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DEFAULT RISK, FIRM'S CHARACTERISTICS, AND RISK SHIFTING

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Default Risk, Firm's Characteristics, and Risk Shifting*

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Abstract

This paper examines the relationship between a firm's risk-shifting behavior and its default risk. Using contingent-claims approaches, we estimate the market value of a firm's assets, the volatility of asset return, and the associated default risk based on the stock prices and book value of debt. Our study shows that, consistent with conventional wisdom and many theoretical models, firms with high default risk tend to increase asset volatility more in the subsequent year, relative to their industry peers. We find that, a firm's risk-shifting is also pronounced when it has very low default risk. In addition, risk shifting is negatively related to firm size, leverage ratio, and current asset volatility. Alternative specifications of default risk confirm that our findings are robust to the choice of default risk measure. A direct estimation of the market values of firms based on market values of stocks and bonds confirms our results based on contingent-claims approaches.

Keywords: default risk, contingent-claims model, risk shifting, agency cost.

JEL classification: G13, G33

1. Introduction

The agency problem of risk-shifting (also known as "asset substitution") arises from the conflict of interest between equityholders and debtholders in a levered firm (Jensen and Meckling, 1976). Equityholders have incentive to increase investment risk after debt is in place in order to extract value from debtholders. A substantial body of theoretical work has extended this study to the various agents (equityholders, firm's managers) with various compensation contracts and risk preferences.[1] Most of these models suggest that a manager (levered firm) under normal circumstances does no shift risk due to many concerns and restrictions, such as bankruptcy and reorganization costs, loss of tax subsidies, loss of future investment opportunity, and the reputation of the company and its managers. A manager (levered firm) will take on a large risk exposure only when the probability of the loss of his compensation (default) is high.

Although these models are appealing, some studies suggest that the agency cost associated with the risk-shifting incentive may not be significant in practice. For example, Fama (1978) argues that a perfect capital market will discipline firms to maximize the combined value of the debt and equity, and avoid agency costs. Haugen and Senbet (1981, 1988) demonstrate that agency costs and liquidation costs can be mitigated or may even be eliminated via the use of complex financial securities and informal reorganizations. Leland (1994) shows that equityholders may not have incentive to shift risk under positive net-worth covenants. Mao (2003) illustrates that, when the volatility of project cash flow increases with investment scale, the combined problem of the risk-shifting and the under-investment (Myers, 1977) will lead to

[1] For example, Leland (1994, 1998) studies the agency cost generated by equityholder-debtholders conflicts; Carpenter (2000) studies a dynamic investment problem of a risk averse manager compensated with a call option on the assets he controls; Goetzmann, Ingersoll and Ross (2003) examine the effect of a compensation contract with "high-water mark" provision on the optimal investment strategies of a hedge fund. Basak, Pavlova and Shapiro (2003) examine the use of benchmarking to control the risk-shifting behavior of a money manager.

an investment policy that maximizes firm-value. Thus, without empirical verification, whether the risk-shifting phenomenon is significant or not is still an open question.

Empirical evidence has been documented to support this risk-shifting hypothesis in the financial industry. Esty (1997a, b) finds that risk-shifting was significant in the savings and loan industry during the 1980s. He observes that a firm increases investment in risky assets after a conversion from mutual to stock ownership. Brown, Harlow and Starks (1996) show that mutual fund managers tend to take more risk in the latter half-year when the fund performs relatively badly in the first half-year. Chevalier and Ellison (1997) show that fund investment inflows depend on its recent performance. The shape of the inflow-performance relationship creates an incentive for fund managers to increase (decrease) the riskiness of their portfolios based on the good (bad) performance of the fund in the first eight months. Brown, Goetzmann and Park (2001) documented a similar risk-shifting investment strategy taken by hedge fund managers. In contrast, there is little direct empirical evidence of this risk-shifting behavior in industrial firms. This may be due partially to the fact that the market value of an industrial firm is unobservable, which makes it impossible to directly measure asset volatility.

To address this lack, this paper examines the risk-shifting problem empirically for firms in all industries. We assume that the stock market is efficient in the sense that the stock prices fully reflect a firm's asset values.[2] To infer the market values of the firm's assets and associated volatilities of the asset return from the observable stock prices, we apply two contingent-claims approaches originated by Merton (1974; hereafter M74) and Leland (1994; hereafter L94). In addition, the likelihood of default can also be calculated via these approaches. Following Brown, Harlow and Starks (1996), and Brown, Goetzmann and Park (2001), we use the volatility of the

[2] At the very least, we can assume that the market is well aware of problems or opportunities that a firm is facing, and fairly reflects the firm's riskiness.

firm's asset value as the measure of the firm's business-operation risk. If the risk-shifting argument is valid, we expect to see firms in the high default risk group to have a higher "risk adjustment ratio" (*RAR*), which is the ratio of asset volatility next year to the asset volatility of this year.

For each year from 1980 to 1999, we compute the default risk and the volatility of the firm's asset return. To control for the industry effect on the risk-shifting incentive, we use an "industry adjusted *RAR*" (*IRAR*), which is computed by subtracting the median *RAR* of all firms with the same two-digit SIC in the same year from the raw *RAR*. We show that the curve of *IRAR,* as a function of default risk, exhibits a "U-shape." Firms with low or high level of default risk display stronger risk-shifting behavior than firms in the medium level of default risk. Further examination in firm's characteristics shows that firm's risk-shifting behavior also depends on its current asset volatility. Risk-shifting is not significant for firms in all default risk groups with high current asset volatility. For firms with modest asset volatility, risk-shifting is pronounced only in high default risk group. Only for firms with low asset volatility, we are able to observe risk-shifting in both low and high default risk groups.

Applying Fama-MacBeth (1973) multivariate regressions, we find that firms shift to a higher risk level when they are higher in default probability, smaller in size, lower in leverage ratio and current asset volatility. In addition, we find that firms take more risk after a recent poor stock performance. This result is consistent with those documented for the mutual fund and hedge fund industries (Brown, Harlow and Starks, 1996; Brown, Goetzmann and Park, 2001). Furthermore, our results are robust to the choice of default risk measure. Using Altman's (1967) Z-score or Ohlson's (1980) O-score, we find that the positive relationship between high default risk (low Z-score or high O-score) and risk-shifting still holds. To validate our estimations based on contingent-claims models, we also estimate the market values of firm's asset and associated volatility in a subset of our sample based on market value of both stock and bond obtained from CRSP and Lehman Brother Bond database (LBBD). The resulted risk adjustment ratios are highly correlated.

The remainder of paper is organized as follows. Section 2 outlines the research methodology used to compute a firm's asset value, volatility of asset returns, and the proxy of default risk. Section 3 describes the data sources and sample selection. Section 4 reports and interprets empirical test results, and Section 5 concludes the paper.

2. Research Methodology

2.1. Firm's asset value and riskiness

The market value of a firm's assets is a measure of the present value of the future cash flow produced by the firm's assets and discounted back at the appropriate discount rates. The uncertainty associated with the firm's asset value is a measure of riskiness in the firm's business operation. Then it follows that risk-shifting should be characterized by an increased volatility of the firm's asset value. We assume the market is efficient and the asset value of a firm and its riskiness can be inferred from its stock price history and liability structure. In M74, for example, a firm's equity value is modeled as a call option contingent on the market value of its assets. The default is determined by the firm's asset value and its debt level at the maturity of the debt. When the firm's value is greater than the liability due on the maturity date, the firm pays the debtholders, whereas if the firm's value falls below the liability, the default occurs and equityholders hand the firm over to the debtholders by declaring bankruptcy.

In this paper, for comparison and sensitivity analysis, we use two different methods to estimate a firm's asset value and associated volatility from the firm's equity value. One method is based on M74 and extended by KMV Company (outlined in Crosbie and Bohn, 2002). Vassalou and Xing (2004) also employ similar approach in their computations of a firm's default risk. In this method the firm's equity value is a treated as a call option on the value of the firm's total assets. The exercise price of the call option is specified as a default level, *X*, which is determined by the firm's liability structure.[3] The expiration date of the call option is set as an evaluating time horizon. When the asset value falls below the default point on a specified evaluation time horizon, *T*, the firm is assumed to default.[4] The other method is based on L94. This model links corporate debt with asset value, firm risk, taxes and bankruptcy cost in a time-independent environment. It is assumed that a firm pays a perpetual coupon payment for its debt and default occurs if the firm fails to meet the required coupon payment by issuing additional equity. In these two models, the market value of a firm's assets is assumed to follow a Geometric Brownian Motion with constant volatility:

$$dV = V(\mu_V dt + \sigma_V dW_t) \tag{1}$$

where V is the firm's asset value, with an instantaneous drift μ_V and a volatility σ_V; W is a standard Wiener process.

