal probability. Thus, along such paths, each project produces expected cash flows of $2\,c+H$. Uncertainty about final cash flows is resolved gradually over time. Thus, the firm can observe at time t_1^- (t_2^-) whether the first (second) cash flow component of a project will be c or $c+H$.

However, the projects may also evolve along paths, where they are hit by a technology shock. Specifically, in every period, there is a probability λ with which the firm becomes vulnerable to such a potential technology shock, which will then occur with probability π. If the technology shock takes place, then each project only produces a final cash flow of c and each project's collateral value drops to zero forever. In other words, if the firm enters the state of increased uncertainty (or λ state), then it is possible that its collateral value goes away.

If a firm's bond expires at a time when the firm is vulnerable to a technology shock, then it may not be able to roll over the bond and, as a consequence, may be forced to partially liquidate one or both projects, depending on the size of the expiring bond. Partial liquidation of a project generates a liquidating cash flow of c, which is contractible, but eliminates the project's non-contractible cash flow, $\widetilde{CF}_t$, at that time t. Figure 1 provides the evolution of cash flows, risks, and shocks over time.

[Insert Figure 1 here]

To provide some intuition, we begin by considering a simple version of the model with exogenous capital market freezes, in which the probability of a technology shock is zero (i.e., $\pi = 0$). That is, we study a world in which the capital market freezes in each period with probability λ but subsequently reopens again. So, bondholders' roll-over incentives are not explicitly modeled in this version. We assume also that $c > I - \frac{1}{2}A$, so bonds are risk-free.

In a second step, we embed bondholders' roll-over decision in a more general model. To do so, we let the probability of a technology shock be greater than zero (i.e., $\pi > 0$), which will produce endogenous capital market freezes. To avoid trivial solutions, we require that:

$$\frac{2\,I - A}{1 - \lambda\,\pi} \;<\; 2\,\bar{v} \;<\; \frac{I - \frac{1}{2}A}{(1-\pi)\,(1-\lambda\,\pi)}\;, \tag{1}$$

and

$$0 \;<\; A \;<\; 2\,I\;. \tag{2}$$

Essentially, the left-hand side of condition (1) ensures that a bond can be rolled over in a state in which the firm is not vulnerable to a technology shock, whereas the right-hand side implies that this is not feasible in a state where the firm may be hit with a technology shock. Condition (2) states that the firm cannot fully fund the projects using its initial net worth, A, which we set equal to zero for the time being. Finally, we also assume that $2\,c > (2\,I - A)/(1 - \lambda\,\pi)$. As will become apparent later, this condition simply ensures that there is enough collateral to satisfy bondholders in full when they do not roll over, since the nominal debt claim is less or equal to $(2\,I - A)/(1 - \lambda\,\pi)$.

2.2 Contracts

At time t_0 the firm needs to raise $2\,I - A$ by issuing debt to fund the two investment projects. We restrict the choice of bond maturities at time t_0 to one or two periods, so bonds either expire at time t_1^- or time t_2^-. The firm's project cash flows at times t_1 and t_2 are not contractible. Only the project's collateral value, c, can be pledged. However, as explained above, to realize this collateral value, the project must be terminated before the cash flow is realized and this is inefficient.

To roll over a bond when it expires at time t_1^- or at time t_2^-, a new bond must be issued with maturity t_2^+. If this is not feasible, then the bondholders have the right to seize assets from one or both projects, depending on the face value of the bond, and realize the collateral value. We assume that, when bondholders request liquidation of a project, the firm already knows each project's next cash flow if no shock occurs. Thus, if the firm only needs to hand over assets from one project to bondholders, it has the option (i.e., flexibility advantage) to keep the one with the (weakly) higher future payoff. For example, if a firm has issued several bonds and only one expires at time t_i^- and cannot be rolled over, then the firm will only need to liquidate assets of the (weakly) worse project and thereby only "sacrifice" CF_i of that project. By contrast, if the firm has only issued a single bond that expires at time t_1^- and cannot be rolled over, then the firm must liquidate assets of both projects and thus must give up CF_i of both projects.

To model granularity of corporate debt, we consider two alternative corporate debt structures at time t_0 that differ by the number of bonds outstanding: the firm can issue one or two bonds. We refer to the former as firm S (or single bond firm) and to the latter as firm M (or multi-bond firm). In particular, since debt will be risky in case of endogenous market freezes, firm S issues at time t_0 a single bond with face value $P_S(t_0, t_2^-) = (2\,I - A)/(1 - \lambda\,\pi)$ that matures at t_2^-. Hence the strategy of firm S is to roll its entire debt over to t_2^+ at time t_2^-, i.e. at *one* point int time.[7] In contrast, firm M has multiple bond issues, one with face value $P_M(t_0, t_1^-) = I - \frac{1}{2}A$ that is due at t_1^- and another one with face value $P_M(t_0, t_2^-) = (I - \frac{1}{2}A)/(1 - \lambda\,\pi)$ that matures at t_2^-. So the two bonds of firm M need to be rolled over to t_2^+ at times t_1^- and t_2^-, i.e., *two* points in time. Notice that if the M firm rolls over its short-term bond at time t_1 to time t_2^+, then the new bond will also be risky and hence its face value is $P_M(t_1, t_2^+) = (I - \frac{1}{2}A)/(1 - \lambda\,\pi)$.[8]

To capture scale economies of one larger issue compared to two smaller issues, we assume that k is the fixed transaction cost per issue (or maturity) at time t_0. Alternatively, k can be thought to capture the fact that a single large bond issue may have a more liquid secondary market, thus leading to a lower illiquidity discount than two smaller bond issues. Thus, firm

[7] An alternative strategy would be to issue a bond that expires at time t_1^- and, if possible, roll it over to t_2^+. We have also investigated this alternative. It is easy to show that this strategy is weakly dominated by the strategy considered in the paper. Intuitively, this is so, because issuing initially a long-term rather than a short-term bond shields time t_1 cash flows (efficiency gain) and inefficiencies arise only at time t_2.

[8] In case of exogenous market freezes, debt is risk-free, i.e., $P_S(t_0, t_2^-) = 2\,I - A$ and $P_M(t_0, t_2^-) = I - \frac{1}{2}A$.

S has a transaction cost advantage, since it requires a single issue costs k, whereas firm M's multiple issues cost $2\,k$. Figure 2 provides the evolution of roll-over decisions over time.

[Insert Figure 2 here]

2.3 Preferences

Finally, we assume investors are risk-neutral and normalize the risk-free interest rate to zero.

3 Solution

3.1 Exogenous Market Freezes

We begin by solving the simple model where the probability of a technology shock is equal to zero (i.e., $\pi = 0$), but the market freezes in each period with probability λ and subsequently reopens again. Since in this setup bondholders always get the face value back, the face value per bond is either $I - \frac{1}{2}A$ (if two bonds are issued) or $2I - A$ (if a single bond is issued).

To determine the value of the single-bond firm S, we need to derive its cash flows along each of four possible paths. First, consider the path where the market freezes in both periods, which occurs with probability λ^2. Since the single bond firm does not have a bond retiring at time t_1, it will collect the expected value of cash flows from both projects, i.e., $2\,c + H$. In the second period, however, firm S faces a roll-over problem since the market freezes again. Therefore, bondholders cause inefficient liquidation of both projects and equityholders receive $2\,c - (2\,I - A)$ at time t_2. Finally, the market reopens again since the technology shock is assumed to be zero in this simpler version of the model and hence the continuation value, $2\,\bar{v}$, becomes available.

Next consider the two paths where the market only freezes once, i.e., either at time t_1 or at time t_2 but not in both periods. Along both paths, equityholders will again receive the continuation value, $2\,\bar{v}$. If the market freezes when firm S does not have a bond repayment due and is open when it has one due, then it generates an expected value of cash flows equal to $2\,(2\,c + H)$ and repays the bond $2\,I - A$, which happens with probability $\lambda\,(1 - \lambda)$. On the other hand, if the market is open at time t_1 but freezes at time t_2, then firm S obtains $2\,c + H$ in the first period, but only $2\,c$ in the second period before repaying $2\,I - A$ to bondholders. This happens with probability $(1-\lambda)\,\lambda$.

Finally, the market does not freeze in either period with probability $(1-\lambda)^2$. Along this path, firm S does not face a roll-over problem and thus generates $2\,(2\,c+H)$ in expected project cash flows, obtains the continuation value, $2\,\bar{v}$, and repays $2\,I-A$ to bondholders. Summing up the values over the four states, the value of firm S equals:

$$V_S(\lambda) \;=\; A-2\,I+4\,c+2\,\bar{v}+H\,(2-\lambda)\;. \tag{3}$$

Next, consider firm M. If the market freezes, then the multi-bond firm is also unable to roll over its bond. Hence firm M must liquidate one project. However, since firms can observe the cash flow state before giving away collateral, firm M will optimally abandon the (weakly) worse project from the set of feasible project payoffs, $\mathcal{P} = \{\{c+H,c+H\},\{c,c+H\},\{c+H,c\},\{c,c\}\}$. This yields an expected project cash flow equal to $c+\frac{3}{4}\,H$, reflecting the (option-like) flexibility advantage that firm M has in deciding which project to terminate and which to continue.

We can now determine the cash flows along the four possible paths. If the market freezes in both periods, which happens with probability λ^2, then firm M is unable to roll over one bond in each period and realizes an expected cash flow of c on the liquidated project and an expected cash flow of $c+\frac{3}{4}\,H$ on the other project in each period. After returning $I-\frac{1}{2}A$ to bondholders in each period and receiving each project's continuation value, $\bar{v}$, firm M's value along this path equals $c-(I-\frac{1}{2}A)+c+\frac{3}{4}\,H+c-(I-\frac{1}{2}A)+c+\frac{3}{4}\,H+2\,\bar{v}$.

Next consider the paths where the market only freezes once, i.e., either at time t_1 or at time t_2 but not in both periods. Firm M's values are identical along both paths since dividends are either first $c-(I-\frac{1}{2}A)+c+\frac{3}{4}\,H$ and then $2\,c+H-(I-\frac{1}{2}A)$ or vices versa. Thus, with probability $\lambda\,(1-\lambda)$ and with probability $(1-\lambda)\,\lambda$, the multi-bond firm generates $c-(I-\frac{1}{2}A)+c+\frac{3}{4}\,H+2\,c+H-(I-\frac{1}{2}A)+2\,\bar{v}$ for shareholders.

Finally, if there are no freezes, which takes place with probability $(1-\lambda)^2$, then firm M's expected payoff to equityholders is same as for firm S in this state, namely $2\,(2\,c+H)-(2\,I-A)+2\,\bar{v}$. Summing up the values over the four states, the value of firm M equals:

$$V_M(\lambda) \;=\; A-2\,I+4\,c+2\,\bar{v}+H\,(2-\tfrac{1}{2}\,\lambda)\;. \tag{4}$$

The difference between the values of firm M and firm S after accounting for the transaction cost per issue k at time t_0 is thus given by:

$$V_M(\lambda) - 2\,k - [V_S(\lambda) - k] \;=\; \tfrac{1}{2}\,\lambda\,H - k\;. \tag{5}$$

Thus, the benefits of debt granularity (i.e., being a multi- rather than a single-bond firm) rise with the probability of market freezes, λ, and with the value of the firm's investment opportunity or payoff, H, but they decline with the level of transaction costs, k. In other words, the multi-bond firm's flexibility advantage dominates when investment opportunities are more important and when market freezes are more likely, whereas the single-bond firm's transaction cost advantage dominates when floatation and illiquidity costs are more important. Depending on the relative magnitude of these two countervailing effects, the simple model predicts that firms might either have a single issue or multiple issues.

