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Corporate Innovation and Maturity Structure of Debt*

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Based on the theories related to the under-investment problems and information asymmetry, we hypothesize that the more active a firm is in innovation, the greater its use of short-term debt. To test this hypothesis, we use patents as a proxy for the outcome of successful innovative investments and examine the relationship between patents and the maturity structure of debt.

We find that, as predicted, more innovative firms rely more on short-term debt than less innovative firms do. Our results suggest that providing easier access to short-term debt markets is more important than improving access to long-term debt markets in terms of promoting innovation.

Key words: Patents, Innovation, Debt Maturity
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I. Introduction

Innovation encompasses activities that bring about benefits to the firms that develop them and to competing firms and consumers. According to McKinsey (2018), the average longevity of S&P 500 firms in the United States was 90 years in 1935, but it decreased to 14 years in the 2010s. Innovation activities are essential for firms to survive in the midst of a rapidly changing business environment. However, firms' uncertainty about the success of innovation efforts is a significant stumbling block. Given the amount of capital that is typically required in undertaking such projects, corporate managers can be reluctant to pursue innovation. As Bhattacharya and Ritter (1983) note, firms that invest in innovative projects tend to disclose minimal information about their projects for fear of a leak of sensitive information. Such a leak would increase the information asymmetry between insiders and outside investors, who would then tend to undervalue the firm. Accordingly, the firm often finds it difficult to raise enough funds to carry out innovation projects.

Early literature on finance and innovation documents the importance of public equity markets to financing innovation (Brown et al. 2009; Hall and Lerner 2010). Acharya and Xu (2013) find that publicly traded firms innovate more through high-quality patents than private firms do, especially in industries that tend to depend on external financing. This body of research points against using banks and debt issuance in financing innovation. However, more recently, evidence that banks play a pivotal role in financing innovative firms across a broad range of industries is growing (Cornaggia et al. 2015; Hochberg et al. 2018; Mann 2018; Mitkov 2020; Robb and Robinson 2014; Yi 2018). Kerr and Nanda's (2015) review emphasizes the importance of bank financing of innovation and states that how banks lend and monitor the financing of innovation is an important and underexplored area of research.

Given the importance of debt financing for innovative firms and the typical difficulties in acquiring equity financing, this study focuses on the effect of firms' innovation activities on their choice of debt maturities. While extensive literature has studied the firm-level determinants of debt maturity and the effect of debt maturity on firms' value, few studies address the empirical determinants of debt maturity for innovative firms in particular.

We seek to fill this gap in the literature. Using Korean firms that are required to be audited by an external auditor, we empirically investigate the relationship between debt maturity and innovation. To our knowledge, this paper is the first to use innovation metrics based on patent data in Korea to explain the maturity structure of debt. Our results have implications for governmental regulatory bodies, financial institutions, and innovative firms. Supporting innovative firms that are financially constrained in achieving their optimal growth are important tasks for both government and financial institutions.

Our study's theoretical underpinning is agency costs, as analyzed by Jensen and Meckling (1976). If a firm has significant growth opportunities, a moral hazard problem can arise because the managers have capital at their disposal and can behave in ways that are not in the best interest of those who supply the capital. Therefore, the bondholders who supply debt financing for a firm that invests in projects that have such growth potential can demand a higher cost of capital. As Myers (1977) points out, in such a case, the firm may reject an innovative project with a high expected rate of return because most of its profits will benefit debtholders. A remedy is needed: For example, the bondholders and the managers (who act in the best interest of shareholders) can enter into a capital supply contract by which both parties can share the benefit of a risky project with large growth opportunities, and using short-term debt can serve such a goal. Barnea et al. (1980) predict that firms that have significant growth opportunities will increase the relative weight of short-term debt because it offers financial flexibility and promotes future investment opportunities. Barclay and Smith (1995, p. 619) state that "a firm with more growth options in its investment opportunity set is likely to have less debt in its capital structure, and the debt it issues is likely to have shorter average maturity." Aivazian et al. (2005) find that shorter debt maturity is associated with more investment for firms with significant growth opportunities.

Based on these arguments, this study focuses on the underinvestment problem in the context of agency conflicts between managers and debtholders. We predict that the more active a firm is in innovation, the more likely its use of short-term debt. To test this conjecture, we use patents as a proxy for a firm's growth potential because patents represent the outcome of successful innovation investments. Specifically, we investigate the relationship between patents and the maturity structure of debt. Our sample covers all listed corporations and unlisted private firms whose financial statements were audited by external auditors in Korea from 1999 to 2014. Our sample is suited to studying the determinants of debt maturity because it contains a large set of private Korean firms that rely heavily on bank financing (Kim et al. 2011). We use patent applications (i.e., filings), patent registrations (i.e., grants), and patent citation counts.[4)]

Two-stage regressions, where leverage is determined simultaneously with debt maturity, reveal that more innovative firms rely more on shorter-term

4) Following the terminology used by the Korean Intellectual Property Office, we use "patent applications" to refer to patent filings and "patent registrations" to refer to patents granted.

debt. Our results are in line with the predictions of theories that focus on the underinvestment problem and information asymmetry. From the perspective of the government and financial institutions that want to promote corporate innovation, our results suggest that providing easier access to short-term debt markets is more important than improving access to long-term debt markets.

The rest of our paper is organized as follows. Section 2 briefly reviews the existing literature on the maturity structure of debt and sets up our hypotheses. Section 3 describes our data and reports on the empirical relationship between the number of patents held and the maturity structure of debt. Section 4 concludes the paper.

II. Hypothesis

Myers (1977) argues that short-term debt can mitigate the underinvestment problem caused by agency conflicts between debt holders and shareholders. Firms that have risky outstanding debt can reject new, potentially profitable projects and underinvest if substantial portions of the projects' payoffs would accrue to debtholders. Shortening the debt maturity reduces this underinvestment problem because it allows debt to be refinanced before the investment option expires. Myers predicts that, because firms with more growth opportunities face more underinvestment problems, they have incentives to use shorter-term debt. Consistent with this prediction, Barclay and Smith (1995), Guedes and Opler (1996), and Barclay, Marx, and Smith (2003) document a negative relationship between debt maturity and growth opportunities.

Titman and Wessels (1988) find that firms that have significant growth opportunities tend to employ debt with maturities that are shorter than the duration of the investments. Repayment of debt before the investment project is completed can resolve the underinvestment problem. Flannery (1986) also claims that firms that have more growth opportunities prefer short-term debt to long-term debt, while firms that have fewer growth opportunities are characterized by a low degree of information asymmetry and are less sensitive to the choice between short-term and long-term debt. Flannery (1986) predicts that firms that do not have growth opportunities will resort to long-term debt. In summary, then, the literature predicts that innovative firms that have ample growth opportunities will favor shorter-term debt in an effort to attenuate the underinvestment problem. Therefore, we hypothesize that innovative firms prefer short-term debt over long-term debt.

The literature uses two proxies to capture innovation activities: R&D expenditures and patents (Fang et al. 2014; Lerner et al. 2011; Park 2021; Yim 2021; Seru 2014). The consensus is that patenting activity is a better proxy than R&D expenditures because patents reflect how effectively a firm has used its innovation input, while R&D expenditures measure only input activities and not the quality of innovation. Therefore, we use a firm's patenting activity to measure its innovation activities.