There exist closed-form solutions for these two models. For the model of M74, the solution is given by the well known Blake-Scholes (1973) formula:

$$S = VN(d + \sigma_V \sqrt{T}) - Xe^{-rT} N(d) \tag{2}$$

where

[3] For example, it is the face value of a pure discount bond in M74 and it is the sum of debt due in one year and half of the long term debt in Vassalou and Xing (2004).
[4] For example, it is specified as the maturity date in M74 and one year in Vassalou and Xing (2004).

$$d = \frac{\ln(V/X) + (r - 1/2\sigma_V^2)T}{\sigma_V \sqrt{T}} \quad (3)$$

and S is the current market value of the equity, V the current asset value of the firm, X the default point, r the risk-free borrowing rate, σ_V the instantaneous volatility of the firm's asset value, T the length of the time horizon, and $N(.)$ a univariate cumulative density function of the standard normal distribution. For the model of L94, the solution is:

$$S = V - (1-\tau)C/r + [(1-\tau)C/r - V_B](V/V_B)^{-X} \quad (4)$$

where $V_B = (1-\tau)C/(r + 0.5\sigma_V^2)$ and $X = 2r/\sigma_V^2$. S, V is the market value of firm's equity and asset respectively, C the continuous coupon payment rate, r the risk-free interest rate, and τ the firm's tax rate.

It is noted that equation (2) or (4) both the asset's value and its associated volatility need to be solved in one equation. KMV developed an iterative algorithm to resolve this problem in M74. The procedure sets an initial guess of the asset volatility and computes the asset values every trading day in a specified time window by solving equation (2) given data on the firm's stock price, the number of shares outstanding, the default point, the evaluation time horizon, and the risk-free interest rate. The volatility of the resulting asset value returns (in this time window) is used as the input to determine a new set of the asset values in the next iteration. The procedure continues in this manner until σ_V converges.[5] For the model of L94, we adopt a similar approach.

Following Crosbie and Bohn (2002) and Vassalou and Xing (2004), we use one year as the time horizon for the evaluation of default risk, and the sum of the "debt due in one year" and half of the "long term debt" as the proxy of default level in solving the model of M74. The

[5] The tolerance level of convergence that we used is 1.0 E-6.

choice of this default level is based on the observation that firms do not default even when their asset value falls below the book value of its total liability because of the long-term nature of their liability. On the other hand, sometimes firms do default even when they have the ability to service their liability *in due*. The default level generally lies somewhere between short-term liability and total liability. KMV argues that the use of 50 percent of long term debt is sensible since it adequately captures the financing constraints of firms. Vassalou and Xing (2004) show that the choice about the portion of long-term debt included is not so sensitive to alter their results qualitatively.[6] We use a calendar year as the time window and the stock volatility as the initial guess of asset volatility in our computation. The risk-free interest rate is proxied by the one-year T-bill rates at the end of each month. The advantage of using the model of L94 is that we do not need to specify a time horizon and default level exogenously. As long as we know the firm's equity value, the annual coupon payment and the tax rate, we can solve for the firm's asset value and associated volatility iteratively.

2.2. Default risk proxies

There are three main classes of models used to measure the default risk of a firm.

One class is based on a firm's accounting information and is derived from statistical analysis, and includes Altman's (1968) Z-score model and Ohlson's (1980) O-score model.[7] A low value of Z-score or a high value of O-score represents a high default probability. Models in the second class, following Jarrow and Turnbull (1995), are the so-called "reduced-form" models.

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[6] We performed a similar sensitivity test and found that our results are robust.

[7] Altman's (1968) Z-score is: Z = 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 / book value of total debt) + (sales / total assets). Ohlson's (1980) O-score is: O = -1.32– 0.407 log(total assets / GNP price-level index) + 6.03(total liability / total assets) – 1.43(working capital / total assets) +0.0766(current liability / current assets) – 1.72(1 if total liability > total assets, else 0) - 2.37(net income / total assets) – 1.86(fund from operation / total liability) + 0.285(1 if net loss for last two years, else 0) – 0.521(net income$_t$ – net income$_{t-1}$)/(|net income$_t$| - |net income$_{t-1}$|).

These models define the time of default as an exogenous intensity process calibrated by the market prices of the firm's debt.[8] The third class of models contains the set of structural models, which are rooted in the contingent-claims approach introduced by Black and Scholes (1973) and M74. These models derive the likelihood of a firm's default from its capital structure and its stock prices.[9]

Although, relative to structural models, reduced-form models are more likely to produce a better fit for any given credit spread data, they break the link between the economics of firm behavior and its default. Also, as shown by Elton, Gruber, Agrawal and Mann (2001), much of the information in the corporate bond spread is unrelated to default risk. In addition, the data required to calibrate and implement reduced-form models are not widely available. All the aforementioned aspects make reduced-form models inappropriate for this study. On the other hand, the structural models have been proven to be superior in measuring default risk. Delianedis and Geske (1998) compute risk neutral default probabilities in M74 framework and show that these risk neutral default probabilities have predictive power on credit migration and default. Vassalou and Xing (2004) estimate a default likelihood indicator using a contingent-claims method which is similar to the one developed by KMV (Crosbie and Bohn, 2002). They show that their approach outperforms accounting models such as Altman's (1968) Z-score and Ohlsom's (1980) O-score in predicting default events. In this study, therefore, we employ the same method to compute a proxy of default risk.

After the market values of a firm's assets and its associated volatility have been computed from equation (2) or (4), the probability of default is the probability that this value falls below the default level at the specified time horizon. That is

[8] See Jarrow, Lando and Turnbull (1997), Lando (1997, 1998), and Duffie and Singleton (1997, 1999) among others.
[9] See Black and Cox (1976), Geske (1977), Leland (1994), Longstaff and Schwartz (1995), and Leland and Toft (1996) among others.

$$p_t = \Pr[V_A^t \le X_t \mid V_A^0 = V] = \Pr[\ln V_A^t \le \ln X_t \mid V_A^0 = V] \quad (5)$$

where p_t is the probability of default at time *t*, V_A^t the market value of the firm's asset at time *t*, and X_t the firm's default level at time *t*.

From equation (1), we know that the market value of the firm's asset is:

$$\ln V_A^t = \ln V_A^0 + (\mu_V - \sigma_V^2 / 2)t + \sigma_V \sqrt{t}\varepsilon \quad (6)$$

where $\varepsilon \sim N(0,1)$ is a standard Brownian motion. Combining equations (5) and (6), we have

$$p_t = N(-DD) = N\left[-\frac{\ln(V_A^0 / X_t) + (\mu_V - \sigma_V^2 / 2)t}{\sigma_V \sqrt{t}}\right] \quad (7)$$

where $DD = \dfrac{\ln(V_A^0 / X_t) + (\mu_V - \sigma_V^2 / 2)t}{\sigma_V \sqrt{t}}$ is the distance-to-default.

As pointed out by Vassalou and Xing (2004), p_t in the above equation is only a "default likelihood indicator" rather than the actual probability of default in practice. We choose p_t as a proxy of default risk for this study.

3. Data Selection and Sample Statistics

We use the annual COMPUSTAT data files to obtain firm-specific accounting information. The sample period is chosen from 1980 to 1999 since the CRSP-COMPUSTAT matched sample contains substantially more firms after 1980, which increases statistical power. For each year the sample consists of firms that have all the valid accounting data required for the computation described in section 2. For example, in computing asset volatility and the M74 default likelihood indicator, we require firms to have valid "debt due in one year" and "long term debt" in the files. We exclude all-equity firms in the sample since our empirical analysis is not relevant to them.

The daily stock price data and returns are from CRSP. To obtain a reliable estimate of a firm's asset volatility, we select only firms with valid stock prices for more than 100 days each year. We exclude closed-end funds, ADRs and foreign incorporated companies since CRSP does not accurately report the total number of outstanding shares for these firms. To reflect a change of the firm's asset value due only to its business operation, we also exclude firms having buy-back or issuing new shares in any sample year.[10] For the stocks that are delisted in the sample period, the delisted returns from CRSP are used. In examining the change in asset volatility, we restrict the sample to firms having a valid asset volatility estimate in two consecutive years. The risk-free rate in the computation for each month is proxied by the one-year Treasury-Bill rate recorded at the end of this month in the CRSP database. The stock performance for each year is measured by the cumulative return over twelve calendar months, which includes dividends and price adjustments due to the stock splits. In applying the model of L94, the tax rates are firm's statutory federal tax rates applicable to the top income bracket.[11]

We use the Lehman Brothers Bond database to estimate the monthly market values of firm's debt for a subset of our sample during 1980 to 1997 in which corporate bond data are available. To be included in our study, we require that the firm has valid data for at least 10 consecutive months in the sample year. Similar to Sweeney *et al*. (1997), we restrict our sample to firms having information available on at least 50% of the outstanding issues of total debt. Applying these criteria yields 5,921 firm-year observations.

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[10] This accounts for less than 1% of records in each sample year.

[11] The rate is 46% from 1979 to 1986, 39.5% in 1987, 34% from 1988 to 1992, and 35% after 1993.