3.2 Endogenous Market Freezes

We now solve the model with endogenous market freezes for the more granular firm M and for the less granular firm S, respectively. Based on bondholders' roll-over decisions at times t_1^- or t_2^-, we derive expected project payoffs at times t_1 and t_2 and the resulting values at time t_0. Finally, initial value differences will inform us about the circumstances under which granularity of corporate debt is more or less important. The solution of this more complex model will allow us to derive a number of additional testable implications for our empirical analysis.

As explained in subsection 2.1, now the firm may become vulnerable to a large risk in each period, i.e., at time t_1^- and at time t_2^-. This happens with probability λ. The technology shock then occurs with probability π. Thus, referring to Figure 1, it is easy to see that cash flows can evolve along seven different paths, depending on whether the firm becomes vulnerable to the shock or not, and whether the shock materializes or not. Recall that, unless a project is liquidated early, all cash flows are realized at time t_2. Bonds are either rolled over or, if this is not feasible, repaid via inefficient project liquidation. When a project is (partially) liquidated, it generates a liquidation value c. By contrast, if it is continued it generates a certain future cash flow of c plus an additional, uncertain cash flow H with probability $\frac{1}{2}$ if no shock occurs.

3.2.1 Roll-Over Decisions and Valuation for the Single-Bond Firm

Let us first consider the debt roll-over decisions for firm S and then determine its value, $V_S(\lambda)$, at time t_0. We proceed recursively by first considering period t_2^-. To keep both projects alive at time t_2^-, firm S needs to roll over its expiring bond issue. We observe that, for bondholders to break even, the bond face value must equal $P_S(t_0, t_2^-) = (2\,I - A)/(1 - \lambda\,\pi)$. This is so since the bond is risky when issued at time t_0, due to a possible technology shock at time t_1^-. In other words, its face value is only paid back with probability $1 - \lambda\,\pi$, i.e., the probability that the firm's operations are not terminated prematurely due to a shock at time t_1.

Consider first the λ state at t_2^-, when it is known that the firm is vulnerable to a technology shock at time t_2. Then the firm will be unable to roll over the bond, since new investors will not contribute $P_S(t_0, t_2^-)$ to pay back the expiring bond. The reason for this inefficiency is that $-(2\,I - A)/(1 - \lambda\,\pi) + (1 - \pi)\,2\,\bar{v} < 0$ by the right-hand side of condition (1). In this case, the expected cash flow of each project at time t_2, $2\,c + H$, is lost (i.e., $\widetilde{CF}_2 = 0$) and instead the projects' collateral value, $2\,c$, is realized, of which $(2\,I - A)/(1 - \lambda\,\pi)$ is used to repay the bondholders. If the technology shock actually occurs at time t_2, then the firm's continuation value drops to zero, so $2\,\bar{v}$ is lost. Otherwise (i.e., with probability $1 - \pi$), the firm continues its presence in the product market and realizes the projects' continuation value, $2\,\bar{v}$.

Next, consider the $1 - \lambda$ state at time t_2^-, when the firm is not vulnerable to a shock. It is easy to see that in this state firm S can roll over its bond, since investors are willing to refinance given that $-(2\,I - A)/(1 - \lambda\,\pi) + 2\,\bar{v} > 0$ by the left-hand side of condition (1). As a result, the firm realizes expected project cash flows from both projects at time t_2, equal to $E[\widetilde{CF}_2] = 2\,c + H$, plus the continuation value, $2\,\bar{v}$.

Moving back in time, we next consider time t_1^-. Firm S does not need to roll over any debt at that time, and thus it does not lose either of the two projects due to roll-over risk. However, if the technology shock is realized, which happens with probability $\lambda\,\pi$, then operations end (i.e., the projects' continuation values vanish) and the projects only produce one final cash flow of $\widetilde{CF}_1 = 2\,c$. With probability $1 - \lambda\,\pi$ no technology shock occurs at time t_1, and firm S produces an expected cash flow $E[\widetilde{CF}_1] = 2\,c + H$.

Table 1. Possible Evolutions of Cash Flows for Firm S

Paths	Probabilities	Cash Flows
(i)	$\lambda\,\pi$	$2\,c$
(ii)	$\lambda\,(1-\pi)\,\lambda\,\pi$	$2\,c+H+2\,c-\frac{2\,I-A}{1-\lambda\,\pi}$
(iii)	$\lambda\,(1-\pi)\,\lambda\,(1-\pi)$	$2\,c+H+2\,c-\frac{2\,I-A}{1-\lambda\,\pi}+2\,\bar{v}$
(iv)	$\lambda\,(1-\pi)\,(1-\lambda)$	$2\,c+H+2\,c+H-\frac{2\,I-A}{1-\lambda\,\pi}+2\,\bar{v}$
(v)	$(1-\lambda)\,\lambda\,\pi$	$2\,c+H+2\,c-\frac{2\,I-A}{1-\lambda\,\pi}$
(vi)	$(1-\lambda)\,\lambda\,(1-\pi)$	$2\,c+H+2\,c-\frac{2\,I-A}{1-\lambda\,\pi}+2\,\bar{v}$
(vii)	$(1-\lambda)\,(1-\lambda)$	$2\,c+H+2\,c+H-\frac{2\,I-A}{1-\lambda\,\pi}+2\,\bar{v}$

Based on bondholders' roll-over decisions and the resulting cash flows, Table 1 summarizes the cash flows to equityholders associated with each of the seven possible paths along which firm S can evolve. Summing over the possible paths and multiplying by their respective probabilities we can derive the value of firm S at time t_0, $V_S(\lambda)$:

$$V_S(\lambda) \;=\; A-2\,I+2\,c\,(2-\lambda\,\pi)+2\,\bar{v}\,(1-\lambda\,\pi)^2+H\,(2-\lambda)\,(1-\lambda\,\pi)\;. \tag{6}$$

3.2.2 Roll-Over Decisions and Valuation for the Multi-Bond Firm

Next, we determine the value of firm M at time t_0, V_M. Recall that firm M issues two bonds at time t_0, one with maturity t_1^- and the other with maturity t_2^-. Again proceeding recursively, we start with time t_2^-, assuming that no shock has occurred yet and that the initial short-term bond has been refinanced at time t_1^- with a new bond with maturity t_2^+ requiring a face value of $(I-\frac{1}{2}A)/(1-\lambda\,\pi)$, which is backed by the contractible continuation value, $2\,\bar{v}$.

Consider first the λ state at time t_2^-, when the firm is vulnerable to a shock. In this case firm M cannot roll over the maturing bond, since it can only pledge a collateral worth $(1-\pi)[2\,\bar{v}-(I-\frac{1}{2}A)/(1-\lambda\,\pi)]$. According to condition (1) this is less than the amount required to roll over the bond, i.e., $(I-\frac{1}{2}A)/(1-\lambda\,\pi)$. The firm must therefore liquidate one project to pay back the face value of the expiring bond. The part of the liquidation value that accrues to equity is given by $c - (I - \frac{1}{2}A)/(1 - \lambda\,\pi)$.

Next we consider the roll over decision in the $1 - \lambda$ state at time t_2^-, in which the firm is not vulnerable to a shock. In this case it is easy to see that firm M can roll over the maturing bond since it can pledge a collateral value of $2\,\bar{v} - (I - \frac{1}{2}A)/(1 - \lambda\,\pi)$. Condition (1) implies that this exceeds $(I - \frac{1}{2}A)/(1 - \lambda\,\pi)$, which is the capital required to roll over the maturing bond.

Moving backwards in time to t_1^-, we first consider the roll-over decision in the λ state. Note that the short-term bond (which has a face value of $I - \frac{1}{2}A$, since it is riskless) expires at this point in time. We note that the expected value of the collateral that can be pledged to new investors of a bond with maturity t_2^+ is $(1-\pi)\,(1-\lambda\,\pi)\,2\,\bar{v}$, which is less than $I - \frac{1}{2}A$ by condition (1). Thus, the maturing short-term bond cannot be rolled over and one project must be liquidated.

Finally, we consider the $1 - \lambda$ state at time t_1^-. In this state the expiring bond can be rolled over since the expected value of the collateral that can be pledged to new bondholders is $(1 - \lambda\,\pi)\ 2\bar{v}$ which exceeds $I - \frac{1}{2}A$ by the left-hand side of condition (1). Thus, the short-term bond can be rolled over in this state.

Having determined in which states the firm can roll over its expiring bonds, we can now solve for the value of the firm associated with each of the seven possible paths. These are summarized in the table below. To provide intuition, we discuss the first three possible paths in more detail. The discussion of the remaining paths follows from similar arguments.

Consider path (i), where the firm becomes vulnerable to a technology shock at time t_1^- and the shock subsequently occurs at time t_1. The probability of this path is $\lambda\,\pi$. In this case, as shown above, the firm cannot roll over the expiring bond. It must partially liquidate one project to repay $I - \frac{1}{2}A$ to the short-term bondholders. The remaining $c - (I - \frac{1}{2}A)$ is left for equity. If the shock occurs at time t_1, then only second project produces a final cash flow of c and the firm's continuation value becomes zero. Thus, along this path, the cash flow to equity equals $2\,c - (I - \frac{1}{2}A)$.

Next, consider path (ii), where the firm becomes vulnerable to a technology shock at time

t_1^-, but the shock subsequently does not occur. At time t_2^-, the firm again becomes vulnerable to a technology shock and the shock subsequently occurs at time t_2. The probability of this path is $\lambda\,(1-\pi)\,\lambda\,\pi$. As above, the firm cannot roll over the short-term bond at time t_1^- and must therefore partially liquidate one project. We assume that the firm already knows which cash flow CF_1 each project would produce, if it is not liquidated and no shock occurs. Thus, the firm will liquidate the (weakly) worse project. The cash flow to equityholders from this partial liquidation is $c-(I-\frac{1}{2}A)$. Along path (ii) the shock does not occur at time t_1, and thus the non-liquidated project generates a first cash flow. Since the firm has chosen to liquidate the weakly worse project, the expected time-t_1^- cash flow of the surviving project is $c+\frac{3}{4}H$. Then at time t_2^- the firm becomes vulnerable to a shock again and thus, as shown above, cannot roll over the long-term bond it has issued at time t_0 with face value $(I-\frac{1}{2}A)/(1-\lambda\pi)$. The firm partially liquidates a project generating a cash flow to equityholders of $c-(I-\frac{1}{2}A)/(1-\lambda\pi)$. Then, at time t_2 the shock occurs and the remaining active project produces a final cash flow of c and the continuation value of the firm becomes zero. Summarizing, the total cash flow to equity along this path is $4\,c-(I-\frac{1}{2}A)+\frac{3}{4}H-(I-\frac{1}{2}A)/(1-\lambda\pi)$.