Firms that have significant growth opportunities prefer short-term debt to long-term debt, a preference that is likely to be revealed if these firms anticipate comparatively certain outcomes of their innovations. Therefore, instead of total patents applied for (i.e., patents filed), we consider the number of patents registered (i.e., patents granted) and the number of citations per patent granted as better proxies for a firm's innovation activities.

Ⅲ. Variables for Empirical Tests

1. Dependent variable: Maturity Structure of Debt

To measure debt maturity accurately, we need to collect data on the maturity of each type of debt a firm issues and calculate a weighted average maturity of its debt. However, disclosure of information on a firm's debt in terms of its maturity is not mandatory in Korea, so it is not available. Instead, we use the proxy variables that allow us to secure the maximum number of firm-year observations: the ratio of non-current liabilities to total liabilities (DEBT1) and the ratio of long-term borrowing to total borrowing (DEBT2). Long-term borrowing is defined as total liabilities minus the items that are not related to borrowing, such as accounts payable and allowances. Our intention is to exclude items that are unrelated to borrowed funds that are raised by debt financing. Although DEBT2 is conceptually a better measure of debt maturity, using it as the dependent variable costs us a significant number of observations because of many missing observations, especially of unlisted firms.

2. Treatment variables: Innovation Activities Variables

Measures that represent innovation activities include R&D investment, the number of patent applications, and the number of patent registrations. Although the ratio of R&D investment (expenses) to total assets is the most widely used gauge of a firm's innovation activities, it does not represent successful innovation, as high R&D expenditures do not guarantee successful innovation and do a poor job in measuring innovations' quality. If managers spend too much on R&D without enhancing their innovations' quality, such expenses can hinder innovation. Aghion et al. (2013) propose that patent-related variables is a better choice for measuring corporate innovation.

Patent registration involves a difficult process. In addition, there is a low probability of transforming a new invention into a successful product. A monopolistic market for an innovative product can limit profits when others mimic or steal its features (Teece 1986). Unlike R&D-related measures, patent-related measures provide information about the successful outcome of innovation, so their use is more appropriate in analyses of innovation activities. However, since patents differ in terms of economic value, we must also consider the quality of an innovation by examining citation counts and the country of registration, rather than relying only on the number of patents registered. For example, Trajtenberg (1990) weights citation counts to determine patent quality, and Putnam (1996) considers the country in which a patent application is filed. We employ both quantity- and quality-related measures of patents: Our measures for the quantity of patents are the number of domestic patent applications and the number of domestic patent registrations, and our measures for the quality of patents are the number of patent applications made in five or more G10 countries outside Korea, the number of patents registered in five or more G10 countries outside Korea, and the citation count. Specifically, we construct five variables that measure a firm's innovative output.[5] The first, APATD, is the cumulative number of patent applications made domestically by each firm from 1999 to the end of a given year. The second, RPATD, is the cumulative number of registered patents made domestically from 1999 to the end of each firm-year. The third, APATD, counts the cumulative number of patent applications made in five or more G10 countries outside Korea from 1999 to the end of each firm-year.

5) Definitions of these variables are provided in the Appendix.

The fourth, RPATF, is the cumulative number of registered patents made in five or more G10 countries from 1999 to the end of each firm-year. The last, CITED, counts the cumulative number of citations by other patents (i.e., non-self-citations received by each patent) from 1999 to the end of each firm-year. To avoid losing firm-year observations with zero values, we add 1 to the actual values of these variables when calculating the natural logarithm. Thus, all measures are calculated as *ln (1 + measure)*.

3. Control Variables

We use several control variables that have been suggested in the debt maturity literature.

1) Firm Size

Large firms tend to have stable cash flows and more assets that can be used as collateral than small firms do, which allows them to carry more debt with longer maturities. Barclay and Smith (1995) and Stohs and Mauer (1996) document that debt maturity increases with firm size. Barclay and Smith (1995) reason that large firms enjoy scale economies in issuing public debt because of a large fixed component of issuance costs. Small firms tend to choose private debt because of its lower fixed costs and lower issuance costs. Therefore, small firms typically choose short-term bank debt over public debt. In addition, Barclay, Marx, and Smith (2003) find a nonlinear relationship between debt maturity and firm size. They observe that very large firms dominate short-term commercial paper issuances because of the large fixed costs of commercial paper programs. Accordingly, very large firms are likely to have shorter maturities of debt than those of medium-sized firms. Diamond

(1991) predicts such a nonlinear relationship between debt maturity and firm size. Therefore, we use both firm size and firm size squared as our control variables. We use the natural log of total assets, LN(TA), as a proxy for firm size. The expected sign of the coefficient for firm size is positive, but the expected sign of the coefficient for firm size squared is negative.

2) Leverage

Diamond (1991) theorizes that the higher the leverage, the larger the liquidity risk and predicts that firms that have high debt tend to favor long-term debt. Similarly, Morris (1992) argues that firms that are highly leveraged tend to issue long-term debt to delay their exposure to bankruptcy risk. Leland and Toft (1996) predict that optimal leverage depends on debt maturity, and when a firm relies on short-term debt, its leverage will be markedly low. In contrast, Dennis et al. (2000) argue that leverage and maturity should be inversely related to limit the agency costs of underinvestment, but the relationship between leverage and debt maturity is uncertain. This study defines “LEVERAGE” as the ratio of total liabilities to total assets.

In practice, decisions about leverage and debt maturity are made simultaneously, so both variables are determined endogenously. We address this endogeneity issue when we investigate the determinants of corporate debt maturity. We employ a two-step instrumental variable regression approach: We use return on assets, tangible asset ratio, and firm age as instruments to estimate leverage in the first stage regression, and the estimated leverage enters as a control variable in our second-stage debt maturity regressions.

3) Credit Quality

According to signaling theory (Flannery 1986), in a separating equilibrium, only high-quality firms can issue short-term debt to signal their quality because they can afford the transaction costs of rolling over short-term debt. Kale and Noe (1990) and Titman (1992) extend Flannery's equilibrium theory in predicting the same inverse relationship between a firm's credit quality and debt maturity, even without imposing transaction costs in raising short-term debt. However, Diamond (1991) suggests a non-monotonic relationship between debt maturity and the firm's credit rating by predicting that firms with very high and very low credit ratings choose short-term debt, whereas firms with medium ratings opt for long-term debt. We use Altman Z-score as a proxy for the quality of a firm's credit such that the higher the Z-score, the higher the quality of a firm's credit.

4) Asset Maturity

Myers (1977) states that firms can reduce default risk by matching asset maturity with debt maturity and predicts a positive relationship between asset maturity and debt maturity. Later studies offer supporting empirical evidence (Barclay et al. 2003; Guedes and Pler 1996; Ozkan 2000; Stohs and Mauer 1996). In a survey of 392 U.S. firms, Graham and Harvey (2001) find that matching debt maturity with asset maturity plays an important role in determining whether to issue short- or long-term debt. Therefore, we expect a positive relationship between debt maturity and asset maturity. Studies typically use the ratio between fixed assets and depreciation expenses as a proxy for asset maturity. However, given the lack of depreciation data for most of the unlisted firms in our sample, we define the "fixed asset ratio"

(FIXED ASSET) as fixed assets divided by the book value of total assets and use it as our proxy for asset maturity to compare with our measure of debt maturity.