[Insert Table 1 Here]

Panel A of Table 1 presents summary statistics for our entire sample. We fix outliers by winsorizing the default likelihood indicators and *RAR* at the 1% level. Since the distributions of volatility and default risk are right skewed, median values are also informative. We report both the mean and median of our sample here. The mean and median stock return volatility is 0.60 and 0.50 respectively. The mean and the median asset return volatility is 0.49 and 0.40 respectively based on M74, and is 0.47 and 0.37 respectively based on L94. The annualized stock return volatility and asset return volatility are computed as the standard deviations of daily returns multiplied by the square root of 250. The median and mean of the "default likelihood indicators" is less than 0.0001 and 0.046 respectively based on M74, and less than 0.0001 and 0.013 respectively based on L94. Following Brown, Harlow and Starks (1996), we use the "risk adjustment ratio," $RAR = \sigma_V^{t+1} / \sigma_V^t$, to measure the firm's risk-shifting behavior, where σ_V^t, σ_V^{t+1} denotes the volatility of the firm's asset value this year and next year, respectively. A value of *RAR* larger than one indicates that a firm shifted asset risk to a higher level. The median *RAR* is 1.012 for the model of M74 and 0.999 for the model of L94, suggesting that during the sample period of 1980 to 1999, firms on average do not alter their asset risk. Since the asset return volatility also depends on many market-specific and industry-specific factors, such as business cycles, interest rates, technological advancements, and product market competition, we also examine the industry adjusted *RAR* (*IRAR*). The sample mean of the *IRAR* is about 0.08 based on both M74 and L94, suggesting that there is no risk-shifting in general.

In Panel B, we report both the means and the medians of stock volatility, asset volatility, and *RAR* for each sample year. The number of firms for each year increases over the sample period, with an average of 3282. Both stock return volatility and asset return volatility display upward trends from 1980s to 1990s. This could be explained by the upward trend of stock volatility in recent years, while the risk adjustment ratio (*RAR*) shows little time trend.

4. Empirical Results

4.1 Default risk and risk shifting

According to the arguments of standard agency paradigm, the risk-shifting game becomes particularly attractive to firms when they are facing high default risk. If a firm's riskiness can be measured by its asset volatility, a firm with a high level of default risk during this time period will attempt to increase the volatility of its asset value next period (i.e. $RAR > 1$). The realized volatility of the asset values may also be determined by market conditions, business cycles, or other economic factors. Compared to its peer firms, however, this firm should have a higher *RAR*. We would expect that *firms in the highest default risk group will shift more risk (higher RAR) than firms in the lower default risk group*.

[Insert Table 2 Here]

To test this hypothesis, each year we rank firms in the sample according to the value of their "default likelihood indicator" and sort them into default risk deciles. We then examine the *IRAR* in each decile.[12] Table 2 presents means and medians of *IRAR* in each default risk decile. There appears to be no clear causal relationship between default risk and *IRAR*. In most years the median *IRAR* in the highest default risk decile appears lower than the median *IRAR* in the

[12] Tests using raw *RAR* yield very similar results.

low risk deciles. As shown in Figure 1, the distribution of mean *IRAR* exhibits a U-shape with respect to the default risk deciles. The mean *IRAR* is higher than the median *IRAR* almost in each decile every year. This shows that a firm prefers to adjust its asset volatility higher when it is far from the default zone. In this case default risk is not a factor in firm's investment decision and since high risk projects usually brings high return, this benefits both the debt and equity holders. This adjustment becomes less preferable when the default risk becomes high since both debtholders and equityholders want to maintain the firm as an integrated entity to keep all of the organizational benefits such as tax shields and future investment opportunities. The firm will moderate its risk exposure as the default risk increases. A firm will increase its asset risk dramatically only when the default risk is extremely high and maintaining current projects means the loss of equity value as an "out-of-money" option. The averaged medians and means among all sample years are depicted in Figure 1. The solid line is the averaged medians based on M74 and dashed line is based on L94; the dash-dotted line is the averaged means based on M74 and dotted line is based on L94. The pooled sample mean and median in each risk decile are similar as the averaged ones depicted in Figure 1.

[Insert Figure 1 Here]

4.2 Firm's Characteristics and risk shifting

The above results, especially the relationship between the medians of *IRAR* and the default risk, do not seem to support the hypothesis that firms facing high default risk engage in more risk shifting. However, we must keep in mind that the univariate analysis may be misleading because the default risk variable could be correlated with other firm characteristics, such as firm size, debt ratio, and current asset volatility, which also affect the firm's incentive and capability to shift risk. The risk shifting hypothesis should be understood in the sense of "other things being the same" and must be examined after we control for these factors.

[Insert Table 3 Here]

To address this concern, we examine the differences in various firm characteristics between firms in the highest default risk decile and the other nine-tenths of the sample with lower default risks.[13] Firm size is the sum of the book value of debt and the market value of common equity. The Long-term debt ratio is total long-term debt divided by firm size. Table 3 reports the difference in mean and median between the two groups in Panel A, B, C and D respectively for both models of M74 and L94. The two groups are significantly different in many aspects. By construction, both the medians and the means of the default likelihood indicators in the highest default risk decile are significantly higher than their counterparties in the lower default risk group. Compared to the firms with lower default risk, the firms in the highest default risk decile are significantly smaller in firm size (about 3-5 times smaller except the difference of the means in Leland's model is relatively smaller) and have a long-term debt ratio more than twice as high in their capital structure. While the means of *RAR* and *IRAR* based on the two models are significantly different between two risk groups, the difference of medians in *RAR* and *IRAR* between two default risk groups is either insignificant for the model of M74 or in the

[13] In the analysis, we do not compare firms between different default risk deciles because there may not exists a definite relationship between default risk and risk shifting when default risk is not very high. Instead we would like to identify the firms facing extremely high default risk only. As emphasized by Brealey and Myers (1991), aggressive risk shifting is more likely to occur in firms under extreme financial distress. We have also examined the differences between firms in the highest default risk *quintiles* and the rest of the sample, and the results are qualitatively similar to those reported in the paper.

opposite direction for the model of L94. In addition, the highest default risk group has significantly higher asset volatility in existing projects (about 1.5 times higher) based on these two models. Parrino and Weisbach (1999) point out that for a firm with high cash flow volatility in the existing asset, there are not many higher risk projects in its investment opportunity set that can increase its overall asset volatility any further. Therefore, the high level of current asset volatility in firms with the highest default risk may prevent us from observing any significant risk-shifting behavior.

[Insert Table 4 Here]

To clarify the above issue, we must control for the current asset volatility when examining the relationship between default risk and risk-shifting behavior. We first sort the sample into default risk deciles for every year, and then reclassify the sample into quintiles according to current asset volatility in the same year. In each asset volatility quintile, we examine the difference in the mean and median *IRAR* between the firms in the highest default risk decile and those in the lower default risk deciles, and the results are reported in Table 4. We observe a monotonically increasing relationship between the number of high default risk firm and asset volatility based on M74, however, both lowest and highest asset volatility quintiles have more high default risk firms based on L94. Based on both models, the mean of risk-shifting variables (*IRAR*) is monotonically decreasing with asset volatility in both low and high default risk groups, which is consistent with the evidence documented in Parrino and Weisbach (1999).[14] In each

[14] The inclusion of default risk in our sorting rules out the possibility that the dependence between IRAR and the current asset volatility is purely caused by a reversion of estimation error in the asset volatility since the mean IRAR in a group with high default risk and high asset volatility could be much higher than that in a group with low default risk and low asset volatility.

asset volatility quintile, firms in the highest default risk decile have higher mean *IRAR* compared to firms in the rest of the sample, and the difference is statistically significant (except in the lowest asset volatility quintile for the model of). For the model of M74, the difference of medians between firms in the highest default risk and firms in the rest of sample are significantly positive except in the highest asset volatility quintile. This indicates that, after controlling for current asset volatility, firms tend to increase asset risk more when they face a high probability of default. However, in the highest asset volatility quintile, the difference of the medians is in the opposite direction. One possible explanation is that asset volatility is so high in this group that it may overwhelm any impact of default risk on risk shifting behavior. High asset volatility from the existing projects restricts a firm from shifting risk to any higher level. Furthermore, in the model of L94, the difference of median *IRAR* between two risk groups does not support the risk-shifting hypothesis even after we control for the current asset volatility. Further detailed study shows that this contradiction to the risk-shifting hypothesis is due to the nonlinearity between default risk and *IRAR*. Figure 2 plots the mean of *IRAR* in each cell of default risk and asset volatility decile. It shows that firms in the highest default risk decile posses relatively higher *IRAR*. However the comparison between firms in the highest default risk decile and other firms in the sample can be confused due to the high asset volatility and the "U-shape" in the relationship of default risk and *IRAR*. For example, in the model of M74, firms in both lowest and highest default deciles exhibit significant risk-shifting when their current asset volatilities are in the lowest decile. For firms in the highest asset volatility decile, their *IRAR* are almost same cross all default risk deciles. For firms with modest current asset volatility, risk-shifting is pronounced in highest default risk decile only. For the results obtained from the model of L94, the nonlinearity between default risk and *IRAR* is more severe.