Along path (iii), the firm becomes vulnerable to a shock both at time t_1^- and at time t_2^- but the shocks do not occur. The analysis up to t_2^- is therefore identical to path (ii) above. But now, in contrast to path (ii), a shock does not occur at time t_2. The remaining active project therefore produces an expected cash flow of $E[\widetilde{C}F_2]=c+\frac{3}{4}H$. In addition, the firm realizes a continuation value of $2\bar{v}$. Summarizing, cash flows along this path is $4\,c-(I-\frac{1}{2}A)+\frac{3}{2}H-(I-\frac{1}{2}A)/(1-\lambda\pi)$.

It is straightforward to determine cash flows to equity along the other paths, since they are based on similar arguments. Table 2 summarizes all possible paths and their corresponding cash flows to equityholders. Adding up each of the seven components and multiplying by the respective probabilities, we can now establish the value of firm M at time t_0, $V_M(\lambda)$:

$$V_M(\lambda) \;=\; A-2\,I+2\,c\,(2-\lambda\,\pi)+2\,\bar{v}\,(1-\lambda\,\pi)^2+H\,(2-\lambda\,\pi)\,[1-\tfrac{1}{4}\,\lambda\,(1+3\,\pi)] \qquad (7)$$

The expressions for the values of firm S and firm M reveal several intuitive properties, such as values are decreasing in λ and π and increasing in the project payoff, H. However, we are mainly interested in the determinants of the value difference between firms S and

Table 2. Possible Evolutions of Cash Flows for Firm M

Paths	Probabilities	Cash Flows
(i)	$\lambda\,\pi$	$c-(I-\frac{1}{2}A)+c$
(ii)	$\lambda\,(1-\pi)\,\lambda\,\pi$	$c-(I-\frac{1}{2}A)+c+\frac{3}{4}H+c-\frac{I-\frac{1}{2}A}{1-\lambda\,\pi}+c$
(iii)	$\lambda\,(1-\pi)\,\lambda\,(1-\pi)$	$c-(I-\frac{1}{2}A)+c+\frac{3}{4}H+c-\frac{I-\frac{1}{2}A}{1-\lambda\,\pi}+c+\frac{3}{4}H+2\,\bar{v}$
(iv)	$\lambda\,(1-\pi)\,(1-\lambda)$	$c-(I-\frac{1}{2}A)+c+\frac{3}{4}H+2\,c+H+2\,\bar{v}-\frac{I-\frac{1}{2}A}{1-\lambda\,\pi}$
(v)	$(1-\lambda)\,\lambda\,\pi$	$2\,c+H+c-\frac{I-\frac{1}{2}A}{1-\lambda\,\pi}+c$
(vi)	$(1-\lambda)\,\lambda\,(1-\pi)$	$2\,c+H+c-\frac{I-\frac{1}{2}A}{1-\lambda\,\pi}+c+\frac{3}{4}H+2\,\bar{v}-\frac{I-\frac{1}{2}A}{1-\lambda\,\pi}$
(vii)	$(1-\lambda)\,(1-\lambda)$	$2\,(2\,c+H)+2\,\bar{v}-\frac{2\,I-A}{1-\lambda\,\pi}$

M to reveal under what circumstances granularity of corporate debt is beneficial.

Assuming that each initial bond issue is associated with a fixed transactions cost, k, the difference between the two values is:

$$V_M(\lambda)-2\,k-[V_S(\lambda)-k]\;=\;\frac{3}{4}\,\lambda\,H\,(1-\pi)\,(\tfrac{2}{3}-\lambda\,\pi)-k\;. \tag{8}$$

As in the simpler version of the model, the benefits of debt granularity (i.e., being a multi- rather than a single-bond firm) decrease with transactions costs k. However, the effects of the other parameters on the relative value of debt granularity are now slightly more subtle and depend on the combined magnitude of the probabilities of becoming vulnerable to a shock and the shock taking place. It is easy to see from equation (8) that, as long as $\lambda\,\pi<\frac{2}{3}$, the benefits of granularity increase with the project payoff, H. Equation (8) also reveals that the benefits of debt granularity are first increasing with the probability of becoming vulnerable to a shock, λ, and beyond some point (i.e., if $\lambda\,\pi>\frac{1}{3}$) decrease with λ.

Furthermore, equation (8) implies that, ignoring transactions costs, the benefit due to debt granularity becomes zero as π goes to one. This is easy to understand since early liquidation becomes less inefficient as $\pi \to 1$. In the limit, if $\pi = 1$, liquidating a project early in the λ state or continuing the project generate an identical cash flow of c (although the former liquidating cash flow is contractible and the latter is not). Thus, in the limit, when the shock always materializes, the value of flexibility generated by debt granularity vanishes.

More generally, equation (8) reveals that, for a large range of plausible parameter values, firm M has a flexibility advantage over firm S, so that, in the absence of floatation and liquidity costs, it is generally optimal to issue granular debt. However, if $\lambda \pi > \frac{2}{3}$, i.e., for very large probabilities of a technology shock, a single long-term bond becomes optimal, even when transactions costs are zero. This is so since large values of $\lambda \pi$ effectively "discount away" the flexibility advantage of firm M in the second period, so that the higher expected payoff of firm S in the first period (i.e., $2c + H > 2c + \frac{3}{4}H$) becomes the dominating factor for the value difference of firms M and S. Therefore, the model's solution also implies that, if a technology shock occurs with a sufficiently high probability, then the firm would prefer to have a single large roll-over risk in the distant future, rather than smaller roll-over risks distributed over different maturities.

3.3 Testable Hypotheses

Figure 3 illustrates the value difference in equation (8) numerically for some base case parameter values, namely the non-contractible project cash flow H is equal to 200, the collateral value, c, and the investment cost, I, are equal to 300, the probability of a technology shock π is equal to 0.8, the continuation value, $\bar{v}$ is equal to 750, and the transaction costs k is equal to 1.[9] Once we include transaction costs, firm S initially dominates firm M for λ–values in the right neighborhood of zero where $V_M < V_S$. As λ rises, however, the the flexibility advantage of firm M becomes increasingly important, whereas the transaction cost advantage of firm S is of course invariant to λ. As a result, the value difference grows and hence λ has to be sufficiently far away from zero for $V_M > V_S$ to hold. Eventually, the value difference declines again and, in some cases, it may become negative for sufficiently high λ–values, because the earlier period's cash flows, where firm S does not face a roll-over

[9]Note that condition (1) implies that the admissible values for π are generally in the $[\frac{1}{2}, 1]$ interval and that, for these base case parameter values, the admissible values for λ are in the $[0, \frac{3}{4}]$ interval.

problem, can be relatively more important than the later period's cash flows.

[Insert Figure 3 here]

Consistent with economic intuition and as seen in the figure, increasing transaction costs works in favor of firm S because it produces a downward shift of the $V_M - V_S$ curve, which implies that a firm with higher frictions will have a lower incentive to implement a more granular debt structure. Since transaction costs are inversely related to firm age and firm size (see, e.g., Fischer et al. (1989)), we obtain our first testable hypothesis.

Hypothesis 1 *Corporate debt structure is more granular for larger and more mature firms.*

Figure 3 plots the $V_M - V_S$ as a function of λ for three different values of the non-contractible project cash flow, H. That is, we vary the base case profitability of $H = 200$ represented by the solid line to higher profitability $H = 300$ (given by the dashed line) or to lower profitability $H = 100$ (given by the dotted line). As seen all cases, there is always an initial region for which firm S dominates due to its transaction cost advantage irrespective of the size of the investment opportunity. So, on the one hand, the graphical illustration suggests that firm S can also dominate firm M for positive λ–values when the growth option is not very valuable (i.e., approximately when $H < 50$). On the other hand, debt granularity management will be increasingly valuable when the investment project's payoff rises. Put differently, it is optimal for firms with more valuable growth opportunities as measured, e.g., by a higher value of Tobin's Q, to have a more granular debt structure. This logic produces our second testable implication.

Hypothesis 2 *Corporate debt structure is more granular for firms with higher (potential) cash flows from future investment or higher values of Tobin's Q.*

Figure 4 continues the numerical analysis by focusing on three different cases for the probability of a technology shock, π, which we set to 0.8 in the base case. In particular, the dashed line considers lower collateral quality in that the probability of collateral to become worthless is higher (i.e., $\pi = 0.85$), while the dotted line assumes $\pi = 0.75$, so that collateral is more likely to withstand the bad state. Intuitively, we can therefore interpret a lower value of π as a higher degree of asset tangibility. The figure reveals that a lower (higher) probability of a technology shock increases (decreases) the benefits of a granular debt structure; i.e., firm M is increasingly more valuable than firm S when the probability of a technology declines. Since asset tangibility is inversely related to this probability in our model, we obtain the following testable implication.

[Insert Figure 4 here]

Hypothesis 3 *Corporate debt structure is more granular for firms with higher asset tangibility.*

Finally, there are two more testable hypotheses that follow from the observation that certain firm characteristics influence condition (1), which we invoke to avoid trivial solutions where firm S always dominates firm M. Observe that firms with a higher initial net worth A (or more loosely speaking firms with higher cash flows from assets in place, which would imply a larger value of A in a present value sense) need to borrow less than $2\,I$ (or can refinance using internal funds in the λ–state). As a consequence, the roll-over problem of firm S will disappear in the λ–state when initial net worth is sufficiently high (or cash flows from assets in place are sufficiently high). Therefore, if leverage is sufficiently low, because initial net worth is sufficiently high, firm S dominates firm M and hence less granular debt structures should be observed in the data.

Hypothesis 4 *Corporate debt structure is more granular for firms with higher financial leverage ratios.*

Hypothesis 5 *Corporate debt structure is more granular for firms with lower cash flows from assets in place.*

4 Data Description

4.1 Sample Selection and Variable Construction

Data for corporate bonds are drawn from the Fixed Income Security Database (FISD) from Mergent, a comprehensive database on issuance information. We obtain issue dates, maturity, initial and historical amounts outstanding, and other relevant information from the database. Accounting data are drawn from the annual Compustat tapes. We exclude financial firms (SIC codes 6000-6999) and utilities (SIC codes 4900-4999), and winsorize the top and bottom 0.5% of variables to minimize the impact of data errors and outliers. The combined data set covers the period from 1991 to 2009.

Granularity is measured based on how dispersed firms' maturity structures are, or using the Herfindahl-Hirschman index of bond maturity concentrations. For each firm, maturities of bonds are grouped into the nearest integer years and their fractions out of total amount of bonds outstanding are calculated to obtain the Herfindahl index. Two measures of granularity is considered: a negative of the index ($GRAN1$) and an inverse of the index ($GRAN2$).[10]

To investigate the empirical predictions of the model, we include a number of control variables in our regression specifications. In particular, we use the market-to-book asset ratio (or Tobin's Q) as a proxy of the firm's growth opportunities: $(AT + (PRC_F * CSHO) - CDQ - TXDB)/AT$. Market leverage ($Lev$) is book debt over market assets: $(DLTT + DLC)(AT + PRCC_F * CSHO - CEQ - TXDB)$. Size ($Size$) is total assets: AT. Asset tangibility (Tan) is measured as plant, property, and equipment scaled by total assets: $PPENT/AT$. Profitability ($Prof$) is operating income before depreciation scaled by total assets: $OIBDP/AT$, which measures cash flows. Age of a firm (Age) is measured as the number of years in the Compustat database prior to each observation.