5) Governance: Managerial Ownership

Datta et al. (2005) and Guney and Ozkan (2005) argue that managerial ownership has a negative effect on debt maturity based on agency conflicts between managers and shareholders. If managers' level of ownership of the firm is low, they will prefer long-term debt to avoid frequent monitoring from outsiders. The higher the level of managerial ownership, the more likely managers are to embrace short-term debt, as their incentives will be aligned with those of the shareholders. Because of data availability, we use the level of ownership of the largest shareholder (LARGE OWNERSHIP) as our measure of managerial ownership, as we assume that the largest shareholder's ownership includes manager's ownership in most of the private firms in our sample. For listed corporations, the largest shareholder's ownership reflects the intensity of monitoring, so it can be a reasonable proxy for the quality of corporate governance.

6) Debt Tax Shield: Marginal Tax Rate

Kane et al. (1985) show theoretically that optimal debt maturity is determined by a tradeoff between the debt tax shield and costs that are associated with debt issuance and bankruptcy. They find a negative relationship between the debt tax shield (i.e., the effective tax rate) and debt maturity but also that the cost of debt issuance is positively related to debt maturity. Hence, tax rates and debt maturity should be inversely related to ensure that the tax benefits of debt are not less than the amortized flotation costs. Because it is difficult to estimate the effective marginal tax rate the firms in our sample face, we use taxes divided by total assets as our proxy for the debt tax shields (TAX).[6]

4. Data

1) Sample Selection

We obtain general information on patents from the Korean Intellectual Property Office's website KIPRIS. The main data items we collect from KIPRIS are the date of patent application, the date of first disclosure to the public, the applicant's and inventor's names, and the date of patent registration. We supplement this data with various disclosures released by the Korea Exchange (KRX) and annual reports of firms. These data provide only general information about patent applications and registrations, often with missing observations. To get data on the quality of patents, we use the WISDOMAIN database, which contains information on citation counts per patent, number of applications for patents made outside Korea, patent ratings, and name of agency institutions.

We obtain corporate financial information from the TS2000 database (KOCOinfo) compiled by the Korea Listed Companies Association, which covers business reports of listed corporations and unlisted private firms that Korean law required be audited by external auditors. We also use the KIS-Value database compiled by NICE Credit Rating Co.

We select sample firms based on four criteria: (1) firms listed on the Korea Exchange (either on the main board KOSPI or the smaller board KOSDAQ) or unlisted private firms that Korean law requires be audited by an external

6) This measure is used by Guedes and Opler (1996) and Kim and Kwon (2005).

auditor during the sample period (1999~2014); (2) manufacturing firms; (3) no firms that were either merged into other firms or delisted from the Korean Exchange; and (4) firms whose fiscal year-end is December 31. Our final sample contains 10,215 firms and 87,912 firm-year observations.

2) Descriptive statistics and correlations among variables

To minimize the effect of outliers, we winsorize all variables at the top and bottom 5% of each variable's distribution. Table 1 shows the descriptive statistics for the dependent and independent variables. Our first measure of debt maturity is DEBT1 (the ratio of non-current liabilities to total liabilities). DEBT1 for our sample is low, averaging 32.5 percent, so our sample firms hold much less long-term debt than short-term debt. Our second proxy for debt maturity is DEBT2 (the ratio of long-term borrowing to total borrowing). Although this measure seems to be a better proxy for debt maturity in principle, lack of data availability poses a significant challenge in empirical analyses. The data for short-term and long-term borrowing are not available for smaller firms, biasing the measure toward relatively large firms, as smaller firms make up about 44.5 percent of our sample and leave only 57,626 firm-year observations. Table 1 shows the mean for DEBT2 is 46 percent, which indicates that larger firms in our sample hold an average of 54 percent of their total borrowing as short-term debt. To maintain the maximum size of the sample given these data limitations, we perform empirical analyses using DEBT1 as our main proxy for debt maturity and report the results as our main findings. We also report the results using DEBT2 as a supplementary proxy for debt maturity, but we caution that they are biased toward the relatively larger firms in our sample.

Summary statistics for our main variables that measure patent-related activities are listed in Table 1. As it is difficult to obtain and maintain patents, the mean values of all patent-related variables are low and the median values are all zero. Clearly, the distributions of patent-related variables are right-skewed. For instance, the 75th percentile of the distributions is at zero for the two foreign-patent-related variables and citation counts. The first variable APATD (the cumulative number of patent applications made domestically) shows a mean value of 0.89. Since this value is calculated as *ln(1+measure)*, it can be converted to a mean value of 1.44 (i.e., *measure* = $e^{\ln(1+measure)}-1$) for raw observations of the measure, implying that on average, the firms in our final sample have cumulatively applied for 1.44 domestic patents from 1999 to the end of each firm-year. The second variable RPATD (the cumulative number of patents registered domestically) shows a mean value of 0.67, implying that on average, our sample firms have 0.95 cumulative domestic patents granted at the end of each firm-year. Similarly, converting the mean value of 0.20 for APATF, we find the average number of patents applied for outside Korea (i.e., in more than five G10 countries) is lower, at 0.22. The average number of patents registered outside Korea is only 0.15 after converting the median value of 0.14 for RPATF. The average citation count is 0.77 per firm-year after converting the mean value of 0.57 for CITED. Because the variables that carry patent counts, patents applied for, and patents registered are highly correlated with each other, we run regressions using each patent-related variable separately.

Panel C of Table 1 reports the summary statistics for the control variables. In our sample, the average firm has a leverage of 58 percent and a fixed asset ratio of 48 percent and has an age of 14.34 years since inception (for unlisted firms) or IPO date (for listed firms).

〈Table 1〉 Summary Statistics

This table reports the summary statistics for the debt maturity, innovation measures, and firm-level variables. The sample consists of 87,912 firm-year observations during the period from 1999 to 2014. Details of the measurements of all variables are given in the Appendix.

	Obs.	Mean	SD	25th Percentile	Median	75th Percentile
Panel A: Debt Maturity						
DEBT1	87,912	0.29	0.22	0.11	0.25	0.43
DEBT2	57,626	0.46	0.28	0.22	0.45	0.70
Panel B: Innovation Measures						
APATD	87,912	0.89	1.27	0.00	0.00	1.61
RPATD	87,912	0.67	1.10	0.00	0.00	1.10
APATF	87,912	0.20	0.66	0.00	0.00	0.00
RPATF	87,912	0.14	0.54	0.00	0.00	0.00
CITED	87,912	0.57	1.13	0.00	0.00	0.69
Panel C: Firm-Level Characteristics						
LEVERAGE	87,912	0.58	0.22	0.43	0.61	0.73
LN(TA)	87,912	23.47	1.43	22.6	23.33	24.22
Z SCORE	87,912	3.04	4.07	1.82	2.63	3.74
FIXED ASSET	87,912	0.48	0.19	0.35	0.49	0.62
LARGE OWNERSHIP	87,912	0.18	0.27	0.00	0.00	0.34
TAX	87,912	0.02	0.02	0.00	0.01	0.02
ROA	87,912	0.07	0.09	0.02	0.05	0.09
TANGIBILITY	87,912	0.38	0.20	0.23	0.37	0.53

Ⅳ. Empirical Results

1. Baseline Model

To determine whether corporate innovation affects debt maturity, we first estimate the following fixed-effect OLS (ordinary least squares) regression model:

$$Debt\ Maturity_{it} = \alpha_0 + \alpha_1 Patents_{it} + \theta' X_{it} + \mu_i + \tau_t + \epsilon_{it},$$

where i is the firm and t is the year.