As shown in Table 3, the probability of default is significantly correlated with several firm characteristics, including current asset volatility, firm size, and long-term debt ratio. A better specification in regressions should accounts for the effect of all these firm characteristics. Results in Table 4 indicate that controlling for asset volatility is important and the relationship between current asset volatility and risk-shifting is negative. Large firms regularly enter debt markets for financing, and have incentive to mitigate the risk-shifting problem so as to reduce the cost of debt financing because the adverse consequence of the risk-shifting problem is anticipated by debtholders, and ultimately borne by the equityholders through an increased cost of debt financing. As a result, we would expect a negative relationship between firm size and risk-shifting behavior. The long-term debt ratio is expected to be positively related to *IRAR*, since a large amount of debt would lead to a more severe risk-shifting problem. To further segment these effects on the risk-shifting behavior, we conduct multivariate regressions to explain the industry adjusted risk adjustment ratio. The independent variables include logarithm of firm size, long-term debt ratio, current asset volatility, and a default risk dummy variable that equals to one for firms in the highest default risk decile and zero for the rest of the sample.

[Insert Table 5 Here]

Our sample includes time-series and cross-sectional data, pooled cross-sectional regressions are not appropriate since serial correlation of regression errors could bias the estimates and overstate their associated *t*-statistics. Thus we employ Fama-MacBeth (1973) regressions in which we first conduct cross-sectional regressions for each year. The coefficients are then averaged over the time series, and their associated *t*-statistics are computed following

Newey and West (1987) to adjust for heteroscedasticity and serial correlation. We present the results of cross-sectional regressions for each year in table 5 and the aggregated results from the Fama-MacBeth (1973) method are report at the bottom of the table. Results in Panel A and B are based on M74 and L94 respectively.

Since we use the industry adjusted *RAR* as the dependent variable, any industry effect on the risk-shifting incentive has been controlled in the analysis. The adjusted R^2 of the cross-sectional regressions varies over time, ranging from 5.2% to 25.3% in Merton's model and 4.6% to 29.1% in Leland's model. On average the model explains about 9% of the variation in the risk-shifting variable, *IRAR*.

The default risk dummy captures the difference between firms in the highest default risk decile and the rest of the sample. The coefficients on this dummy are all positive except in 1999 for the model of L94. The values of these coefficients vary significantly over the sample period, ranging from 0.02 to 0.38 based on M74 and from -0.007 to 0.49 based on L94. The average value of the coefficients on the default risk dummy is 0.22 in Merton's model and 0.15 in Leland's model. The corresponding Newey and West (1987) adjusted *t*-statistic is 9.25 in the model of M74 and L94 respectively. This result strongly supports our proposition that firms tend to shift more risk when they face a high probability of default. Furthermore, the effect of default risk is economically significant. The value of the coefficient on the default risk dummy equals to the difference of *IRAR* between the high and low default risk groups, holding everything else equal. It suggests that firms in the highest default risk decile increase asset volatility about 15% or 22% more in the subsequent year, compared to their industry peers.

The coefficients on current asset volatility are negative for all the twenty regressions over the sample period of 1980 to 1999 in both models of M74 and L94, and the average value is –

0.535 with a *t*-statistic of –11.13 in the model of M74 and -0.501 with -12.16 in the model of L94. This result is consistent with our findings in Table 4. The coefficients on firm size are negative for all regressions, and the average value is statistically significant, suggesting that larger firms are less likely to shift risk. This is because they often rely on the public debt market and have an incentive to reduce the cost of debt financing. To our surprise, the coefficient on long-term debt ratio is also statistically significantly negative.[15] This may be explained by the fact that larger firms use more long-term debt in their capital structure (Harris and Raviv, 1991) and firms with large amounts of debt are usually those relying on the debt market for financing, thereby having strong incentives to avoid any debt agency problem, like risk-shifting. For this reason, the long-term debt ratio could be negatively related to *IRAR*. It is also suggested by Leland (1998) that "agency cost may not be positively associated with optimally chosen levels of leverage."

4.3 Stock performance and risk shifting

Empirical studies have documented that mutual fund and hedge fund managers tend to take more risk subsequent to a relatively poor fund performance (Brown, Harlow and Starks, 1996; Brown, Goetzmann and Park, 2001). Motivation for this behavior is that fund managers' compensations depend on the recent performance of the fund. In industrial companies, poor stock performance may also motivate managers to take more risk since managers are often compensated with stock options. As a result, we expect that a poorly performing stock would be associated with a high risk adjustment ratio.

[Insert Table 6 Here]

[15] However a univariate regression shows that the coefficient on long-term debt ratio is significantly positive.

To test this hypothesis, for each year-end we sort the sample into stock return deciles according to the total return of the firm's stock that year. We define a performance dummy variable that is equal to one for firms in the lowest stock return decile and zero for the rest of the sample. Multivariate regressions are conducted to examine the impact of poor stock performance on risk-shifting behavior, and the results are reported in Table 6. The coefficients on the poor stock return dummy are positive in most years. The average value of these coefficients is 0.037 and 0.022 based on M74 and L94 respectively. They are much smaller than their counterparts on the default risk dummy, and are only marginally significant. Firms shift much less risk as they experience a poor stock performance than the case when they face high default probability. The magnitude and statistic significance of the coefficients on firm size and current asset volatility are similar to those reported in Table 5 when we include the high default risk dummy. The coefficient on long-term debt ratio is negative but only marginally significant.

4.4 Robustness tests

In this study so far, we have adopted Merton's (1974) and Leland's (1994) contingent-claims models to infer the market values of a firm's assets, the associated volatilities, and default probability from its stock price history and book value of the debt. While our above results generally support the conventional wisdom that a levered firm would take more risk when it faces financial distress, such as high probability of default or poor stock performance, one concern remains. The concern is whether there exist some model misspecifications that systematically bias the results and cause a spurious relationship to arise. To address this concern, we conduct two robustness tests.

In the first test, we examine the relationship between risk shifting and default probability based on two alternatively measures of default risk. These are Altman's (1968) Z-score and Ohlson's (1980) O-score, which are based on accounting information only and are well accepted in the empirical literature.[16]

[Insert Table 7 Here]

As shown in Panel A of Table 7, the Z-score is significantly negatively correlated with our default likelihood indicator derived from the contingent-claims models. The Spearman rank correlation coefficient between Z-score and the default risk indicator is -0.55 and -0.59 based on the model of M74 and L94 respectively. The O-score is significantly positively correlated with our default probability measures with a correlation coefficient of 0.58 to the default risk indicator derived from the model of M74 and 0.60 to the one derived from the model of L94. The rank correlation between default risk indicators derived from two contingent-claims models is 0.94.

In the second test, we use the monthly bond data from Lehman Brothers Bond database (LBBD) to estimate the monthly market values of firm's total debt in a subset of our sample and calculate the annual volatility of firm's asset value. Since LBBD includes investment grade bonds only (also include "fallen angels") it is not appropriate to test the risk shifting behavior directly in this sub sample. We, instead, compare this volatility with those calculated based on M74 and L94. Panel B, C of table 7 reports the Spearman rank correlation among these three estimated asset volatilities and RAR respectively. Asset volatility estimated based on LBBD is

[16] These measures are recently used in Dichev (1998), and Griffin and Lemmon (2002) in studying the relationship between a firm's default risk and stock returns.

positively correlated with the computed volatility measures with a correlation coefficient of 0.70 and 0.71 respectively. RAR estimated based on LBBD is also positively correlated with the computed RAR based on M74 and L94 with a correlation coefficient of 0.55 and 0.50 respectively. All correlation coefficients are statistically significant.

5. Conclusion

Based on the agency literature, when management interests are completely aligned with the interest of equityholders, they have incentive to increase the firm's riskiness. However, there exist many mechanisms preventing them from exploiting the debtholders. The significance of the risk-shifting remains questionable. The positive evidence on risk-shifting behavior has been empirically documented in the financial industry (Esty, 1997a, b; Brown, Harlow and Starks, 1996; Chevalier and Ellison, 1997; Brown, Goetzmann and Park, 2001), but there is little direct empirical evidence of risk-shifting in industrial firms. This is because the market value of assets for industrial firms is unobservable. In this study, we fill this lack by employing contingent-claims methodology (Merton, 1974; Leland, 1994) to infer the market value of assets, asset volatility, and default probability from stock price history and the book value of debt. We find that firms, in the high default risk group or the poor recent stock performance group, tend to increase asset risk more subsequently, relative to their industry peers. This evidence is consistent with the conventional wisdom and many theoretical models.