4.2 Summary Statistics

Sample statistics are reported in Table 3. As seen in Panel A, out of total of 16,697 firm-year observations, firms have only one bond in 7,335 cases and at least two bonds outstanding

[10]Being granularity measures of corporate bonds, $GRAN1$ and $GRAN2$ do not consider maturity structures of private debt (i.e. bank loans). In the empirical analysis later, we address this issue by considering private debt as explanatory variables. See also Mian and Santos (2011) on a related analysis of syndicate loans.

in 9,362 cases. The sample is skewed to large and high leverage firms, because firms are required to have corporate bonds to be considered. In the sample of firms with at least two bonds outstanding, for example, the average and median assets are 11.9 and 3.5 billion dollars, respectively, median age is 28 years, and average leverage is 0.28.

[Insert Table 3 here]

We find an interesting stylized fact that a number of firms have only one bond outstanding. There are 7,335 observations of one bond firms out of 16,697 total observations. They are typically younger firms (13 years vs. 28 years) with smaller amounts of assets ($1,769B vs. $11,896B). We note that one-bond firms might have also considered being granular, because they could have split the amounts and spread out roll-over dates by issuing multiple smaller bonds with different maturities, but they did not do so possibly because, being young and small, they have low incentives to become granular and high transaction costs.

Distributions of the granularity measures, $GRAN1$ and $GRAN2$, among firms with at least two bonds are reported in Figure 5 and 6, respectively. One being an inverse of the other, $GRAN1$ is skewed to the right whereas $GRAN2$ is to the left. There are a few peaks in Figure 5. The one at -1 represents firms that have the same maturities for all the bonds outstanding, meaning that these firms are not spreading out maturity structures. The tall bar at -0.5 in Figure 5 represents firms with two different maturities in equal bond amounts.

[Insert Figures 5 and 6 here]

Panel B of Table 3 reports the distribution of the total number of 16,176 corporate bond issuances over the 1991–2009 period. To examine the basic time-series variation of bond issuances and granularity, we tabulate the mean and median numbers of issues per firm along with issuing firms' levels of granularity as measured by $GRAN1$ and $GRAN2$. On average, firms issue from 1.57 to 3.45 bonds per year. Although the average number of issues varies quite a bit over time, the granular measures at the firms' bond issuance points are fairly stable ranging from -0.48 to -0.56 ($GRAN1$), which is an indication that firms actively manage debt maturity structures.

Table 4 reports a set of univariate correlations of our variables. On the one hand, granularity is strongly positively correlated with the size, age, and tangibility, revealing that large, mature firms with pledgable assets (i.e., collateral) tend to have more granular debt structures. On the other hand, granularity is negatively correlated with the market-to-book and leverage ratios, which appears inconsistent with our theory, possibly because simple univariate correlation analysis does not show complex relations among these variables. The correlation coefficients of granularity measures with number of bonds and average bond maturity are also positive. If firms do not consider granularity management at all in their financing decisions, then a small but positive relation between the granularity and the number of bonds might arise mechanically. However, we find large coefficients of 0.39 and 0.62. Also, if some firms are only able issue very short-term debt rather various layers of long-term debt, then such firms would have a limited ability to design granular debt structures, which explains why the correlation with Mat should be positive. Overall, these observations suggest that controlling for these variables should be important in the multivariate regression analysis that follows.

[Insert Table 4 here]

5 Empirical Tests

5.1 Cross-Sectional Results

In this section, we test our model's main predictions using the following panel regression:

$$GRAN_{i,t+1} = \alpha_i + y_t + \beta X_{i,t} + \epsilon_{i,t} \quad (9)$$

where $X_{i,t}$ is a vector of explanatory and control variables, α_i is a firm or industry level fixed effect, and y_t is a time effect. Explanatory variables include market-to-book, leverage, size, age, tangibility and profitability, which are proxies for the key variables in our empirical predictions. We include the number of bonds as a control variable, because there could be a mechanical relation with granularity as firms' issue more bonds. Also, firms that can issue long-term bonds have higher chance of being granular compared to firms that can only issue short-term bonds. We therefore control for average maturity for each firm. Standard errors are clustered at the Fama-French 48 industry level to account for within-industry correlations.

Panel A of Table 5 provides the estimation results of model (9) using $GRAN1$ as dependent variable. Overall, the independent variables are associated with granularity as predicted by our theory. For example, the market-to-book ratio is reliably positively associated with this granularity measure across all the specifications that we consider. This evidence supports our hypothesis that firms with more valuable growth opportunities have a higher incentive to spread out the maturity structure in order to protect their valuable projects from inefficient liquidation.

The coefficients on firm size, as measured by total book value of assets, are significant and positive across all regression models. Age is also positively related to granularity, although its effect becomes negative (but statistically insignificant) when firm fixed effects included. These results are consistent with our hypotheses that small, young firms, faced with high transaction costs and limited access to the financial markets, are not able to spread out their maturity structure and forego benefits of granularity.

[Insert Table 5 here]

Market leverage is also positively associated with granularity and is statistically significant across all the models considered. Although consistent with our theory's prediction, this result can be partly due to endogeneity between leverage and granularity. Having granular debt structures, firms may have higher debt capacity and therefore could have higher leverage. Another endogeneity channel is that firms might consider amounts of bond issuance and maturity structures simultaneously.

Asset tangibility and cash flow are reliably related to granularity as predicted by our theory. Tangibility tends to be positively related, although its statistical significance becomes marginal or disappear when we control for firm fixed effects or when firms are required to have at least two bonds outstanding. The effect of cash flow ($Prof$) is also consistent with our theory, being negatively associated with granularity especially among the full sample of firms. Other control variables, such as total number of bonds and average debt maturity, are positively associated, but they do not reduce the explanatory power of other key variables, showing the robustness of results.

Several robustness checks are performed. First, in the last couple of rows in Table 5, we provide regression results with firm fixed effects after excluding firms with only one bond. Since there are many firms with only one bond in the sample, it is possible that the results in Table 5 are mainly driven by one bond firms. If one-bond firms are not able to issue multiple bonds with different maturities for reasons not captured by the control variables, having too many one-bond firms in the sample can be an issue. The results are similar to those with the full sample. Market-to-book. size, age, leverage and tangibility are mostly related positively, and profitability is negatively to granularity. Overall, the results are not driven by one-bond only firms.

In Panel B of Table 5, we report results based on the inverse of the Herfindahl index ($GRAN2$) as an alternative measure, since the results with $GRAN1$ could possibly driven by its positively skewed distribution. As seen in the table, the results are fairly similar to the results based on $GRAN1$ in Panel A and thus are further confirming our model's predictions.

5.2 Speed-Of-Adjustment Results

In this section, we investigate whether our granularity proxies move over time toward target levels of granularity. For this purpose, the following speed-of-adjustment (SOA) regressions of debt granularity are estimated:

$$GRAN_{i,t+1} = \alpha_i + y_t + \gamma GRAN_{i,t} + \beta X_{i,t} + \epsilon_{i,t} \quad (10)$$

The speed of adjustment is then given by $1-\gamma$, and the target granularity level is $\frac{\beta}{1-\gamma}X_{i,t}$.[11]

The SOA estimation results for $GRAN1$ and $GRAN2$, respectively, are reported in Panel A and Panel B of Table 6. The results indicate that the granularity measures mean-revert to a target granularity level. The estimated AR(1) coefficient (γ) is around 0.8 to 0.5, meaning that the speed-of-adjustment is around 0.2-0.5. When fixed effects are included in the models, the SOA estimates particularly increase (γ decreases), as indicated by Flannery and Rangan (2006) in the SOA regression of debt ratios. The results overall show relatively rapid time-variations towards target granularity levels.

[Insert Table 6 here]

[11] To see this, consider the following model: $\Delta GRAN_{i,t+1} = a(Target_{i,t} - GRAN_{i,t}) + \eta_{i,t}$ where $Target_{i,t}(\equiv \frac{\beta}{a}X_{i,t})$ is a target level of granularity.

In addition to the SOA estimates, Table 6 also provides the target granularity estimation results, and we further confirm that the predictions from our theory is consistent with what is found in data. Market-to-book, size and leverage are positively linked to target granularity across all the models considered. The other variables (age, tangibility and profitability) are also overall related with the target granularity in a way that is consistent with our hypotheses.

Overall, these speed-of-adjustment tests results lead us to conclude that firms actively manage their debt granularity structures. That is, firms make frequent adjustments towards certain target granularity structures that are consistent with the model and with the test results in the previous subsection.

5.3 Time-Series Results

In this section, we provide time-series evidence for granularity. Specifically, we examine whether newly-issued bonds' maturities are determined according to our theory. For this purpose, we run a series of binomial choice regressions:

$$Prob(I_i^{K_j}) = a_1 m_i^{K_1} + a_2 m_i^{K_2} + a_3 m_i^{K_3} + a_4 m_i^{K_4} + a_5 m_i^{K_5} + a_6 m_i^{K_6} + a_7 m_i^{K_7} + \alpha_n + y_t \quad (11)$$

where K_j represent maturity buckets, $I_i^{K_j}$ issuance dummies for each newly-issued bond i, and $m_i^{K_j}$ are deviations of the issuing firm's maturity profiles from its benchmark's. The maturity buckets K_j are defined as follows. For maturity shorter than 10 years, there are five two-year buckets. In other words, for $1 \leq j \leq 5$, K_j is from $2j - 1$ to $2j$ years. For maturities longer than 10 years, there are two maturity buckets K_6 and K_7. K_6 corresponds to years from 11 to 20 and K_7 to years from 21 or longer. α_n is a firm fixed effect for the issuing firm n and y_t is year fixed effects.

The independent variable $m_i^{K_j}$ (the deviation of maturity profiles from the benchmark) is defined in the following way. Each firm's maturity profiles are first calculated as fractions of pre-existing bond amounts in each maturity bucket K_j. In order to obtain the benchmark maturity profile, firms are sorted into high (top 50%) and low (bottom 50%) groups based on the variables (Q, market leverage, age, size, tangibility, profitability, and average maturity) for each Fama-French industry group. This procedure provides us with industry-neutral breakpoints and 128 maturity profile groups. The benchmark profile of each group is then obtained by averaging maturity profiles in that group. The deviations from the benchmark profiles are obtained by subtracting average maturity profiles of the group that the issuing firm belongs to.

The dependent variable is the issuance variable, $I_i^{K_j}$, which takes a value of one if the bond's maturity falls in the K_j bucket. If the bond issued has a different maturity, then $I_i^{K_j}$ is zero. For the new issue to be sufficiently important, we experiment with different relative issuance size cut-offs. We note that this time-series analysis is conditional in that it estimates a maturity choice problem given the firm issues a bond.