The dependent variable ($Debt\ Maturity_{it}$) is the long-term debt ratio of firm i in year t. Our main independent variable ($Patents_{it}$) captures corporate innovation and is the natural logarithm of 1 plus the number of patents filed or granted to firm i. X_{it} is a vector of the control variables firm size, firm size squared, asset maturity, and tax (a proxy for debt tax shield). We include industry fixed effects using the variable μ_i to control for omitted industry-specific characteristics that are constant over time. The variable τ_t is year fixed effects to account for intertemporal variation that may affect the relationship between debt maturity and innovation. Standard errors are clustered at the industry and year levels.

Table 2 reports pooled OLS regression results for our baseline model using the full sample of 87,912 firm-year observations from 1999 to 2014. We use two measures of debt maturity (i.e., long-term debt ratio) as the dependent variable: DEBT1 (the ratio of non-current liabilities to total liabilities) and DEBT2 (the ratio of long-term borrowing to total borrowing). Because of many missing observations for DEBT2, we have a much smaller sample of 57,626 for the regressions using DEBT2 as the dependent variable. For our estimation, we regress long-term debt ratios on the innovation variable RPATD (the cumulative number of registered patents awarded domestically), leverage, and the control variables. We include year and industry fixed effects. The results from the full sample using DEBT1 and DEBT2 as dependent variables are provided in Table 2. The coefficients on the cumulative number of registered patents awarded domestically (RPATD) are negative and statistically significant in both regressions, suggesting that an increase in innovation activities, as measured by patents, is associated with a decreased use in long-term debt. The coefficients on the control variables are generally consistent with existing empirical studies. The coefficients on firm size, LN(TA), Altman Z-Score, and asset maturity (FIXED ASSET) are positive and significant, while those on large ownership and marginal tax rates (TAX) are negative and significant. These results suggest that larger firms, firms that have a low probability of bankruptcy, and firms that have longer maturity of assets tend to have longer maturity of debt. Firms with a high proportion of shares held by the largest shareholder and firms that are subject to high tax rates are likely to favor short-term debt.

Next, we investigate differences in the maturity structure of debt between public and private firms and between firms listed on the main board and the minor board. Table 2 shows the results for sub-samples grouped according to the exchanges on which shares are listed and traded. KOSPI, the main board in Korea, is where stocks of relatively large firms are listed, and KOSDAQ is the smaller board, where stocks of smaller firms, including those in high-technology industries, are listed. Table 2 also reports the regression results for unlisted private firms. Recent studies document that firms that are listed in different stock markets may show different investment strategies and innovation activities (Ha and Kim 2021; Kim and Nam 2019).

Agency theory, as proposed by Jensen and Meckling (1976), proposes that, on average, private firms suffer from fewer agency problems than larger firms do because they are often owner-managed or have highly concentrated ownership. These features motivate their owners to monitor management closely to maximize their firms' long-term value (Bhide 1993; Jensen 1989). Asker et al.'s (2015) empirical study documents that private U.S. firms are subject to fewer short-term pressures than publicly traded firms are. Their results show that, compared with private firms, public firms invest much less and are less responsive to investment opportunities, suggesting that short-term pressures on public firms can distort investment decisions. We examine systematic differences in innovation behavior among firms in different markets by dividing our full sample into three groups: public firms listed on the main board KOSPI, public firms listed on the minor board KOSDAQ, and unlisted private firms.

Table 2 shows that the coefficient on the cumulative number of registered patents (RPATD) is negative but not significant, indicating that, for firms listed on the main board KOSPI, the relationship between debt maturity and innovation activities is negative but not statistically significant. Similar results are found for firms listed in the minor board KOSDAQ, also reported in Table 2, with a negative but insignificant coefficient on RPATD. Finally, Table 2 shows that the results for unlisted firms are consistent with our main results from the full sample, with a negative and significant coefficient on RPATD. Thus, our subsample results in Table 2 suggest that our full sample result of a significant and negative relationship between debt maturity and innovation are mainly driven by unlisted private firms.

However, using OLS regressions can be problematic because decisions on debt maturity and leverage are typically made simultaneously. In addition, corporate debt maturity affects the relationship between leverage and corporate growth opportunities (Barclay et al. 2003; Johnson 2003; Kim et al. 2004; Kim and Kwon 2005; Park 2012; Shin 2013). We use a two-stage regression model to address these features and to control for omitted variables bias.

〈Table 2〉 Baseline regression results explaining debt maturity using variables for cumulative patents

This table presents the main analysis for the relationship between corporate innovative activities and debt maturity based on pooled OLS regressions. The sample consists of 87,912 firms during the period from January 1, 1999 to December 31, 2014. The dependent variables are measures of debt maturity: DEBT1 (non-current liabilities/total liabilities) and DEBT2 (long-term borrowing/total borrowing). The patent-related variable is RPATD (cumulative patents registered domestically). Further information on variables' definitions and data sources is provided in the Appendix. The figures in parentheses are robust standard errors. *, **, and *** denote significance at the 1%, 5%, and 10% level, respectively.

Independent Variables	Predicted Sign	Dependent Variable: DEBT1				Dependent Variable: DEBT2			
		Full Sample	KOSPI	KOSDAQ	Unlisted	Full Sample	KOSPI	KOSDAQ	Unlisted
RPATD	-	-0.0054***	-0.0012	-0.0016	-0.0077***	-0.0092***	-0.0043	-0.0087	-0.0106***
		(0.0017)	(0.0040)	(0.0046)	(0.0021)	(0.0031)	(0.0081)	(0.0081)	(0.0036)
LEVERAGE	+/-	0.1364***	0.1499***	0.0158	0.1508***	0.3830***	0.4684***	0.2153***	0.3839***
		(0.0119)	(0.0506)	(0.0291)	(0.0120)	(0.0200)	(0.1050)	(0.0578)	(0.0217)
LN(TA)	+	0.3378***	-0.2986**	-0.0076	0.4887***	0.0370	-0.1774	-0.3627*	0.1371**
		(0.0294)	(0.1308)	(0.0951)	(0.0350)	(0.0506)	(0.2422)	(0.1885)	(0.0647)
LN(TA)^2	-	-0.0068***	0.0065**	-0.0000	-0.0100***	0.0001	0.0051	0.0075*	-0.0019
		(0.0006)	(0.0025)	(0.0020)	(0.0008)	(0.0011)	(0.0047)	(0.0040)	(0.0014)
Z SCORE	+	0.0139***	0.0055	-0.0048*	0.0180***	0.0756***	0.0539***	0.0450***	0.0795***
		(0.0015)	(0.0058)	(0.0029)	(0.0014)	(0.0029)	(0.0158)	(0.0096)	(0.0031)
FIXED ASSET	+	0.4487***	0.3899***	0.3858***	0.4571***	0.5504***	0.4596***	0.4200***	0.5615***
		(0.0089)	(0.0458)	(0.0293)	(0.0092)	(0.0148)	(0.0799)	(0.0591)	(0.0156)
LARGE OWNERSHIP	-	-0.0603***	-0.0058	-0.0241	-0.0601***	-0.0610***	-0.0671	-0.0355	-0.0607***
		(0.0040)	(0.0213)	(0.0179)	(0.0041)	(0.0062)	(0.0415)	(0.0297)	(0.0065)
TAX	-	-0.7145***	-0.5705**	-0.5225***	-0.8071***	-0.6305***	0.5604	-0.4017	-0.7797***
		(0.0559)	(0.2522)	(0.1641)	(0.0599)	(0.1224)	(0.4612)	(0.3911)	(0.1345)
YEAR/INDUSTRY EFFECT		YES	YES	YES	YES	YES	YES	YES	YES
Observations		87,912	4,696	6,853	76,363	57,626	3,151	4,220	50,255
R-Squared		0.1424	0.1355	0.1398	0.1514	0.1188	0.1051	0.1134	0.1256
Number of Firms		10,215	424	722	9,069	9,006	395	643	7,968