Our empirical result extends the risk-shifting theory further. It shows that the relation between a firm's risk shifting behavior and its default risk is highly nonlinear. The curve of firm's "risk adjustment ratio" and its default risk exhibits a "U-shape." Firms in both lowest and highest default risk groups tend to take more risk and raise the volatility of their assets. When a firm is far enough from default, it has incentive to increase firm's risk to pursue a higher return since high returns are often associated with high risks. As a firm's default risk increases, it will reduce its risk exposure in order to avoid entering the default zone since default incurs a cost to both debtholders and equityholders. When a firm is very close to default, the firm's equityholders will increase firm's risk dramatically and the firm enters a "gambler's region" since the equityholders have limited liability. If the gamble successes, the equityholders win; if the gamble fails, the debtholders bear the loss.

In addition, we find that firm's risk-shifting behavior is also strongly related to its characteristics, such as firm size, leverage ratio, and current asset volatility in particular. The correlations between firm's risk adjustment and firm size, leverage ratio and asset volatility are all negative. The nonlinearity between the firm's default risk and its risk-shifting is more significant when a firm has relatively low current asset volatility. Alternative specifications of default risk and firm's bond price data confirm that our findings are robust to the choice of default risk measure.

The contribution of this study is two fold. First, we adopt the contingent-claims models to jointly estimate the market value of assets and default risk. This methodology allows us for the first time to directly examine the change of asset risk for industrial firms so that their risk-shifting behavior could be evaluated. Most of the previous empirical studies could only assess the risk-shifting problem using proxy variables rather than taking a direct approach. Second, we extend studies of the debt agency problem by documenting direct evidence of risk-shifting behavior in industrial firms, and the relationship between risk-shifting and various firm characteristics. Our results support the implications of many theoretical models. The negative relationship between risk shifting and current asset volatility may result from the difference in investment flexibility between industrial firms and financial firms. Industrial firms may not have as much flexibility as financial firms in adjusting their asset volatility, especially the volatility in existing projects.

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Table 1. Sample Summary Statistics

Panel A reports summary statistics for the entire sample from 1980 to 1999. Panel B reports the medians of stock volatility, asset volatility, and default likelihood indicator (DLI) in each sample year, which are estimated based on the contingent claims models described in section 2. The “risk adjustment ratio” (RAR) that measures the firm’s risk-shifting behavior, is defined as the ratio of asset volatility next year and asset volatility this year. Industry adjusted risk adjustment ratio (IRAR) is the difference between RAR and the median RAR of the firms in the same two-digit SIC coded industry and in the same year.

Panel A: Sample statistics

Variables	NOBS	Mean	Median	Std Dev	Min	Max
Stock Volatility	65631	0.5987	0.5019	0.3795	0.1416	2.2809
Asset Volatility (Merton)	65631	0.4919	0.3972	0.3407	0.0947	2.0775
Asset Volatility (Leland)	65631	0.4768	0.3716	0.3426	0.1091	2.0396
DLI (Merton)	65631	0.0456	0.0000	0.1392	0.0000	0.7838
DLI (Leland)	65631	0.0128	0.0000	0.0541	0.0000	0.3854
RAR (Merton)	65631	1.1108	1.0122	0.4901	0.3547	3.6213
RAR (Leland)	65631	1.0926	0.9990	0.4792	0.3407	3.5073
IRAR (Merton)	65631	0.0880	0	0.4719	-1.3708	2.9550
IRAR (Leland)	65631	0.0832	0	0.4581	-1.2939	2.8320

Panel B: Means of stock volatility, asset volatility, and RAR for each sample year

Year	NOBS	Mean Stock Volatility	Mean Asset Volatility (Merton)	Mean RAR (Merton)	Mean Asset Volatility (Leland)	Mean RAR (Leland)
1980	2884	0.4871	0.3787	0.9690	0.4138	0.8946
1981	2926	0.4487	0.3616	1.0788	0.3756	0.9903
1982	3098	0.4903	0.3847	1.1041	0.3803	1.0391
1983	3071	0.4879	0.4062	0.9475	0.3955	0.9514
1984	3262	0.4501	0.3688	1.1310	0.3620	1.0873
1985	3188	0.4776	0.3916	1.2213	0.3786	1.1948
1986	3134	0.5379	0.4448	1.3425	0.4300	1.3216
1987	3249	0.6731	0.5565	0.8452	0.5384	0.8086
1988	3258	0.5706	0.4601	1.0209	0.4335	1.0268
1989	3137	0.5355	0.4298	1.3077	0.4058	1.2372
1990	3140	0.6576	0.5128	1.1451	0.4729	1.1649
1991	3094	0.6808	0.5407	1.1871	0.5002	1.2142
1992	3208	0.7129	0.5856	1.0802	0.5608	1.0307
1993	3319	0.6840	0.5787	1.0239	0.5532	1.1174
1994	3444	0.6149	0.5248	1.0599	0.5161	1.0071
1995	3560	0.6075	0.5125	1.1171	0.4941	1.1006
1996	3615	0.6253	0.5316	1.0737	0.5109	1.0814
1997	3736	0.6395	0.5402	1.2424	0.5228	1.2477
1998	3807	0.7461	0.6209	1.0716	0.6060	1.0694
1999	3501	0.7594	0.6218	1.2272	0.6070	1.2246
Average	3282	0.5943	0.4876	1.1098	0.4729	1.0905

Panel C: Medians of stock volatility, asset volatility, and RAR for each sample year

Year	NOBS	Median Stock Volatility	Median Asset Volatility (Merton)	Median RAR (Merton)	Median Asset Volatility (Leland)	Median RAR (Leland)
1980	2884	0.4370	0.3304	0.9031	0.3620	0.8357
1981	2926	0.4021	0.3112	1.0096	0.3154	0.9324
1982	3098	0.4366	0.3335	0.9875	0.3178	0.9445
1983	3071	0.4288	0.3507	0.8883	0.3333	0.9003
1984	3262	0.3858	0.3119	0.9925	0.3000	0.9646
1985	3188	0.4063	0.3242	1.1121	0.3023	1.0953
1986	3134	0.4531	0.3661	1.2737	0.3415	1.2504
1987	3249	0.6101	0.4851	0.7498	0.4595	0.7209
1988	3258	0.4769	0.3741	0.9255	0.3326	0.9480
1989	3137	0.4448	0.3533	1.2020	0.3190	1.1334
1990	3140	0.5534	0.4207	1.0433	0.3677	1.0661
1991	3094	0.5677	0.4378	0.9985	0.3823	1.0323
1992	3208	0.5890	0.4783	0.9763	0.4278	0.9164
1993	3319	0.5645	0.4690	0.9573	0.4348	1.0456
1994	3444	0.5137	0.4251	0.9747	0.4021	0.9315
1995	3560	0.5075	0.4104	1.0490	0.3805	1.0314
1996	3615	0.5507	0.4471	1.0046	0.4223	1.0023
1997	3736	0.5544	0.4558	1.1637	0.4371	1.1681
1998	3807	0.6577	0.5184	0.9892	0.5048	0.9860
1999	3501	0.6660	0.5085	1.1452	0.4895	1.1434
Average	3282	0.5103	0.4056	1.0173	0.3816	1.0024

Table 2. Industry adjusted risk adjustment ratio (IRAR) and default risk deciles.

This table reports the medians and means of the industry adjusted risk adjustment ratio (IRAR) in each default risk decile for every sample year. Asset volatility and default likelihood indicator are estimated based on the contingent claims models described in section 2. Each year firms are assigned into default risk deciles according to the value of their default likelihood indicators.

(A) Means of IRAR based on Merton's (1974) model

	Default Risk Deciles									
Year	L	2	3	4	5	6	7	8	9	H
1980	0.1517	0.0769	0.1157	0.0603	0.0624	0.0496	0.0256	0.0122	0.0405	0.0565
1981	0.2173	0.1232	0.0801	0.0366	0.0166	-0.0179	0.0234	0.0140	0.0170	0.1180
1982	0.1917	0.1193	0.0973	0.0689	0.0960	0.0906	0.0772	0.0951	0.0554	0.1721
1983	0.1768	0.1012	0.0945	0.0287	0.0299	0.0297	0.0060	-0.0047	0.0512	0.1059
1984	0.3828	0.1966	0.1311	0.0967	0.0379	0.0931	0.0698	0.0490	0.0805	0.2424
1985	0.2053	0.1846	0.1156	0.0869	0.0357	0.0537	0.0133	0.0117	0.0622	0.1865
1986	0.2636	0.1629	0.1006	0.0804	0.0733	0.0220	-0.0020	0.0117	-0.0642	0.0388
1987	0.0910	0.0169	0.0467	0.0622	0.0377	0.0359	0.0855	0.0909	0.1678	0.2756
1988	0.1917	0.1028	0.0501	0.0758	0.0264	0.0716	0.0715	0.0612	0.0877	0.1524
1989	0.2329	0.0948	0.0607	0.0973	0.0904	0.0369	0.0853	0.0568	0.0573	0.2230
1990	0.1160	0.0804	0.0717	0.1022	0.0442	0.0513	0.0560	0.0830	0.0805	0.3104
1991	0.2277	0.0904	0.0998	0.1368	0.1321	0.1225	0.1701	0.2049	0.2720	0.3200
1992	0.1339	0.0652	0.0488	0.0978	0.0542	0.0481	0.0818	0.0999	0.1160	0.2492
1993	0.0905	0.1090	0.0549	0.0192	0.0344	0.0400	0.0507	0.0345	0.0361	0.1597
1994	0.0646	0.0434	0.0587	0.0613	0.0924	0.0516	0.0667	0.0659	0.0847	0.2211
1995	0.1471	0.1444	0.0545	0.0570	0.0395	0.0093	0.0488	0.0189	0.0113	0.1139
1996	0.1934	0.1189	0.0852	0.0570	0.0583	0.0415	0.0220	0.0020	0.0368	0.0758
1997	0.1777	0.1225	0.1053	0.1344	0.0417	-0.0016	0.0043	0.0314	0.0242	0.1510
1998	0.1505	0.0937	0.1073	0.0805	0.0624	0.0212	0.0265	0.0524	0.0673	0.1296
1999	0.2083	0.1596	0.0756	0.0623	0.0477	0.0158	-0.0016	0.0174	0.0331	0.1216
Average	0.1807	0.1103	0.0827	0.0751	0.0557	0.0432	0.0491	0.0504	0.0659	0.1712