If firms manage their granularity of maturity profile relative to benchmarks, then the probability of issuing a bond in the K_j maturity bucket will be negatively linked to the deviation of bond fractions in that bucket, $m_i^{K_j}$. The coefficient a_j will be negative and smaller than coefficients on other maturity buckets, a_i where $i \neq j$. To examine these predictions, linear probability models are estimated for each maturity bucket K_j. Other probability models such as panel logit models are considered and the results are qualitatively similar. Firm and year fixed effects are included in the estimation. Any economy-wide supply side effects on firms' issuance are supposed to be absorbed by the year fixed effect. Standard errors are clustered at the Fama-French 48 industry level.

Results in Panel A of Table 7 confirm the model's insights. Panel A1 provides the results based on the sample of bonds with issue sizes greater than 3% of firms' total pre-existing bond amounts. Except for the shortest maturity bucket (K_1), all diagonal coefficients are negative and statistically significant at 1% or 5% level, suggesting that firms engage in granularity management by avoiding maturity towers. For the five to six year maturity bucket, for example, the coefficient on K_3 is -0.423, meaning that firms are 42.3% less likely to issue bonds with 5-6 year maturity if the firm has bonds outstanding in the bucket K_3. Perhaps because bank loans and other private debt are confounding our analysis for shorter maturities, the weakest result is found at the shortest maturity bucket (K_1), which is still negative and statistically significant at the 10% level. Non-diagonal coefficients are in many cases positive and not significant. The results in Panel A2 based on the sample with the issue cutoff at 5% are even stronger, further confirming firms' motives to maintain granular bond maturity structures when the relative size of the new issue is larger.

[Insert Table 7 here]

In addition, we examine in Table 7 whether the diagonal coefficients are, on average, smaller than the other six coefficients in the same binomial choice regression (i.e., column). For this purpose, we test the following null hypothesis, H_0, in the last rows of Table 7: $a_i - \frac{1}{6}\sum_{n \neq i} a_n = 0$. The results reveal that the diagonal coefficients are always smaller than the average of non-diagonal coefficients. The difference $(a_i - \frac{1}{6}\sum_{n \neq i} a_n)$ is negative across all maturity buckets, ranging from -0.07 to -0.99 in Panel A1. Furthermore, they are all statistically significant at 5% level except for the seven to eight maturity bucket, in which case the statistical significance is marginal. When the 5% issue cutoff is used in Panel A2, the results are stronger with the hypothesis rejected in all cases at the 5% level.

In Panel B1 and Panel B2 of Table 7, we perform the same empirical analyses after excluding all option-embedded bonds such as callable, convertible, and putable and bonds with sinking fund provisions as a robustness check. This exercise is important and informative because effective maturities could be shorter with these option-embedded bonds. Compared to the ones in the full sample, the results are qualitatively similar in the sample of straight bonds. Overall, the test results for the time-series of bond issuance decisions reinforce the speed-of-adjustment test results from the previous subsection. That is, they lead us to conclude that firms actively manage their debt granularity structures especially when they issue new bonds.

6 Conclusion

This paper is, to our knowledge, the first to study the granularity structure of corporate debt (i.e., the degree to which firms spread out their bonds' maturity dates across time). We build a two-period model with roll-over risk, which has adverse effects on the firm's real investment process, to derive a number of novel, testable implications. In our setting, it can be advantageous to diversify the debt roll-over problem across debt maturity dates. For example, our model predicts that corporate debt structure is more granular for larger and more mature firms, for firms with better investment opportunities, for firms with more tangible assets, and for firms with lower values of assets in place or lower levels of current cash flows.

In a large panel data set of corporate bond issuers during the 1991–2009 period, we document empirical evidence that supports our theory's predictions in cross-sectional tests and in time-series tests. In the cross-section, corporate debt structure is more granular and adjusts faster over time for larger and more mature firms, for firms with better investment opportunities, for firms with more tangible assets, for firms with higher leverage ratios, for firms with lower values of assets in place, and for firms with lower levels of current cash flows. In the time-series, we also document that firms actively engage in granularity management in the sense that newly issued corporate bond maturities are inversely related to pre-existing bond maturity profiles.

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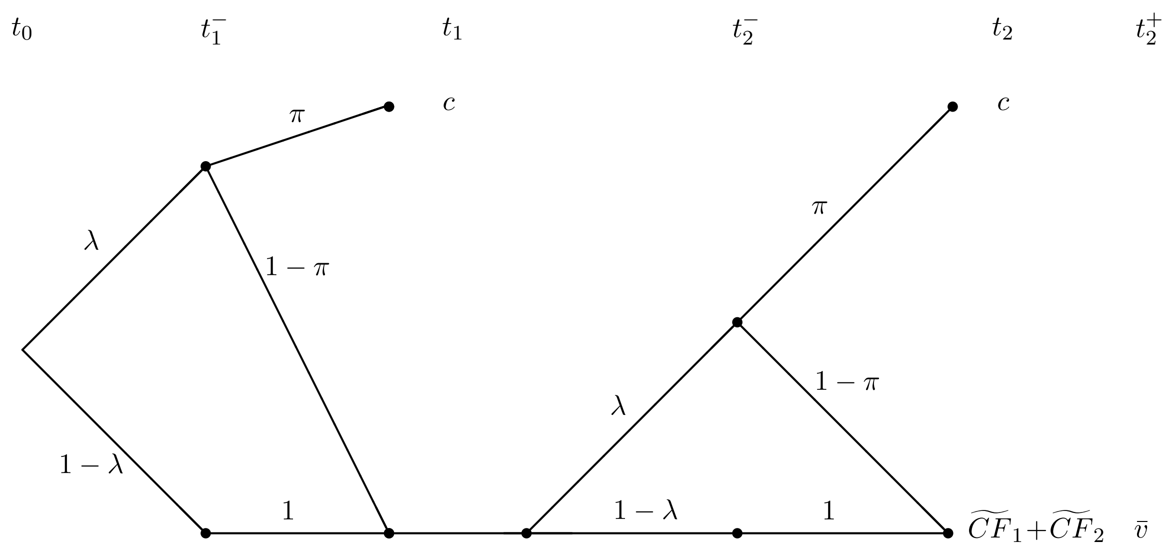
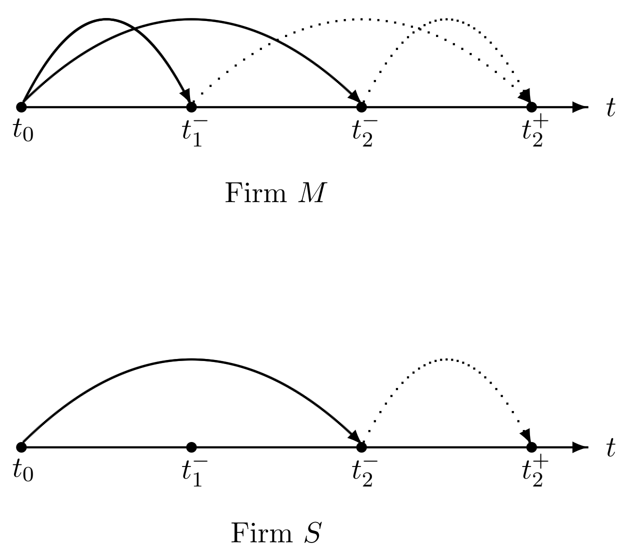
Figure 1. Evolution of Cash Flows, Risks, and Shocks



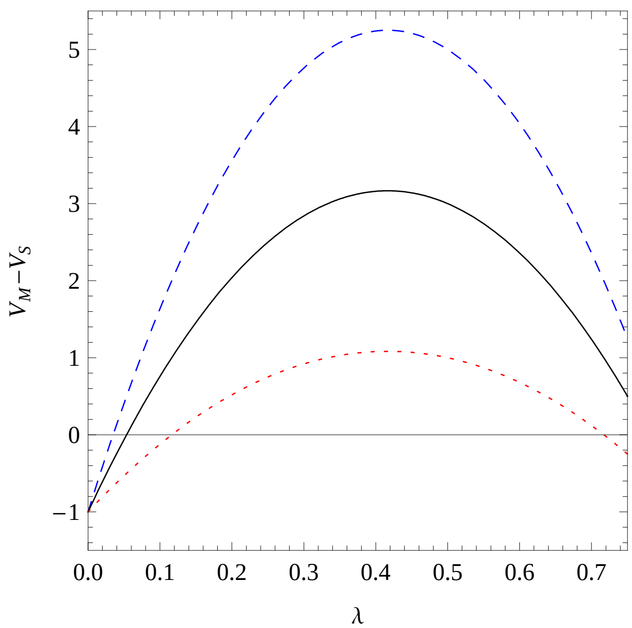
This figure plots the time line of cash flows, risks, and shocks. In each of the two periods, there is a probability λ with which the firm becomes vulnerable to a technology shock, which will then occur with probability π. If the technology shock takes place, each project only pays off one final cash flow of c and the collateral value vanishes forever, so project collateral value is either c or 0. Project cash flows in the absence of a technology shock, $\widetilde{CF}_1$ and $\widetilde{CF}_2$, are realized at time t_2; they are either c with probability $\frac{1}{2}$ or $c+H$ with probability $\frac{1}{2}$. In the absence of a technology shock, the firm's (pledgable) continuation value becomes available at time t_2^+.

Figure 2. Evolution of Roll-Over Decisions



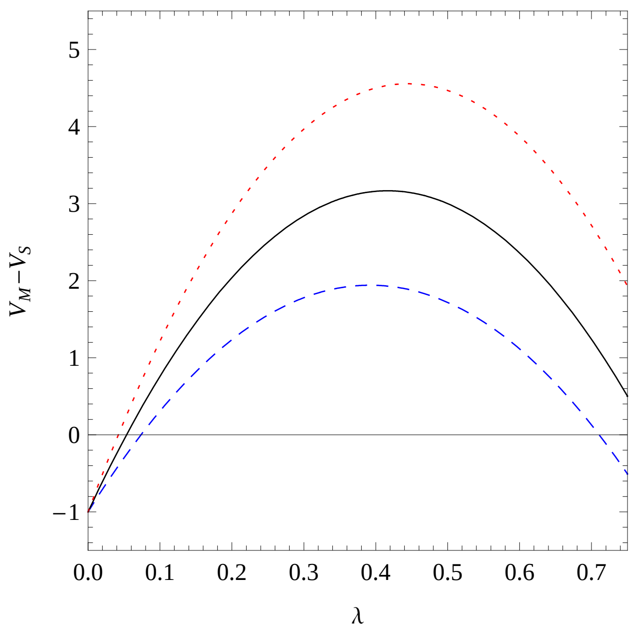
This figure plots the time line of roll-over decisions of the multi-bond firm (Firm M) with two smaller bond issues, which expire at time t_1^- and t_2^-, and single-bond firm (Firm S) with one large bond issue, which expires at time t_2^-. An expiring bond issue needs to be rolled over into time t_2^+ to obtain the firm's continuation value.