2. Two-Stage Least Squares Regression

Using unbalanced panel data, we estimate a linear regression model in which current or cumulative corporate innovation activities shape decisions related to the maturity of current corporate debt. As Barclay et al. (2003) point out, OLS estimates for leverage variables are prone to biases caused by endogeneity if debt maturity and leverage are determined simultaneously. Anecdotal evidence suggests that firms typically decide on the amount and maturity of debt at the same time, so the leverage and debt maturity variables are likely to be determined endogenously. To address the possibility of bias resulting from endogeneity, we employ the two-stage least squares (2SLS) regression analysis. In the first stage, we estimate leverage using return on assets and tangibility of assets as instruments. The instrumental variables are chosen based on previous research on the determinants of leverage (see, for example, Johnson 2003; Barclay and Smith 1995).

The essence of the instrumental-variable approach is to find exogeneous variables that are uncorrelated with corporate patents but strongly correlated with the capital structure.

One such instrumental variable for leverage is the firm's profitability. Following Datta et al. (2005), we choose return on assets (ROA) as an instrumental variable that captures the firm's profitability. According to the pecking order theory of capital structure by Myers (1984), firms will prefer retained earnings (internal capital) to external financing. This implies that more profitable firms will have lower leverage. Therefore, return on assets is expected to be highly correlated with the leverage.

Our second instrumental variable for leverage is the tangibility of assets (TANGIBILITY), which is measured as the proportion of the value of property, plant, equipment plus the value of inventory in total assets (Barclay et al. 2003; Johnson 2003; Rajan and Zingales 1995; Stohs and Mauer 1996). Using the tangibility of assets as an instrumental variable is justifiable in part because bankruptcy costs are an important determinant of the firm's leverage level, and tangible assets tend to reduce bankruptcy costs and increase leverage. In addition, asset tangibility and the maturity of assets are not highly correlated with the firm's investment opportunities.

In sum, our final choices of explanatory variables in the first stage of regression are the two instrumental variables (ROA and TANGIBILITY) and the control variables included in our baseline OLS model. Our choice is driven mainly by the availability of data items for our sample firms. We use the leverage ratio estimated in the first stage as an explanatory variable in the second stage to explain debt maturity.

Table 3 reports the results of the first- and second-stage regression from the instrumental variable approach with DEBT1 as the dependent variable. Results in Table 3 using the full sample are followed by three sets of subsample results. The coefficients estimated in the first-stage regression are significant in most cases.

The second-stage regressions results show that the coefficient for cumulative patents registered domestically (RPATD) is negative and significant at the 1% level in the full sample and in the subsample of unlisted firms. According to agency theory, firms with many growth options are likely to be affected by the underinvestment problem because of agency costs, which can be mitigated using short-term debt. Therefore, our results in this section support the agency cost hypothesis that debt maturity decreases with growth options. However, the coefficients for patents in KOSPI- and KOSDAQ-listed firms are not significant. Therefore the overall evidence appears to be driven primarily by unlisted private firms.

Other control variables show coefficients that are similar to those reported in the earlier OLS analyses, which do not consider the interrelationship between leverage and debt maturity. As expected, the coefficient for the predicted leverage is positive and significant in most cases.

The estimated signs of the most of the control variables are in line with the predicted sign. Our regression results also indicate that the coefficient of leverage is significantly positive, so Korean firms favor long-term debt as their leverage ratios increase to avoid the liquidity risks that increase with leverage. This result is in line with earlier studies' predictions, such as those of Diamond (1991), Flannery (1986), and Leland and Toft (1996).

Firm size is positive and significant at the 1% level in all regression models, which is consistent with Barnea et al. (1980). From the perspective of agency costs associated with debt, large firms' bankruptcy risk is reduced because of diversified investments, and agency conflicts are less likely to be severe because of less information asymmetry between insiders and outside investors. These factors suggest that the larger a firm is, the greater amount of debt it can issue. Thus, large firms tend to rely more on long-term debt than on short-term debt.

The coefficient for asset maturity is positive and significant at the 1% level, suggesting that firms try to match the maturity of debt with asset maturity to reduce default risk and mitigate agency cost, which is the key idea behind the maturity-matching hypothesis.

Table 4 shows the results of the second-stage regressions with the ratio of long-term borrowing to total borrowing (DEBT2) as the dependent variable, proxying for debt maturity. The 2SLS results using DEBT2 are qualitatively the same as those obtained with DEBT1 (ratio of non-current liabilities to total liabilities). The coefficients for patent activities are negative and significant at the 1% level for the full sample and the subsample of unlisted firms. Thus, the evidence supports the hypothesis that, as firms increase their numbers of patent applications and registrations, their reliance on short-term debt increases. However, this evidence seems to apply primarily to unlisted private firms.

Other control variables show coefficients that are similar to those reported in the previous analyses using DEBT1. The coefficient for leverage is significant and positive, suggesting that firms prefer long-term debt as their leverage increases and that firms tend to avoid long-term debt when their leverage ratios are high for fear of increased liquidity risk.

The coefficient for firm size is positive and significant at 1%, and the coefficient for the squared term of firm size is negative in all specifications. These results indicate that the relative reliance on long-term debt increases with firm size but decreases after firm size exceeds a certain level, after which the firm prefers short-term debt.

〈Table 3〉 2SLS regression results explaining debt maturity using patents and other firm-specific control variables: DEBT1

The table shows the second-stage regression results from a two-stage least squares regression model. The dependent variable for second-stage regression is DEBT1 (non-current liabilities/total liabilities). The patent-related variable is RPATD (cumulative patents registered domestically). The predicted leverage is from the first-stage regressions, where the dependent variable is LEVERAGE (total liabilities/book value of shareholder equity). The independent variables in the first-stage regressions are ROA (operating income/total assets), and TANGIBILITY (tangible assets/total assets). LN(TA) is the natural log of the firm's total assets in addition to all control variables in the second-stage regressions. Z-SCORE is Altman's (1968) Z-score, which is estimated by the following equation: Z-SCORE =1.2 × (working capital / total assets) + 1.4 × (retained earnings / total assets) + 3.3 × (earnings before interest and tax / total assets) + 0.6 × (market value of equity / total liabilities) + 1.0 × (sales / total assets). FIXED ASSET is the ratio of fixed assets to total assets. LARGE OWNERSHIP is the equity ownership of the largest shareholders. The number of observations is based on available data for all variables for 87,912 public and private firms that Korean law required be audited by external auditors and were listed on the KOSPI or KOSDAQ market from 1999 to 2014. The figures in parentheses are industry-year two-way clustered standard errors. *, **, and *** denote significance at the 1%, 5%, and 10% level, respectively.