(B) Medians of IRAR based on Merton's (1974) model

	Default Risk Decile									
Year	L	2	3	4	5	6	7	8	9	H
1980	0.0633	0.0051	0.0206	-0.0063	0.0293	-0.0059	-0.0154	-0.0449	-0.0273	-0.0441
1981	0.1114	0.0646	0.0405	0.0069	-0.0013	-0.0306	-0.0458	-0.0422	-0.0477	-0.0384
1982	0.0270	0.0206	0.0125	-0.0254	0.0153	0.0067	-0.0058	-0.0005	-0.0194	-0.0186
1983	0.1042	0.0484	0.0290	0.0000	-0.0124	-0.0178	-0.0492	-0.0501	-0.0214	-0.0402
1984	0.1539	0.0521	0.0065	-0.0332	-0.0377	-0.0035	-0.0446	-0.0321	-0.0153	0.0413
1985	0.0943	0.0533	0.0323	0.0146	-0.0255	-0.0284	-0.0553	-0.0512	-0.0273	-0.0104
1986	0.1811	0.1030	0.0352	0.0189	0.0092	-0.0182	-0.0623	-0.0888	-0.1076	-0.0988
1987	-0.0189	-0.0537	-0.0364	-0.0147	-0.0239	-0.0141	0.0100	0.0196	0.0672	0.0924
1988	0.0367	0.0125	-0.0121	0.0023	-0.0142	0.0000	0.0077	-0.0296	0.0010	-0.0228
1989	0.0957	0.0398	-0.0095	0.0041	-0.0268	-0.0223	-0.0171	-0.0300	-0.0518	-0.0172
1990	0.0046	-0.0116	0.0021	0.0079	-0.0241	-0.0076	-0.0110	0.0000	0	0.0727
1991	0.0140	-0.0122	-0.0013	0	-0.0258	-0.0242	0.0083	0.0174	0.0182	0.0091
1992	0.0554	0.0105	-0.0097	-0.0045	-0.0179	-0.0324	-0.0090	0.0125	0.0000	0.0055
1993	0.0526	0.0424	0.0040	-0.0135	-0.0123	-0.0261	-0.0018	-0.0275	-0.0190	0.0165
1994	0.0077	-0.0072	0	-0.0130	0.0001	-0.0213	0.0058	0.0000	-0.0010	0.0487
1995	0.1046	0.0533	0.0028	0.0153	-0.0170	-0.0466	-0.0242	-0.0568	-0.0494	-0.0294
1996	0.1330	0.0448	0.0045	0.0000	0	-0.0262	-0.0541	-0.0808	-0.0435	-0.0021
1997	0.1094	0.0623	0.0278	0.0249	0	-0.0494	-0.0568	-0.0400	-0.0845	-0.0173
1998	0.0944	0.0376	0.0063	-0.0002	-0.0120	-0.0611	-0.0366	-0.0625	0	-0.0014
1999	0.1302	0.0869	0.0201	0	-0.0015	-0.0481	-0.0730	-0.0576	-0.0622	-0.1107
Average	0.0777	0.0326	0.0088	-0.0008	-0.0099	-0.0239	-0.0265	-0.0323	-0.0245	-0.0083

(C) Means of IRAR based on Leland's (1994) model

	Default Risk Deciles									
Year	L	2	3	4	5	6	7	8	9	H
1980	0.1776	0.1010	0.0855	0.0827	0.0316	0.0340	0.0268	0.0057	0.0080	-0.0186
1981	0.2115	0.1249	0.0660	0.0354	0.0497	-0.0225	0.0074	-0.0336	0.0058	0.0671
1982	0.1643	0.0792	0.0699	0.0599	0.0902	0.0948	0.0769	0.0489	0.0394	0.1224
1983	0.1677	0.0792	0.0533	0.0181	0.0137	0.0183	-0.0058	0.0233	0.0297	0.1247
1984	0.3464	0.1349	0.1024	0.1176	0.0746	0.0476	0.0637	0.1016	0.0444	0.1571
1985	0.1979	0.1726	0.1090	0.0886	0.0624	0.0351	0.0187	0.0432	0.0723	0.1886
1986	0.2266	0.1356	0.1105	0.1148	0.0594	0.0131	0.0512	-0.0034	-0.0483	-0.0516
1987	0.0776	0.0186	0.0528	0.0553	0.0706	0.0670	0.0667	0.0983	0.1228	0.2218
1988	0.1441	0.1072	0.0622	0.0399	0.0323	0.0307	0.0626	0.0753	0.0871	0.1614
1989	0.2300	0.1374	0.0697	0.0895	0.0694	0.1110	0.0620	0.0443	0.0843	0.0657
1990	0.0882	0.0571	0.0730	0.0474	0.0546	0.1006	0.0497	0.1088	0.1618	0.2545
1991	0.1105	0.0822	0.1121	0.0998	0.1240	0.1687	0.2494	0.1798	0.3244	0.2787
1992	0.1526	0.0695	0.0826	0.0926	0.0571	0.0754	0.0769	0.1387	0.0904	0.2583
1993	0.0215	0.0664	0.0505	0.0341	0.0323	0.0278	0.0095	0.0483	0.0577	0.2011
1994	0.0861	0.0619	0.0491	0.0566	0.0724	0.0716	0.0896	0.0603	0.1622	0.0739
1995	0.1622	0.1483	0.0686	0.0487	0.0562	0.0363	0.0391	0.0182	0.0060	0.0369
1996	0.1896	0.1054	0.0900	0.0951	0.0536	0.0391	0.0265	0.0101	0.0522	0.0900
1997	0.1559	0.1099	0.1037	0.0995	0.0599	0.0407	0.0190	0.0148	0.0564	0.1223
1998	0.1495	0.1242	0.0788	0.0710	0.1011	0.0363	0.0127	0.0697	0.0900	0.0898
1999	0.2384	0.1567	0.0747	0.0380	0.0548	0.0321	0.0527	0.0112	0.0270	0.0571
Average	0.1649	0.1036	0.0782	0.0692	0.0610	0.0529	0.0528	0.0532	0.0737	0.1250

(D). Medians of IRAR based on Leland's (1994) model

					Default Risk Deciles					
Year	L	2	3	4	5	6	7	8	9	H
1980	0.0967	0.0539	0.0493	0.0453	-0.0021	0.0000	-0.0256	-0.0367	-0.0212	-0.0413
1981	0.1432	0.0786	0.0605	0.0039	0.0145	-0.0243	-0.0277	-0.0524	-0.0567	-0.0752
1982	0.0426	0.0166	-0.0013	-0.0085	0.0007	0.0176	0.0000	-0.0263	-0.0477	-0.0266
1983	0.1027	0.0448	0.0073	-0.0094	-0.0211	-0.0514	-0.0545	-0.0142	-0.0173	0.0419
1984	0.1225	0.0502	0.0004	0.0008	-0.0236	-0.0543	-0.0368	-0.0043	-0.0368	0.0061
1985	0.0859	0.0740	0.0035	-0.0029	-0.0072	-0.0405	-0.0354	-0.0363	-0.0232	0.0000
1986	0.1600	0.0718	0.0356	0.0113	0.0190	-0.0636	-0.0105	-0.0868	-0.0977	-0.1396
1987	-0.0159	-0.0327	-0.0185	-0.0355	-0.0029	-0.0002	0.0000	0.0386	0.0437	0.0589
1988	0.0141	-0.0002	-0.0011	-0.0187	-0.0171	-0.0251	0.0013	-0.0031	0.0070	0.0952
1989	0.1328	0.0499	0.0143	0.0000	-0.0161	-0.0092	-0.1039	-0.0310	-0.0748	-0.2031
1990	-0.0033	-0.0187	0.0000	-0.0403	-0.0325	0.0000	-0.0010	0.0335	0.0840	0.0790
1991	-0.0046	0.0000	-0.0209	-0.0051	-0.0413	-0.0122	0.0437	0.0003	0.0499	0.0077
1992	0.0680	0.0365	0.0000	-0.0106	-0.0186	-0.0148	-0.0381	0.0000	-0.0332	-0.0338
1993	-0.0110	0.0001	0.0080	0.0028	-0.0181	-0.0331	-0.0362	-0.0001	0.0000	0.1203
1994	0.0325	0.0102	0.0040	-0.0073	0.0000	-0.0086	0.0120	-0.0139	0.0049	-0.0762
1995	0.1206	0.0761	0.0156	0.0000	0.0099	-0.0435	-0.0510	-0.0513	-0.0499	-0.0632
1996	0.1348	0.0315	0.0131	0.0077	-0.0136	-0.0076	-0.0667	-0.0714	-0.0301	-0.0352
1997	0.0900	0.0503	0.0357	0.0011	-0.0128	-0.0177	-0.1041	-0.0520	-0.0684	-0.0024
1998	0.0918	0.0558	-0.0004	-0.0273	0.0082	-0.0486	-0.0447	-0.0412	0.0000	-0.0340
1999	0.1727	0.0761	0.0071	0.0000	-0.0094	-0.0350	-0.0386	-0.0393	-0.0600	-0.0859
Average	0.0788	0.0362	0.0106	-0.0046	-0.0092	-0.0236	-0.0309	-0.0244	-0.0214	-0.0204