Figure 3. Benefits of Debt Granularity (H)



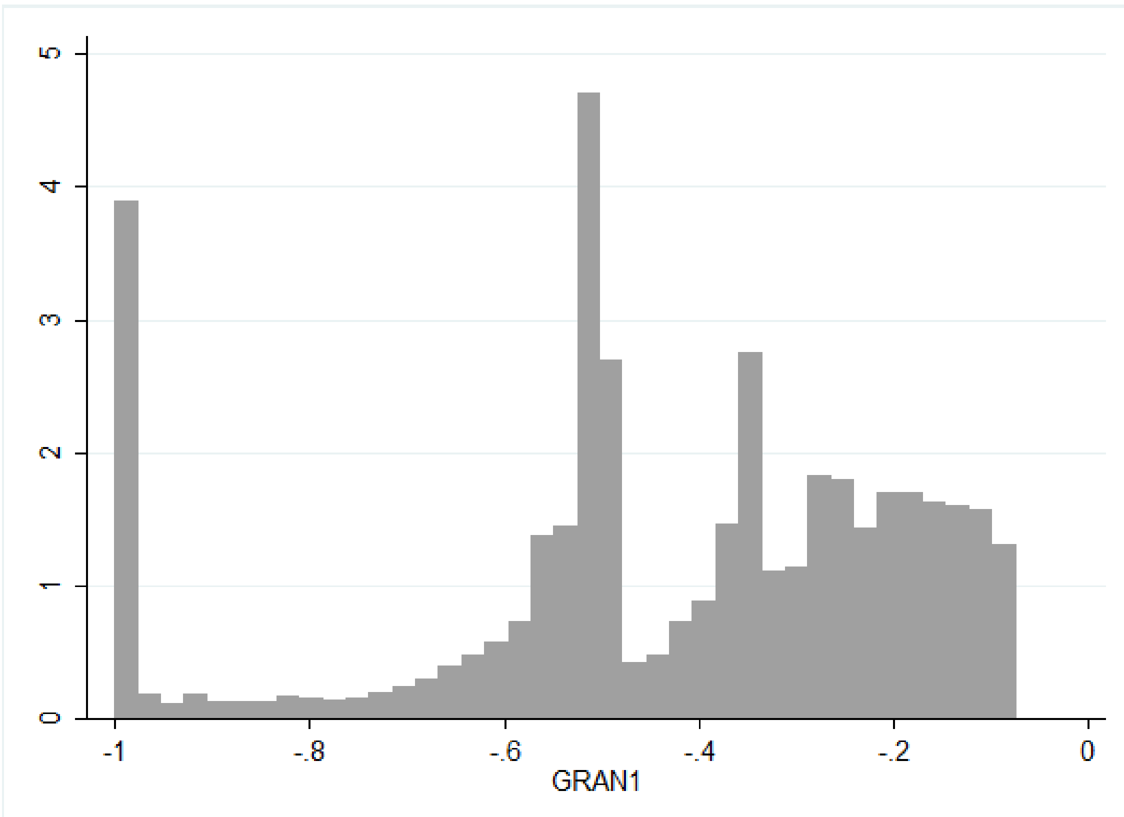
This figure plots the effect of the non-contractible cash flow H on the value difference of firms M and S, $V_M - V_S$, as a function of the probability of becoming vulnerable to a technology shock λ. The base case depicted by the black, solid line, assumes that the non-contractible project cash flow H is equal to 200, the collateral value, c, and the investment cost, I, are equal to 300, the probability of a technology shock π is equal to 0.8, the continuation value, $\bar{v}$ is equal to 750, and the transaction costs k is equal to 1. The blue, dashed line assumes $H = 300$ and the red, dotted line assumes $H = 100$.

Figure 4. Benefits of Debt Granularity (π)



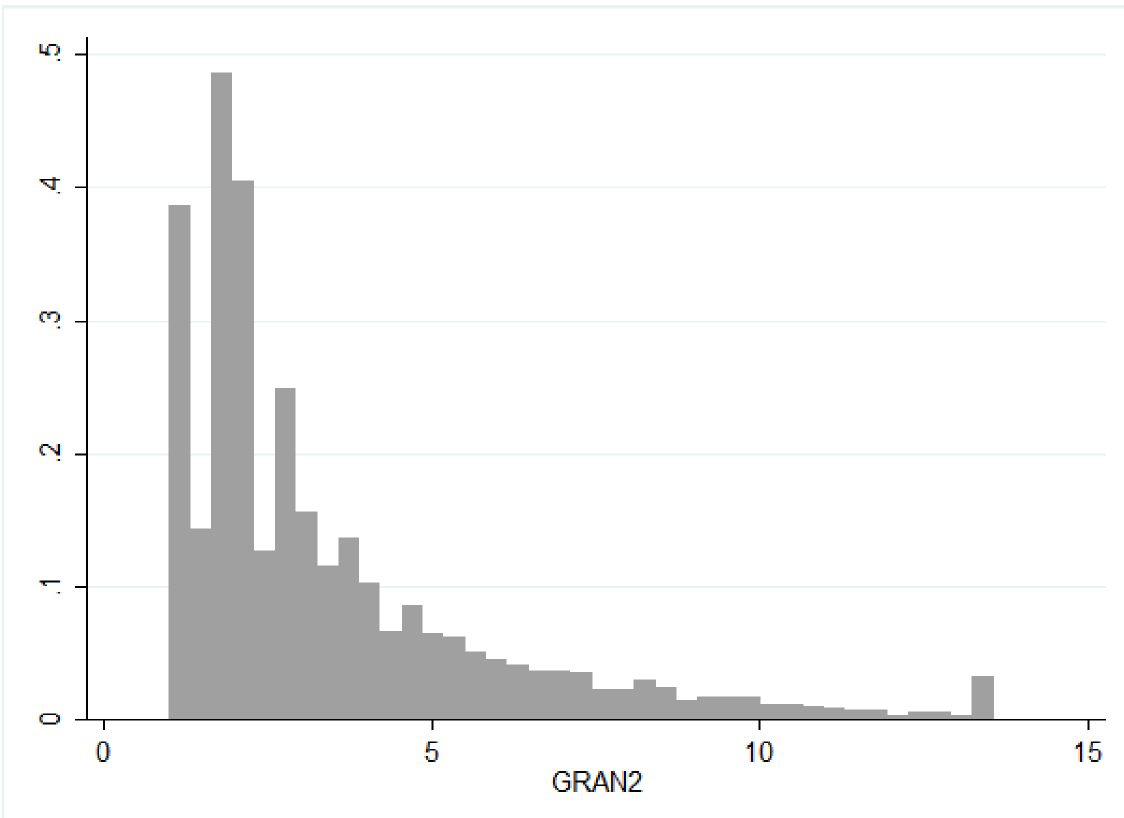
This figure plots the effect of the profitability of a shock π on the value difference of firms M and S, $V_M - V_S$, as a function of the probability of becoming vulnerable to a technology shock λ. The base case depicted by the black, solid line, assumes that the non-contractible project cash flow H is equal to 200, the collateral value, c, and the investment cost, I, are equal to 300, the probability of a technology shock π is equal to 0.8, the continuation value, $\bar{v}$ is equal to 750, and the transaction costs k is equal to 1. The blue, dashed line assumes $\pi = 0.85$ and the red, dotted line assumes $\pi = 0.75$.

Figure 5. Distribution of Granularity Measures ($GRAN1$)



This figure plots the histogram of the granularity measure, $GRAN1$, winsorized at the top and bottom 0.5%. Firms are required to have more than or equal to two bonds outstanding to be included in the sample. $GRAN1$ is defined as a negative of the Herfindahl index of bond fractions. The bond fractions are calculated by first grouping maturities into the nearest integer years and then calculating fractions out of total bond outstanding. $GRAN2$ is an inverse of the Herfindahl index of bond fractions.

Figure 6. Distribution of Granularity Measures ($GRAN2$)



This figure plots the histogram of the granularity measure, $GRAN2$, winsorized at the top and bottom 0.5%. Firms are required to have more than or equal to two bonds outstanding to be included in the sample. $GRAN2$ is defined as an inverse of the Herfindahl index of bond fractions. The bond fractions are calculated by first grouping maturities into the nearest integer years and then calculating fractions out of total bond outstanding. $GRAN2$ is an inverse of the Herfindahl index of bond fractions.

Table 3. Sample Descriptive Statistics

The sample is drawn from the Fixed Income Security Database (FISD) from Mergent and the annual Compustat files, excluding financial and utility firms for the period from 1991 to 2009. There are total of 9,362 firm-year observations and 16,176 corproate bond issues. Panel A reports summary statistics for firms at least one bond ($NumBond = 1$) and for firms with more than two bonds ($NumBond \geq 2$). $GRAN1$ is defined as a negative of the Herfindahl index of bond fractions. The bond fractions are calculated by first grouping maturities into the nearest integer years and then calculating fractions out of total bond outstanding. $GRAN2$ is an inverse of the Herfindahl index of bond fractions. $Size$ is the total assets in million dollars. Age is the number of years in the Compustat file prior to observations. Q is the market-to-book ratio and Lev is the market value of leverage. Tan and $Prof$ are the tangibility and profitability. $NumBond$ is the number of bonds outstanding and Mat is the average of firms' bond maturities. Panel B reports statistics of bonds issues. Total Issues is the total number of bond issues for each year, and Mean Issues per Firm is the average number of issues by firms. $GRAN1$ and $GRAN2$ are defined as a negative and an inverse of the Herfindahl index of bond fractions, respectively, where bond fractions are calculated by first grouping maturities into the nearest integer years and then calculating fractions out of total bond outstanding. The reported numbers for $GRAN1$ and $GRAN2$ are averages numbers of the bond issue sample.

Panel A: Sample Statistics

	$NumBond \geq 2$			$NumBond = 1$		
	Mean	Std Dev	Median	Mean	Std Dev	Median
$GRAN1$	-0.43	0.26	-0.38			
$GRAN2$	3.46	2.56	2.62			
$Size$	11895.8	35896.4	3459.7	1768.5	6857.7	667.8
Age	24.9	13.4	28	17.0	11.83	13
Q	1.66	0.95	1.38	1.71	1.04	1.38
Lev	0.28	0.18	0.24	0.28	0.19	0.24
Tan	0.36	0.23	0.31	0.30	0.23	0.23
$Prof$	0.12	0.09	0.13	0.10	0.13	0.11
$NumBond$	8.24	15.36	4	1	0	1
Mat	9.98	5.69	8.41	8.23	6.03	6.59
$Obs.$	9362			7335		

Panel B: Corporate Bond Issues

	Mean Issues per Firm	Total Issues	$GRAN1$	$GRAN2$
1991	2.94	717	-0.48	2.10
1992	3.14	1078	-0.49	2.03
1993	3.18	1288	-0.49	2.03
1994	3.37	708	-0.51	1.95
1995	3.45	1074	-0.51	1.97
1996	2.93	1065	-0.51	1.97
1997	2.45	1158	-0.54	1.86
1998	2.52	1391	-0.56	1.79
1999	2.73	1066	-0.52	1.92
2000	2.30	706	-0.52	1.93
2001	2.29	1005	-0.50	2.01
2002	2.27	732	-0.50	2.01
2003	1.83	854	-0.52	1.91
2004	1.57	668	-0.56	1.80
2005	1.61	466	-0.53	1.89
2006	1.72	492	-0.56	1.79
2007	1.78	590	-0.54	1.84
2008	1.93	427	-0.53	1.89
2009	1.77	691	-0.48	2.08

Table 4. Correlations

The sample is from the Fixed Income Security Database (FISD) from Mergent and the annual Compustat files, excluding financial and utility firms for the period from 1991 to 2009. $GRAN1$ is defined as a negative of the Herfindahl index of bond fractions. The bond fractions are calculated by first grouping maturities into the nearest integer years and then calculating fractions out of total bond outstanding. $GRAN2$ is an inverse of the Herfindahl index of bond fractions. $Size$ is the total assets in million dollars. Age is the number of years in the Compustat file prior to observations. Q is the market-to-book ratio and Lev is the market value of leverage. Tan and $Prof$ are tangibility and profitability. $NumBond$ is the number of bonds outstanding and Mat is the average of firms' bond maturities. The sample period is from 1991 to 2009 and there are total of 16,697 firm-year observations.