Independent Variables	Full Sample		Listed Firms: KOSPI		Listed Firms: KOSDAQ		Unlisted Firms	
	First Stage (LEVERAGE)	Second Stage DEBT1	First Stage (LEVERAGE)	Second Stage DEBT1	First Stage (LEVERAGE)	Second Stage DEBT1	First Stage (LEVERAGE)	Second Stage DEBT1
RPATD		-0.0053***		-0.0012		0.0039		-0.0062***
		(0.0011)		(0.0023)		(0.0037)		(0.0015)
LEVERAGE		1.0213***		0.0742		1.3913***		1.2182***
(Predicted)		(0.0457)		(0.0970)		(0.1909)		(0.0521)
LN(TA)	-0.1539***	0.4467***	-0.2254***	-0.3119***	-0.2011***	0.1958***	-0.1288***	0.5926***
	(0.0091)	(0.0181)	(0.0520)	(0.0733)	(0.0317)	(0.0713)	(0.0112)	(0.0231)
LN(TA)^2	0.0032***	-0.0090***	0.0043***	0.0068***	0.0038***	-0.0038**	0.0027***	-0.0122***
	(0.0002)	(0.0004)	(0.0010)	(0.0014)	(0.0007)	(0.0015)	(0.0002)	(0.0005)
Z-SCORE	-0.0596***	0.0700***	-0.0272***	0.0033	-0.0641***	0.0851***	-0.0632***	0.0896***
	(0.0003)	(0.0029)	(0.0009)	(0.0032)	(0.0010)	(0.0126)	(0.0003)	(0.0036)

FIXED ASSET	-0.2026***	0.5381***	-0.1223***	0.3835***	-0.1975***	0.5103***	-0.2259***	0.5813***
	(0.0047)	(0.0072)	(0.0187)	(0.0241)	(0.0149)	(0.0291)	(0.0051)	(0.0086)
LARGE OWNERSHIP	-0.0073***	-0.0547***	-0.0250**	-0.0085	-0.0805***	0.0866***	-0.0019	-0.0594***
	(0.0016)	(0.0031)	(0.0119)	(0.0167)	(0.0081)	(0.0228)	(0.0017)	(0.0034)
TAX	0.1539***	-0.4647***	-0.0666	-0.6293***	0.1791**	-0.6938***	0.2139***	-0.5557***
	(0.0280)	(0.0487)	(0.1246)	(0.1741)	(0.0836)	(0.1666)	(0.0304)	(0.0551)
ROA	-0.2124***		-0.3925***		-0.0383**		-0.2135***	
	(0.0065)		(0.0282)		(0.0166)		(0.0073)	
TANGIBILITY	0.1226***		0.0488***		0.1666***		0.1305***	
	(0.0046)		(0.0182)		(0.0154)		(0.0049)	
YEAR/INDUSTRY EFFECT	YES	YES	YES	YES	YES	YES	YES	YES
Observations	87,912	87,912	4,696	4,696	6,853	6,853	76,363	76,363
Number of Firms	10,215	10,215	424	424	722	722	9,069	9,069
R-Squared	0.5086	0.0763	0.4208	0.1895	0.6332	0.0131	0.5188	0.0747
F Value	13.86		18.84		8.88		5.80	

〈Table 4〉 2SLS regression results explaining debt maturity using patents and other firm-specific control variables: DEBT2

The table shows the second-stage regression results from a two-stage least squares regression model. The dependent variable for second-stage regression is DEBT2 (long-term borrowing/total borrowing). The patent-related variable is RPATD (cumulative patents registered domestically). The predicted leverage is from the first-stage regressions, where the dependent variable is LEVERAGE (total liabilities/book value of shareholder equity). The independent variables in the first-stage regressions are ROA (operating income/total assets) and the TANGIBILITY (tangible assets/total assets), in addition to all control variables in the second-stage regressions. LN(TA) is the natural log of the firm's total assets. Z-SCORE is Altman's (1968) Z-score, which is estimated by the following equation: Z-SCORE =1.2 × (working capital / total assets) + 1.4 × (retained earnings / total assets) + 3.3 × (earnings before interest and tax / total assets) + 0.6 × (market value of equity / total liabilities) + 1.0 × (sales / total assets). FIXED ASSET is the ratio of fixed assets to total assets. LARGE OWNERSHIP is the equity ownership of the largest shareholders. The number of observations is based on available data for all variables for 57,626 public and private firms that Korean law required be audited by external auditors and that were listed on the KOSPI or KOSDAQ market from 1999 to 2014. The figures in parentheses are industry-year two-way clustered standard errors. *, **, and *** denote significance at the 1%, 5%, and 10% level, respectively

Independent Variables	Full Sample		Listed Firms: KOSPI		Listed Firms: KOSDAQ		Unlisted Firms	
	First Stage (LEVERAGE)	Second Stage DEBT2	First Stage (LEVERAGE)	Second Stage DEBT2	First Stage (LEVERAGE)	Second Stage DEBT2	First Stage (LEVERAGE)	Second Stage DEBT2
RPATD		-0.0116***		0.0019		-0.0098*		-0.0095***
		(0.0025)		(0.0065)		(0.0059)		(0.0029)
LEVERAGE		2.9624***		3.0723***		1.3488***		2.7750***
(Predicted)		(0.1345)		(0.7631)		(0.1977)		(0.1339)
LN(TA)	-0.1876***	0.4255***	-0.3203***	0.5876**	-0.2708***	-0.0869	-0.1194***	0.3374***
	(0.0109)	(0.0454)	(0.0466)	(0.2954)	(0.0411)	(0.1320)	(0.0140)	(0.0519)
LN(TA)^2	0.0037***	-0.0073***	0.0058***	-0.0084	0.0050***	0.0024	0.0024***	-0.0057***
	(0.0002)	(0.0010)	(0.0009)	(0.0054)	(0.0009)	(0.0027)	(0.0003)	(0.0011)
Z-SCORE	-0.0919***	0.3190***	-0.1098***	0.3450***	-0.1177***	0.1678***	-0.0874***	0.2977***
	(0.0006)	(0.0128)	(0.0021)	(0.0857)	(0.0019)	(0.0220)	(0.0006)	(0.0124)

FIXED ASSET	-0.2953***	1.0056***	-0.3208***	1.1592***	-0.3174***	0.6257***	-0.2952***	0.9765***
	(0.0056)	(0.0271)	(0.0196)	(0.2162)	(0.0178)	(0.0544)	(0.0061)	(0.0267)
LARGE OWNERSHIP	-0.0047***	-0.0485***	-0.0185*	-0.0210	-0.0503***	0.0204	-0.0002***	-0.0600***
	(0.0017)	(0.0065)	(0.0105)	(0.0455)	(0.0085)	(0.0274)	(0.0018)	(0.0064)
TAX	0.5994***	-1.9522***	0.7016***	-1.0834	0.7912***	-1.5488***	0.5709***	-1.7658***
	(0.0356)	(0.1439)	(0.1155)	(0.6675)	(0.1088)	(0.3758)	(0.0396)	(0.1449)
ROA	-0.0563***		-0.0465*		0.1996***		-0.1003***	
	(0.0081)		(0.0267)		(0.0219)		(0.0092)	
TANGIBILITY	0.1446***		0.0896***		0.2030***		0.1459***	
	(0.0053)		(0.0178)		(0.0173)		(0.0058)	
YEAR/INDUSTRY EFFECT	YES	YES	YES	YES	YES	YES	YES	YES
Observations	57,626	57,626	3,151	3,151	4,220	4,220	50,255	50,255
Number of Firms	9,006	9,006	395	395	643	643	7,968	7,968
R-Squared	0.4439	0.0301	0.1120	0.1236	0.5748	0.0208	0.4161	0.0310
F Value	12.35		12.31		8.64		12.10	

3. Robustness Tests

1) System GMM Approach

The two-stage least squares regression approach using unbalanced panel data has benefits because of increased degrees of freedom with a larger number of observations. However, Hsiao (1985) shows that OLS estimators are biased and inconsistent if firm-specific unobserved heterogeneity is not treated properly.