Table 3. Characteristic differences between firms with high and low default risk.

This table presents characteristic differences between firms in high default risk group and low default risk group. Each year we sort the sample into default risk deciles according to the values of their default likelihood indicator. The high default risk group consists of firms in the highest default risk decile, and the rest firms are classified into the low default risk group. Asset volatility and default likelihood indicator (DLI) are estimated based on the contingent claims model described in section 2. The risk adjustment ratio (RAR) is defined as the ratio of asset volatility next year and asset volatility this year. Industry adjusted risk adjustment ratio (IRAR) is the difference between RAR and the median RAR of the firms in the same two-digit SIC coded industry and in the same year. Firm size is the sum of the book value of debt and the market value of common equity. Long-term debt ratio is total long-term debt divided by firm's size. T-test and Wilcoxon rank-sum test are used to examine the difference of means and medians between the two groups respectively.

(A) Sample means of firm's characteristic variables based on Merton's (1974) model

	NOBS	DLI	RAR	IRAR	Asset Volatility	Size	Debt Ratio
High Default Risk	6559	0.402	1.197	0.177	0.770	485.444	0.327
Low Default Risk	59038	0.006	1.101	0.078	0.461	2068.280	0.155
Difference		0.396	0.096	0.098	0.309	-1582.837	0.173
P-value		0.000	0.000	0.000	0.000	0.000	0.000

(B) Sample medians of firm's characteristic variables based on Merton's (1974) model

	NOBS	DLI	RAR	IRAR	Asset Volatility	Size	Debt Ratio
High Default Risk	6559	0.346	1.012	0.002	0.613	47.083	0.326
Low Default Risk	59038	0.000	1.012	0.000	0.383	153.066	0.121
Difference		0.346	0.000	0.002	0.231	-105.983	0.204
P-value		0.000	0.142	0.883	0.000	0.000	0.000

(C) Sample means of firm's characteristic variables based on Leland's (1994) model

	NOBS	DLI	RAR	IRAR	Asset Volatility	Size	Debt Ratio
High Default Risk	6563	0.124	1.125	0.128	0.682	1611.007	0.319
Low Default Risk	59068	0.000	1.089	0.078	0.454	1943.243	0.156
Difference		0.123	0.036	0.050	0.228	-332.236	0.163
P-value		0.000	0.000	0.000	0.000	0.030	0.000

(D) Sample medians of firm's characteristic variables based on Leland's (1994) model

	NOBS	DLI	RAR	IRAR	Asset Volatility	Size	Debt Ratio
High Default Risk	6563	0.067	0.969	-0.002	0.466	54.200	0.323
Low Default Risk	59068	0.000	1.000	0.000	0.365	149.000	0.123
Difference		0.067	-0.033	-0.002	0.101	-95.200	0.200
P-value		0.000	0.000	0.004	0.000	0.000	0.000

Table 4. Differences in the risk-shifting behavior between firms with high and low default risk conditional on current asset volatility

This table reports differences in RAR and IRAR between firms in high default risk group and low default risk group in each current asset volatility quintile. Each year we sort the sample into default risk deciles according to the values of their default likelihood indicator. The high default risk group consists of firms in the highest default risk decile, and the rest firms are classified into the low default risk group. The firms are then assigned into current asset volatility quintiles according to their asset volatilities in current year. Asset volatility and default risk indicator are estimated based on the contingent claims models described in section 2. The risk adjustment ratio is defined as the ratio of asset volatility next year and asset volatility this year. Industry adjusted risk adjustment ratio (IRAR) is the difference between RAR and the median RAR of the firms in the same two-digit SIC coded industry and in the same year. T-test and Wilcoxon rank-sum test are used to examine the difference of means and medians between the two groups respectively.

(A) Means and medians of IRAR based on Merton's (1974) model

	NOBS		Mean of IRAR			Median of IRAR		
Quintiles of Asset Volatility	High Default Risk	Low Default Risk	High Default Risk	Low Default Risk	*p*-value	High Default Risk	Low Default Risk	*p*-value
L	795	12342	0.4600	0.2104	0.0000	0.1219	0.0758	0.0059
2	709	12421	0.3300	0.0932	0.0000	0.0526	0.0072	0.0002
3	982	12149	0.2331	0.0596	0.0000	0.0429	-0.0034	0.0007
4	1260	11870	0.1929	0.0380	0.0000	0.0393	-0.0173	0.0000
H	2809	10294	0.0162	-0.0264	0.0000	-0.0977	-0.0851	0.0165

(B) Means and medians of IRAR based on Leland's (1994) model

	NOBS		Mean of IRAR			Median of IRAR		
Quintiles of Asset Volatility	High Default Risk	Low Default Risk	High Default Risk	Low Default Risk	*p*-value	High Default Risk	Low Default Risk	*p*-value
L	1214	11820	0.2081	0.1886	0.1872	0.0452	0.0664	0.0006
2	921	12104	0.2017	0.0997	0.0000	-0.0185	0.0074	0.0068
3	951	12074	0.1955	0.0711	0.0000	-0.0104	-0.0014	0.4755
4	1010	12015	0.1866	0.0535	0.0000	0.0236	-0.0097	0.0002
H	2408	10589	-0.0091	-0.0312	0.0308	-0.1117	-0.0842	0.0008

Table 5. Default risk and industry adjusted risk adjustment ratio (IRAR) in multivariate regressions

This table presents results of cross-sectional regressions for each sample year in Panel A, and Fama-MacBeth (1973) regressions in Panel B to explain IRAR. The risk adjustment ratio (RAR) is defined as the ratio of asset volatility next year and asset volatility this year. Industry adjusted risk adjustment ratio (IRAR) is the difference between RAR and the median RAR of the firms in the same two-digit SIC coded industry and in the same year. Each year we rank firms into default risk deciles, and default risk dummy is equal to one for firms in the highest default risk decile, and zero for the rest sample. Log of Size is the logarithm of firm size that is the sum of the book value of debt and market value of common equity. Long-term debt ratio is total long-term debt divided by total assets. Asset volatility is the volatility of asset return, which is estimated based on the contingent claims model described in section 2. T-statistics are adjusted for heteroskedasticity and serial correlation following Newey and West (1987), and reported in the parentheses below each coefficient.

(A) Merton's (1974) model

Year	Intercept	Default Risk Dummy	Log of Size	Long-term Debt Ratio	Current Asset Volatility	Adjusted R^2
1980	0.3787	0.0200	-0.0212	-0.1475	-0.4921	0.0554
1981	0.4295	0.1482	-0.0203	-0.3027	-0.6260	0.0736
1982	0.7794	0.1196	-0.0808	0.0534	-0.8340	0.1737
1983	0.3362	0.1756	-0.0146	-0.2744	-0.4354	0.0471
1984	0.9215	0.2110	-0.0936	-0.1605	-0.9426	0.1495
1985	0.5782	0.2635	-0.0378	-0.1765	-0.7722	0.0980
1986	0.5601	0.2016	-0.0224	-0.3365	-0.7826	0.1270
1987	0.4734	0.2046	-0.0533	0.0068	-0.2836	0.0828
1988	0.5511	0.2171	-0.0455	-0.1393	-0.5319	0.0777
1989	0.5724	0.3255	-0.0359	-0.3188	-0.6346	0.0666
1990	0.6188	0.3803	-0.0551	-0.2026	-0.4997	0.1104
1991	1.4109	0.3363	-0.1619	-0.2699	-0.7571	0.2532
1992	0.6452	0.3221	-0.0593	-0.1602	-0.4187	0.0757
1993	0.4897	0.2391	-0.0449	-0.1343	-0.3315	0.0636
1994	0.5067	0.2280	-0.0498	-0.0749	-0.3253	0.0529
1995	0.4452	0.2019	-0.0298	-0.2718	-0.3786	0.0520
1996	0.3789	0.1604	-0.0171	-0.2214	-0.3686	0.0562
1997	0.6101	0.2610	-0.0408	-0.3603	-0.4972	0.0633
1998	0.6033	0.1628	-0.0421	-0.3595	-0.3761	0.0644
1999	0.5498	0.1570	-0.0269	-0.4165	-0.4088	0.0711
Fama-MacBeth	0.5920	0.2168	-0.0477	-0.2134	-0.5348	0.0907
	(11.2897)	(9.2505)	(-6.3382)	(-7.9236)	(-11.1301)	(7.8925)