	$GRAN1$	$GRAN2$	$Size$	Age	Q	Lev	Tan	$Prof$	$NumBond$	Mat
$GRAN1$	1									
$GRAN2$	0.77	1								
$Size$	0.54	0.57	1							
Age	0.34	0.31	0.37	1						
Q	-0.03	-0.05	0.05	0.02	1					
Lev	-0.15	-0.11	-0.33	-0.29	-0.55	1				
Tan	0.11	0.15	0.00	-0.08	-0.16	0.16	1			
$Prof$	0.14	0.10	0.21	0.21	0.28	-0.30	0.14	1		
$NBond$	0.39	0.62	0.38	0.21	-0.03	-0.06	0.13	0.05	1	
Mat	0.23	0.30	0.25	0.13	0.04	-0.19	0.08	0.12	0.13	1

Table 5. Cross-Sectional Analysis

This table provides results for the following panel regression estimations: $GRAN_{i,t+1} = \alpha_i + y_t + \beta X_{i,t} + \epsilon_{i,t}$ where $X_{i,t}$ is a matrix of explanatory variables, α_i is a firm or industry level fixed effect, and y_t is a year fixed effect. Panel A and Panel B report results based on $GRAN1$ and $GRAN2$, respectively. In columns named All Firms, the entire sample of firms is considered in the regressions. In the last two columns, only firms with at least two bonds outstanding are included in the regressions. $GRAN1$ and $GRAN2$ are the negative and the inverse of the Herfindahl index of bond amounts, respectively. $Size$ is the total assets in million dollars. Age is the number of years in the Compustat file prior to observations. Q is the market-to-book ratio and Lev is the market value of leverage. Tan and $Prof$ are tangibility and profitability. $NumBond$ is the number of bonds outstanding and Mat is the average of firms' bond maturities. Numbers in parentheses are t-statistics for which standard errors are clustered at the Fama-French 48 industry level.

Panel A: $GRAN1$

	All Firms						Number of Bonds ≥ 2	
Q	0.057	0.06	0.061	0.057	0.06	0.057	0.039	0.036
	(5.33)	(5.92)	(6.01)	(6.20)	(7.33)	(9.45)	(2.83)	(3.29)
$Size$	0.127	0.113	0.132	0.113	0.113	0.104	0.094	0.086
	(27.67)	(18.93)	(26.31)	(18.34)	(12.38)	(11.55)	(10.30)	(10.45)
Age	0.005	0.004	0.005	0.004	-0.008	-0.012	0.049	0.052
	(9.93)	(8.42)	(10.42)	(8.47)	(-0.29)	(-0.42)	(1.42)	(1.52)
Lev	0.29	0.291	0.292	0.28	0.353	0.331	0.203	0.183
	(8.55)	(9.26)	(9.62)	(8.87)	(13.02)	(15.56)	(5.38)	(5.10)
Tan	0.127	0.077	0.102	0.077	0.001	0.024	0.052	0.066
	(5.26)	(2.84)	(4.20)	(2.51)	(0.03)	(0.57)	(1.48)	(1.89)
$Prof$	-0.15	-0.137	-0.197	-0.149	-0.09	-0.06	-0.086	-0.057
	(-4.34)	(-3.46)	(-5.85)	(-4.46)	(-3.27)	(-3.69)	(-0.89)	(-0.88)
$NumBond$		0.006		0.006		0.005		0.003
		(3.28)		(3.44)		(3.08)		(3.10)
Mat		0.004		0.004		0.003		0.003
		(3.82)		(3.81)		(2.42)		(3.11)
Obs.	16593	16593	16593	16593	16593	16593	9288	9288
R^2	0.456	0.5	0.469	0.504	0.735	0.745	0.701	0.709
Year FE	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	No	No	Yes	Yes	No	No	No	No
Firm FE	No	No	No	No	Yes	Yes	Yes	Yes

Panel B: $GRAN2$								
	All Firms						Number of Bonds ≥ 2	
Q	0.22	0.175	0.219	0.147	0.19	0.155	0.29	0.232
	(2.44)	(2.80)	(3.00)	(2.96)	(2.32)	(2.74)	(2.28)	(2.55)
$Size$	0.805	0.556	0.835	0.551	0.646	0.542	0.974	0.838
	(13.80)	(8.54)	(14.04)	(8.39)	(7.87)	(6.19)	(10.08)	(7.01)
Age	0.028	0.019	0.028	0.019	0.186	0.145	0.393	0.449
	(11.64)	(9.56)	(13.81)	(10.32)	(1.43)	(1.15)	(1.13)	(1.35)
Lev	1.37	1.138	1.267	1.039	1.3	1.022	1.632	1.262
	(3.39)	(5.06)	(4.11)	(5.70)	(4.20)	(4.12)	(3.43)	(3.34)
Tan	1.104	0.497	0.896	0.511	-0.061	0.213	0.433	0.711
	(4.43)	(3.93)	(3.57)	(3.37)	(-0.27)	(0.91)	(1.46)	(2.16)
$Prof$	-1.567	-1.078	-1.876	-1.141	-0.09	-0.06	-0.086	-0.057
	(-6.11)	(-6.14)	(-7.65)	(-6.02)	(-2.26)	(-2.23)	(-0.82)	(-0.69)
$NumBond$		0.087		0.086		0.063		0.054
		(4.90)		(4.80)		(3.34)		(3.20)
Mat		0.043		0.042		0.029		0.042
		(5.98)		(5.92)		(6.85)		(4.50)
Obs.	16593	16593	16593	16593	16593	16593	9288	9288
R^2	0.409	0.606	0.429	0.608	0.772	0.803	0.738	0.768
Year FE	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	No	No	Yes	Yes	No	No	No	No
Firm FE	No	No	No	No	Yes	Yes	Yes	Yes

Table 6. Speed-Of-Adjustment Analysis

This table provides results for the following panel regression estimations: $GRAN_{i,t+1} = \alpha_i + y_t + \gamma GRAN_{i,t} + \beta X_{i,t} + \epsilon_{i,t}$ where $X_{i,t}$ is a matrix of explanatory variables, α_i is a firm or industry level fixed effect, and y_t is a year fixed effect. Panel A and Panel B report results based on $GRAN1$ and $GRAN2$, respectively. In columns named All Firms, the entire sample of firms is considered in the regressions. In the last two columns, only firms with at least two bonds outstanding are included in the regressions. $GRAN1$ and $GRAN2$ are the negative and the inverse of the Herfindahl index of bond amounts, respectively. $Size$ is the total assets in million dollars. Age is the number of years in the Compustat file prior to observations. Q is the market-to-book ratio and Lev is the market value of leverage. Tan and $Prof$ are tangibility and profitability. $NumBond$ is the number of bonds outstanding and Mat is the average of firms' bond maturities. Numbers in parentheses are t-statistics for which standard errors are clustered at the Fama-French 48 industry level.

Panel A: $GRAN1$								
	All Firms						Number of Bonds ≥ 2	
$GRAN1_{t-1}$	0.799	0.782	0.795	0.78	0.55	0.535	0.345	0.336
	(84.94)	(64.92)	(75.30)	(66.71)	(21.34)	(20.06)	(22.97)	(20.30)
Q	0.028	0.028	0.027	0.027	0.05	0.048	0.033	0.031
	(11.80)	(10.56)	(10.99)	(10.63)	(6.31)	(7.21)	(1.99)	(2.06)
$Size$	0.031	0.03	0.033	0.03	0.063	0.059	0.064	0.059
	(29.30)	(16.82)	(20.52)	(16.75)	(10.66)	(10.17)	(9.54)	(9.04)
Age	0.000	0.000	0.000	0.000	0.043	0.046	0.110	0.117
	(2.76)	(2.22)	(2.92)	(2.24)	(0.48)	(0.51)	(3.99)	(3.30)
Lev	0.102	0.111	0.107	0.112	0.251	0.241	0.153	0.141
	(8.69)	(10.51)	(10.92)	(10.28)	(8.79)	(9.90)	(3.41)	(3.34)
Tan	0.028	0.016	0.013	0.01	-0.04	-0.029	-0.013	-0.006
	(3.07)	(1.54)	(1.78)	(1.09)	(-1.25)	(-0.84)	(-0.50)	(-0.20)
$Prof$	-0.041	-0.043	-0.049	-0.044	-0.06	-0.056	-0.025	-0.026
	(-3.05)	(-2.46)	(-2.91)	(-2.62)	(-2.40)	(-2.63)	(-0.75)	(-0.78)
$NumBond$		0.001		0.001		0.003		0.002
		(2.52)		(2.70)		(2.62)		(2.51)
Mat		0.002		0.004		0.003		0.003
		(5.76)		(3.81)		(3.22)		(4.45)
Obs.	14183	14183	14183	14183	14183	14183	8564	8564
R^2	0.808	0.811	0.809	0.811	0.829	0.832	0.764	0.769
Year FE	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	No	No	Yes	Yes	No	No	No	No
Firm FE	No	No	No	No	Yes	Yes	Yes	Yes

Panel B: $GRAN2$								
	All Firms						Number of Bonds ≥ 2	
$GRAN1_{t-1}$	0.855	0.798	0.849	0.797	0.663	0.619	0.627	0.59
	(36.37)	(23.53)	(34.90)	(23.50)	(23.17)	(14.89)	(21.34)	(13.90)
Q	0.104	0.102	0.103	0.099	0.162	0.145	0.216	0.186
	(7.54)	(5.45)	(6.57)	(5.72)	(3.35)	(3.36)	(2.36)	(2.32)
$Size$	0.147	0.145	0.158	0.145	0.349	0.315	0.524	0.482
	(10.61)	(8.90)	(9.70)	(8.65)	(8.34)	(7.45)	(9.52)	(7.90)
Age	0.002	0.002	0.002	0.002	0.254	0.302	1.098	1.234
	(2.62)	(2.09)	(2.54)	(1.93)	(0.89)	(1.01)	(3.47)	(3.10)
Lev	0.365	0.413	0.373	0.412	0.808	0.709	0.949	0.805
	(5.48)	(10.24)	(9.36)	(11.91)	(3.99)	(4.05)	(2.53)	(2.45)
Tan	0.138	0.066	0.038	0.026	-0.08	0.048	-0.023	0.112
	(3.68)	(1.41)	(1.31)	(0.65)	(-0.47)	(0.26)	(-0.12)	(0.53)
$Prof$	-0.247	-0.273	-0.306	-0.286	-0.22	-0.211	-0.126	-0.118
	(-3.16)	(-2.89)	(-3.27)	(-3.21)	(-1.51)	(-1.48)	(-0.45)	(-0.42)
$NumBond$		0.014		0.014		0.027		0.024
		(3.40)		(3.36)		(2.58)		(2.43)
Mat		0.016		0.004		0.02		0.029
		(8.87)		(3.81)		(8.20)		(5.98)
$Obs.$	14183	14183	14183	14183	14183	14183	8564	8564
R^2	0.876	0.882	0.877	0.882	0.885	0.891	0.861	0.867
Year FE	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	No	No	Yes	Yes	No	No	No	No
Firm FE	No	No	No	No	Yes	Yes	Yes	Yes