In empirical research on the corporate maturity structure of debt, Ozkan (2000) and Antoniou et al. (2006) apply a dynamic model known as the System GMM (generalized method of moments) to address the firm-specific heterogeneity and endogeneity problems. Employing the System GMM, Antoniou et al. (2006) find a robust and negative relationship between growth opportunities and debt maturity. The System GMM estimator Arellano and Bover (1995) and Blundell and Bond (1998) suggest uses the first differences of the lagged dependent variable as instrumental variables.

Table 5 reports the results obtained from the System GMM estimator. To evaluate the validity of instruments for the System GMM estimator, we perform a specification test (Arellano and Bond 1991) based on AR(2). The p-values of AR(2) in the System GMM model indicate that we fail to reject the null hypothesis of no second-order serial correlation in the first differenced residuals. Therefore, the model appears to be reasonable.

Although we lose a substantial number of observations because of the requirement that differenced variables should be used, we find that the System GMM results using the lagged debt maturity variables are consistent with the 2SLS results reported in the previous section; that is, the System GMM results show that corporate innovation activities are significantly negatively related to the weight of long-term borrowing. At the same time, we find that the coefficients for control variables show predicted signs that are consistent with signaling, liquidity, maturity matching, and debt tax shield hypotheses.

〈Table 5〉 System GMM regression results explaining debt maturity

This table reports the System GMM estimation results. The patent-related variable is RPATD (cumulative patents registered domestically). Robust standard errors are in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. AR(1) and AR(2) are p-values of Arellano-Bond tests for first-order and second-order serial correlation in the first-differenced residuals, under the null hypothesis of no serial correlation.

Independent Variables	Predicted Sign	Dependent Variable: DEBT1			
		Full Sample	KOSPI	KOSDAQ	Unlisted
RPATD	−	-0.0101***	0.0006	-0.0213***	-0.0122***
		(0.0025)	(0.0053)	(0.0073)	(0.0030)
LAGGED DEBT1	+	0.6000***	0.3833***	0.5120***	0.6110***
		(0.0113)	(0.0439)	(0.0387)	(0.0120)
LEVERAGE	+/-	0.1780***	0.0888	0.1588***	0.1876***
		(0.0170)	(0.0762)	(0.0474)	(0.0178)
LN(TA)	+	0.0540	0.1291	0.1770	0.1037
		(0.0609)	(0.2380)	(0.2453)	(0.0730)
LN(TA)^2	−	-0.0008	-0.0020	-0.0031	-0.0019
		(0.0013)	(0.0046)	(0.0050)	(0.0016)
Z-SCORE	+	0.0274***	0.0109	0.0174***	0.0296***
		(0.0020)	(0.0078)	(0.0047)	(0.0021)
FIXED ASSET	+	0.5410***	0.4074***	0.5048***	0.5508***
		(0.0120)	(0.0524)	(0.0418)	(0.0126)
LARGE OWNERSHIP	−	-0.0260***	-0.0138	-0.0296	-0.0259***
		(0.0044)	(0.0193)	(0.0226)	(0.0046)
TAX	−	-0.5245***	-0.7318***	-0.5764***	-0.5315***
		(0.0717)	(0.2539)	(0.2142)	(0.0790)
CONSTANT		-1.1246	-2.1548	-2.6597	-1.7054**
		(0.7169)	(3.1239)	(3.0128)	(0.8476)
AR(1) Test		0.0000	0.0000	0.0000	0.0000
AR(2) Test		0.5909	0.7337	0.0399	0.4382
Observations		68,964	3,783	5,166	60,015
Number of Firms		9,346	404	679	8,263

2) Incremental Approach

The previous analyses use the total debt outstanding as the base for our measure of debt maturity. However, this approach has a few potential drawbacks. For example, a negative impact of corporate innovation on long-term debt may be spurious because most firms do not adjust their capital structure frequently (Leary and Roberts 2005). In addition, financial leverage and the maturity structure of debt may be the result of past decisions (Dang and Phan 2016; Tosun and Senbet 2019). Therefore, an incremental approach that reflects new debt issues may prove a better approach to investigating the determinants of debt maturity (Guedes and Opler 1996). To address these issues, we incorporate incremental non-current liabilities in our model to estimate the relationship between corporate innovation and the maturity of new debt.[4] As in the previous analyses, we use an instrumental variable (IV) regression model to control for potential endogeneity.

Table 6 shows the results from the second-stage regressions with the incremental weight of non-current liabilities as the dependent variable. The coefficients for cumulative patents registered domestically (RPATD) are negative and significant at the conventional level for the full sample and all three subsamples. In addition, the coefficient estimates of the control variables are generally consistent with empirical evidence documented in the literature. Statistically significant and negative estimates for corporate innovation activities support the hypothesis that firms' reliance on short-term debt rather than long-term debt increases with their innovation activities, proxied by the cumulative number of patents registered domestically.

4) Note that this measure may not be ideal because the incremental non-current liabilities represent not only new debt issues but also repayments of existing debt.

〈Table 6〉 2SLS regression results explaining debt maturity: Incremental Approach

The table shows the second-stage regressions results from the two-stage least squares regression model. The dependent variable for the second-stage regression is the lag variable of DEBT1: △DEBT1. The patent-related variable is RPATD (cumulative patents registered domestically). The predicted leverage is from the first-stage regressions, where the dependent variable is LEVERAGE (total liabilities/book value of shareholder equity). The independent variables in the first-stage regressions are ROA (operating income/total assets), and TANGIBILITY (tangible assets / total assets) in addition to all control variables used in the second-stage regressions. First-stage regression results are omitted. The number of observations is based on available data for all variables for 9,845 public and private firms that Korean law required be audited by external auditors and were listed on KOSPI or KOSDAQ from 1999 to 2014. The figures in parentheses are firm-year two-way clustered standard errors. *, **, and *** denote significance at the 1%, 5%, and 10% level, respectively.

Independent Variables	Predicted Sign	Dependent Variable: △DEBT1			
		Full Sample	KOSPI	KOSDAQ	Unlisted
RPATD	−	-0.0088***	-0.0063**	-0.0084**	-0.0087***
		(0.0015)	(0.0031)	(0.0037)	(0.0018)
LEVERAGE	+/−	0.6577***	-0.0258	0.5471***	0.8058***
(Predicted)		(0.0681)	(0.1846)	(0.2001)	(0.0776)
LN(TA)	+	-0.0241	-0.1629*	0.0131	-0.0467
		(0.0264)	(0.0869)	(0.0967)	(0.0342)
LN(TA)^2	−	0.0010*	0.0035**	0.0001	0.0016**
		(0.0006)	(0.0017)	(0.0020)	(0.0007)
Z-SCORE	+	0.0315***	-0.0055	0.0206	0.0449***
		(0.0051)	(0.0057)	(0.0130)	(0.0057)
FIXED ASSET	+	0.1997***	-0.0268	0.1331***	0.2353***
		(0.0121)	(0.0362)	(0.0305)	(0.0132)
LARGE OWNERSHIP	−	-0.0556***	0.0201	-0.0139	-0.0608***
		(0.0037)	(0.0185)	(0.0243)	(0.0040)
TAX	−	-0.0030	-0.5181**	-0.1472	-0.0310
		(0.0698)	(0.2397)	(0.1942)	(0.0756)
YEAR/INDUSTRY EFFECT		YES	YES	YES	YES
Observations		78,642	4,363	6,276	68,003
R-Squared		0.0253	0.0229	0.0170	0.0273
Number of Firms		9,845	418	710	8,717

V. Conclusions

If a firm is financed primarily with short-term debt, it can be exposed to liquidity risk because of the costs incurred in extending the debt's maturity or the difficulty in refinancing when the earlier debt matures. However, if a firm relies heavily on long-term debt, it will be subject to inefficiency in cash management because of the need to hoard a large amount of excess cash. In short, debt maturity decisions can incur agency costs and can generate significant information-signaling effects and tax effects. Therefore, like their decisions related to the amount of leverage, firms' decisions regarding the maturity of their debt are important financing decisions.

This study begins with the underinvestment problem stipulated by agency theory. We hypothesize that more innovative firms rely more on short-term debt than they do on long-term debt and that firms that rely more on long-term debt will be less engaged in innovation activities. We employ the number of patents registered and the citation counts of patents as proxies for a firm's innovation activity because they indicate the successful outcome of firms' innovation activities and signify future growth opportunities.

Our empirical results show a negative relationship between the weight of long-term debt and firms' patent applications. This suggests that firms with more patents rely more heavily on short-term debt when compared to other firms. The results are consistent with the prediction of agency cost theory that firms with many growth options rely on short-term debt over long-term debt to mitigate the agency costs that result from managers' incentive to underinvest.

This study contributes to the corporate investment and capital structure literature by providing insight into the effect of innovative investment on the maturity structure of debt. Our findings have implications for the design of managerial incentives to promote innovation. For example, debt maturity can be used as an incentive to balance between rewarding success and tolerating failure for risky projects. From the policy perspective, our results suggest that providing access to short-term debt markets is more important for promoting innovation than improving access to long-term debt markets, especially for innovative private firms.

Some caveats must be addressed. To measure debt maturity accurately, we need data on the maturity of each outstanding debt issue and a weighted average debt maturity using market values of debt as weights. Compustat Global Database provides such data for U.S. firms. Unfortunately, however, such information is not required to be disclosed publicly in Korea and is thus not available. Therefore, we use a crude measure, the ratio of short-term debt to total debt, as a proxy for debt maturity.

Agency issues around the cost of debt can occur when shareholders appropriate wealth from debtholders by transferring risk to debtholders. Debtholders require a higher risk premium as compensation for the uncertainty associated with a risky project. Therefore, studies on the maturity structure of debt reflecting a risk premium may be a fruitful topic for future research.

Corporate financing is affected heavily by external events and changes in macro-economic conditions. In particular, a financial crisis can impart an external shock that can change the investment environment and financing patterns. Studying the maturity structures of debt before and after a pseudo-natural shock like a financial crisis may also be a fruitful topic for future research. Another avenue for further study is an investigation of firms' decisions regarding types of debt and debt maturity from the perspective of innovation activities. Such an exercise pertains to remedies that would reduce conflicts of interest among claim holders, as Blackwell and Kidwell (1988) and Whited (1992) point out.

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Appendix

〈Appendix Table 1〉 Variable Definitions and Sources

This table contains descriptions of the variables used in the analyses to test hypotheses on the determinants of the maturity structure of debt. These include innovation measures and financial information. Accounting data are from KOCOinfo (Korea Listed Companies Association), and patent data are from the KIPRIS (Korea Intellectual Property Rights Information Service) and WISDOMAIN.

Variables	Description	Sources
Panel A: Debt Maturity (Long-term Debt Index)		
DEBT1	The ratio of non-current liabilities to total liabilities	KOCOinfo
DEBT2	The ratio of the long-term borrowing to total borrowing	KOCOinfo
Panel B: Innovation Measures		
APATD	Natural log of 1 plus the cumulative number of patent applications made domestically in a given year	KIPRIS, WISDOMAIN
RPATD	Natural log of 1 plus the cumulative number of registered patents made domestically in a given year	KIPRIS, WISDOMAIN
APATF	Natural log of 1 plus the cumulative number of patent applications made in more than four G10 countries outside Korea in a given year	KIPRIS, WISDOMAIN
RPATF	Natural log of 1 plus the cumulative number of registered patents made in more than four G10 countries outside Korea in a given year	KIPRIS, WISDOMAIN
CITED	Natural log of 1 plus the cumulative number of citations by other patents in a given year	KIPRIS, WISDOMAIN
Panel C: Firm-level Control Variables		
LEVERAGE	The ratio of total liabilities to total assets	KOCOinfo
LN(TA)	Natural log of total assets	KOCOinfo
Z-SCORE	1.2 × (working capital / total assets) + 1.4 × (retained earnings / total assets) + 3.3 × (earnings before interest and tax / total assets) + 0.6 × (market value of equity / total liabilities) + 1.0 × (sales / total assets)	KOCOinfo
FIXED ASSET	The ratio of fixed assets to total assets	KOCOinfo
LARGE OWNERSHIP	Equity ownership of the largest shareholder	KOCOinfo
TAX	The ratio of tax expenses to total assets	KOCOinfo
AGE	Natural log of the number of years since firm inception	KOCOinfo
TANGIBILITY	The ratio of tangible assets to total assets	KOCOinfo
ROA	The ratio of operating income to total assets	KOCOinfo

요 약

본 연구는 대리인 이론의 과소투자 문제를 기반으로 기업의 혁신활동이 부채만기 구조에 미치는 영향을 분석하였다. 성장기회가 높은 기업일수록 기업혁신 활동에 수반되는 편익을 채권자와 경영자가 공유하는 과정에서 단기부채의 사용이 많을 수 있다는 점에 착안하여, 기업의 특허 출원 건수, 등록 건수, 인용 건수 등을 기업의 성장가능성을 대변하는 지표로 보고 부채만기 구조와의 관련성을 분석하였다. 분석 결과, 특허를 많이 보유하고 있는 기업일수록 단기부채 활용도가 높은 것으로 나타나고 있다. 대리인 비용 가설에 따르면 성장옵션을 많이 보유한 기업에서는 경영자의 과소투자 유인에 따른 대리인 비용이 발생하며, 이를 줄이기 위해 단기부채가 상대적으로 많이 사용된다고 보고 있다. 따라서 본 연구의 결과는 성장옵션이 클수록 부채만기가 줄어든다는 대리인 비용 가설을 지지한다.

국문색인어: 특허, 기업혁신, 부채만기