Table 7. Time-Series Analysis

Linear probability models are estimated for each maturity bucket: $Prob(I_i^{K_j}) = a_1 m_i^{K_1} + a_2 m_i^{K_2} + a_3 m_i^{K_3} + a_4 m_i^{K_4} + a_5 m_i^{K_5} + a_6 m_i^{K_6} + a_7 m_i^{K_7} + \alpha_n + y_t$ where K_j is five two-year maturity buckets defined as $2j-1$ to $2j$ years for maturities shorter than 10 years ($j \leq 5$), and two maturity buckets (11 to 20 years and 11 years or longer) for maturities longer than 10 ($j = 6$ or $j = 7$). The variable $m_i^{K_j}$ is obtained by subtracting a benchmark from each firm's maturity profile where the maturity profile is defined as fractions of pre-existing bond amounts in each maturity bucket K_j. After firms are sorted into 128 (=2^7) groups based on seven variables (Q, market leverage, age, size, tangibility, profitability, and average maturity) for each Fama-French industry category, the benchmark is obtained by averaging maturity profiles in each group. Issuance dummy $I_i^{K_j}$ is one if the bond i's maturity falls in K_j, and is zero if the bond has a different maturity than K_j. α_n is a firm fixed effect for the issuing firm n and y_t is a year fixed effect. Panel A1 is a sample with bond issues greater than 3% of firms' pre-existing bonds, and Panel A2 is bond issues greater than 5%. Panel B1 and B2 exclude all bonds with option features (callability, convertibility, putability and sinking fund provisions) from the sample. The hypothesis test ($H_0 : a_i - \frac{1}{6}\sum_{n \neq i} a_n = 0$) is also reported. Numbers in parenthesis are t-statistics for which standard errors are clustered at the Fama-French 48 industry level.

	Panel A1: Issue Cutoff at 3%, All Bonds						
	K_1: 1-2 Yr	K_2: 3-4 Yr	K_3: 5-6 Yr	K_4: 7-8 Yr	K_5: 9-10 Yr	K_6: 11-20 Yr	K_7 21- Yr
m^{K_1}	**-0.09**	-0.221	-0.452	-0.193	0.191	0.126	0.241
	(-1.87)	(-4.14)	(-6.66)	(-2.98)	(2.52)	(2.02)	(4.40)
m^{K_2}	0.037	**-0.194**	-0.403	-0.158	-0.039	0.178	0.106
	(1.02)	**(-5.01)**	(-6.71)	(-1.98)	(-0.52)	(2.78)	(2.17)
m^{K_3}	0.007	0.022	**-0.423**	-0.178	-0.109	0.099	0.12
	(0.38)	(0.82)	**(-6.16)**	(-2.00)	(-1.31)	(1.84)	(3.35)
m^{K_4}	0.018	0.031	-0.096	**-0.111**	-0.317	0.038	0.016
	(0.66)	(1.05)	(-2.08)	**(-2.16)**	(-4.61)	(0.58)	(0.50)
m^{K_5}	0.013	0.013	-0.001	0.067	**-0.772**	0.249	-0.05
	(0.47)	(0.52)	(-0.01)	(1.48)	**(-8.38)**	(6.80)	(-0.97)
m^{K_6}	0.057	0.062	-0.006	0.047	-0.039	**-0.364**	-0.285
	(1.98)	(1.44)	(-0.11)	(0.88)	(-0.46)	**(-4.38)**	(-3.69)
m^{K_7}	0.107	0.08	0.175	0.15	-0.125	-0.197	**-0.974**
	(3.32)	(2.30)	(2.13)	(1.79)	(-1.19)	(-2.03)	**(-9.91)**
Obs.	6053	6053	6053	6053	6053	6053	6053
H_0	-0.12	-0.19	-0.31	-0.07	-0.71	-0.43	-0.99
	(-2.46)	(-5.04)	(-4.62)	(-1.60)	(-8.00)	(-5.35)	(-10.60)

	Panel A2: Issue Cutoff at 5%, All Bonds						
	K_1: 1-2 Yr	K_2: 3-4 Yr	K_3: 5-6 Yr	K_4: 7-8 Yr	K_5: 9-10 Yr	K_6: 11-20 Yr	K_7 21- Yr
m^{K_1}	**-0.113**	-0.238	-0.467	-0.17	0.261	0.129	0.245
	(-2.36)	(-4.06)	(-6.00)	(-2.41)	(3.34)	(2.44)	(4.45)
m^{K_2}	0.032	**-0.191**	-0.409	-0.163	-0.048	0.184	0.095
	(0.97)	**(-4.92)**	(-6.71)	(-2.00)	(-0.61)	(2.83)	(2.00)
m^{K_3}	0.023	0.008	**-0.415**	-0.177	-0.107	0.084	0.129
	(1.11)	(0.28)	**(-5.97)**	(-2.02)	(-1.27)	(1.54)	(3.79)
m^{K_4}	0.016	0.01	-0.117	**-0.124**	-0.329	0.037	0.041
	(0.60)	(0.35)	(-2.39)	**(-2.41)**	(-5.04)	(0.58)	(1.25)
m^{K_5}	0.019	0.012	0.011	0.067	**-0.763**	0.238	-0.031
	(0.75)	(0.39)	(0.24)	(1.41)	**(-8.19)**	(6.36)	(-0.58)
m^{K_6}	0.051	0.061	0.032	0.064	-0.024	**-0.414**	-0.278
	(2.07)	(1.54)	(0.54)	(1.21)	(-0.30)	**(-4.91)**	(-3.57)
m^{K_7}	0.11	0.079	0.211	0.168	-0.142	-0.192	**-1.009**
	(3.13)	(2.11)	(2.50)	(2.32)	(-1.35)	(-1.85)	**(-10.86)**
Obs.	5732	5732	5732	5732	5732	5732	5732
H_0	-0.148	-0.152	-0.31	-0.094	-0.708	-0.482	-1.04
	(-2.97)	(-4.77)	(-4.62)	(-2.04)	(-8.07)	(-5.82)	(-11.71)

Panel B1: Issue Cutoff at 3%, Straight Bonds Only							
	K_1: 1-2 Yr	K_2: 3-4 Yr	K_3: 5-6 Yr	K_4: 7-8 Yr	K_5: 9-10 Yr	K_6: 11-20 Yr	K_7 21- Yr
m^{K_1}	**-0.063**	-0.095	-0.177	-0.121	-0.388	-0.034	0.145
	(-0.57)	(-1.07)	(-1.25)	(-1.51)	(-3.65)	(-0.45)	(1.58)
m^{K_2}	0.229	**-0.286**	-0.418	-0.03	-0.237	0.009	0.02
	(2.52)	**(-2.64)**	(-5.04)	(-0.32)	(-1.81)	(0.11)	(0.30)
m^{K_3}	0.016	0.096	**-0.505**	-0.038	-0.231	-0.067	0.173
	(0.24)	(1.37)	**(-3.79)**	(-0.34)	(-1.35)	(-0.69)	(1.75)
m^{K_4}	0.075	0.066	-0.002	**-0.062**	-0.389	-0.136	0.012
	(0.94)	(1.06)	(-0.02)	**(-0.78)**	(-2.78)	(-1.17)	(0.15)
m^{K_5}	0.066	0.016	-0.091	0.179	**-1.006**	0.28	-0.024
	(0.95)	(0.30)	(-1.22)	(2.75)	**(-10.45)**	(3.07)	(-0.34)
m^{K_6}	0.034	0.066	-0.219	0.006	-0.33	**-0.144**	-0.106
	(0.40)	(0.75)	(-2.23)	(0.06)	(-2.17)	**(-1.06)**	(-1.05)
m^{K_7}	0.203	0.038	-0.061	0.049	-0.259	0.037	**-0.764**
	(2.80)	(0.50)	(-0.50)	(0.65)	(-2.34)	(0.34)	**(-8.66)**
Obs.	1856	1856	1856	1856	1856	1856	1856
H_0	-0.15	-0.31	-0.37	-0.07	-0.74	-0.16	-0.8
	(-1.32)	(-2.75)	(-3.40)	(-0.85)	(-7.50)	(-1.28)	(-8.23)

Panel B2: Issue Cutoff at 5%, Straight Bonds Only							
	K_1: 1-2 Yr	K_2: 3-4 Yr	K_3: 5-6 Yr	K_4: 7-8 Yr	K_5: 9-10 Yr	K_6: 11-20 Yr	K_7 21- Yr
m^{K_1}	**-0.086**	-0.105	-0.119	-0.068	-0.358	-0.075	0.18
	(-0.75)	(-0.90)	(-0.82)	(-0.69)	(-2.79)	(-0.89)	(1.74)
m^{K_2}	0.265	**-0.281**	-0.403	-0.024	-0.235	0.022	0.019
	(3.03)	**(-2.52)**	(-4.53)	(-0.23)	(-1.71)	(0.26)	(0.27)
m^{K_3}	0.09	0.098	**-0.51**	0.006	-0.26	-0.117	0.213
	(1.23)	(1.16)	**(-3.69)**	(0.05)	(-1.40)	(-1.16)	(2.03)
m^{K_4}	0.096	0.034	-0.041	**-0.101**	-0.41	-0.125	0.028
	(1.22)	(0.47)	(-0.44)	**(-1.29)**	(-2.84)	(-1.04)	(0.42)
m^{K_5}	0.078	0.039	-0.036	0.199	**-0.979**	0.228	-0.005
	(0.99)	(0.58)	(-0.37)	(2.57)	**(-9.70)**	(2.34)	(-0.07)
m^{K_6}	0.068	0.07	-0.19	0.03	-0.379	**-0.221**	-0.137
	(0.82)	(0.81)	(-1.75)	(0.34)	(-2.21)	**(-1.47)**	(-1.22)
m^{K_7}	0.234	0.014	-0.047	0.097	-0.28	0.067	**-0.819**
	(2.63)	(0.19)	(-0.35)	(1.32)	(-2.31)	(0.55)	**(-10.20)**
Obs.	1648	1648	1648	1648	1648	1648	1648
H_0	-0.2	-0.3	-0.39	-0.14	-0.7	-0.22	-0.86
	(-1.76)	(-2.58)	(-3.44)	(-1.90)	(-6.72)	(-1.59)	(-9.16)