(B) Leland's model

Year	Intercept	Default Risk Dummy	Log of Size	Long-term Debt Ratio	Current Asset Volatility	Adjusted R^2
1980	0.3748	0.0358	-0.0173	-0.3681	-0.4125	0.0623
1981	0.3511	0.0862	-0.0104	-0.4561	-0.4480	0.0644
1982	0.6776	0.1351	-0.0665	-0.2426	-0.6540	0.1324
1983	0.3055	0.1246	-0.0105	-0.3083	-0.4407	0.0559
1984	0.8362	0.0868	-0.0852	-0.3118	-0.7817	0.1367
1985	0.5923	0.1901	-0.0382	-0.3530	-0.7664	0.0957
1986	0.5026	0.0996	-0.0191	-0.4073	-0.6796	0.1167
1987	0.4661	0.1474	-0.0505	-0.1100	-0.2560	0.0697
1988	0.5490	0.1373	-0.0464	-0.1510	-0.5455	0.0928
1989	0.5701	0.1272	-0.0372	-0.5843	-0.5248	0.0547
1990	0.6293	0.4935	-0.0622	-0.0565	-0.5028	0.1179
1991	1.4818	0.2739	-0.1729	-0.3598	-0.8203	0.2906
1992	0.7878	0.3419	-0.0751	-0.4591	-0.4504	0.0976
1993	0.3594	0.0282	-0.0336	0.2856	-0.3166	0.0825
1994	0.5407	0.1374	-0.0546	-0.2798	-0.2565	0.0462
1995	0.4778	0.1132	-0.0331	-0.4233	-0.3626	0.0507
1996	0.4787	0.1333	-0.0249	-0.3907	-0.4297	0.0669
1997	0.6444	0.1234	-0.0440	-0.4482	-0.5311	0.0670
1998	0.6664	0.0987	-0.0475	-0.4219	-0.4045	0.0743
1999	0.6038	-0.0073	-0.0324	-0.4266	-0.4263	0.0833
Fama-MacBeth	0.5948	0.1453	-0.0481	-0.3137	-0.5005	0.0929
	(9.9878)	(5.2085)	(-5.6564)	(-8.1559)	(-12.1643)	(7.3425)

Table 6. Stock performance and industry adjusted risk adjustment ratio (IRAR) in multivariate regressions

This table presents results of cross-sectional regressions for each sample year in Panel A, and Fama-MacBeth (1973) regression in Panel B to explain IRAR. The risk adjustment ratio (RAR) is defined as the ratio of asset volatility next year and asset volatility at this year. Industry adjusted risk adjustment ratio (IRAR) is the difference between RAR and the median RAR of the firms in the same two-digit SIC coded industry and in the same year. Each year we rank firms into stock return deciles according to the change of stock price in the year-end. The poor stock return dummy is equal to one for firms in the lowest stock return decile, and zero for the rest sample. LogSize is the logarithm of firm size that is the sum of the book value of debt and market value of common equity. Long-term debt ratio is total long-term debt divided by total assets. Asset volatility is the volatility of asset return, which is estimated based on the contingent claims model described in section 2. T-statistics are adjusted for heteroskedasticity and serial correlation following Newey and West (1987), and reported in the parentheses below each coefficient.

(A) Merton's (1974) model

Year	Intercept	Poor Stock Return Dummy	Log of Size	Long-term Debt Ratio	Current Asset Volatility	Adjusted R^2
1980	0.4325	-0.0544	-0.0220	-0.1168	-0.5055	0.0567
1981	0.3334	0.0887	-0.0232	-0.1797	-0.5706	0.0686
1982	0.7592	-0.0105	-0.0815	0.1753	-0.7785	0.1694
1983	0.2014	0.1003	-0.0167	-0.0974	-0.3315	0.0398
1984	0.8456	0.0434	-0.0955	0.0323	-0.8556	0.1396
1985	0.4626	0.0735	-0.0402	0.0457	-0.6450	0.0820
1986	0.4980	0.0260	-0.0238	-0.1690	-0.6998	0.1167
1987	0.3773	0.0608	-0.0539	0.1687	-0.2216	0.0670
1988	0.4463	0.0625	-0.0464	0.0301	-0.4364	0.0655
1989	0.3280	0.1826	-0.0349	-0.0863	-0.4806	0.0541
1990	0.4886	0.0560	-0.0535	0.0545	-0.3832	0.0701
1991	1.2747	0.0597	-0.1607	-0.0324	-0.6286	0.2362
1992	0.5512	-0.0021	-0.0570	0.1154	-0.2941	0.0473
1993	0.3634	0.0579	-0.0434	0.0716	-0.2274	0.0437
1994	0.3833	0.0697	-0.0492	0.1231	-0.2289	0.0372
1995	0.3958	-0.0064	-0.0291	-0.0782	-0.2975	0.0363
1996	0.2869	0.0499	-0.0166	-0.0743	-0.2973	0.0476
1997	0.5293	0.0271	-0.0420	-0.1315	-0.3960	0.0461
1998	0.6447	-0.0591	-0.0449	-0.2080	-0.3483	0.0569
1999	0.6357	-0.0848	-0.0306	-0.2732	-0.4038	0.0661
Fama-MacBeth	0.5119	0.0370	-0.0483	-0.0315	-0.4515	0.0774
	(10.1420)	(2.5835)	(-6.5975)	(-1.0459)	(-9.6660)	(7.1108)

(B) Leland's (1994) model

Year	Intercept	Poor Stock Return Dummy	Log of Size	Long-term Debt Ratio	Current Asset Volatility	Adjusted R^2
1980	0.4128	-0.0403	-0.0183	-0.3233	-0.4175	0.0627
1981	0.2927	0.0558	-0.0122	-0.3933	-0.4159	0.0623
1982	0.6685	-0.0181	-0.0674	-0.1334	-0.6039	0.1263
1983	0.1984	0.0937	-0.0145	-0.1398	-0.3511	0.0508
1984	0.7995	0.0251	-0.0864	-0.2189	-0.7417	0.1343
1985	0.5064	0.0682	-0.0435	-0.1296	-0.6435	0.0828
1986	0.4653	0.0224	-0.0198	-0.3293	-0.6395	0.1140
1987	0.3956	0.0539	-0.0506	-0.0247	-0.2244	0.0630
1988	0.4930	0.0346	-0.0470	-0.0545	-0.4936	0.0877
1989	0.4000	0.1523	-0.0379	-0.4611	-0.4357	0.0563
1990	0.5750	0.0380	-0.0620	0.0267	-0.4688	0.0943
1991	1.3983	0.0415	-0.1740	-0.1544	-0.7285	0.2780
1992	0.7304	-0.0269	-0.0742	-0.1658	-0.3311	0.0652
1993	0.3103	0.0507	-0.0346	0.3280	-0.2965	0.0832
1994	0.4553	0.0707	-0.0536	-0.2350	-0.2285	0.0458
1995	0.4591	-0.0110	-0.0329	-0.3113	-0.3181	0.0456
1996	0.4308	0.0187	-0.0253	-0.2601	-0.3737	0.0606
1997	0.6353	0.0013	-0.0483	-0.2659	-0.4606	0.0609
1998	0.7318	-0.0698	-0.0503	-0.3278	-0.3943	0.0731
1999	0.7606	-0.1259	-0.0364	-0.4170	-0.4615	0.0884
Fama-MacBeth	0.5559	0.0217	-0.0495	-0.1995	-0.4514	0.0868
	(9.2231)	(1.4816)	(-5.8886)	(-5.0539)	(-12.5536)	(7.7886)

Table 7. Robustness Tests

Panel A reports Spearman rank correlation among our measures of default probability, Altman's Z-score, and Ohlson's O-score. Our measures of default likelihood indicator (DLI) are estimated based on the contingent claims models described in section 2. Low Z-score and high O-score represent high default probability. The *p*-value is reported in parentheses below the correlation coefficients. Panel B present Spearman rank correlation among the asset volatilities calculated based on Lehman Brother Bond Database (LBBD) and those calculated based on Merton's (1974) model and Leland's (1994) model. Panel C present Spearman rank correlation among the risk adjustment ratio (RAR) calculated based on LBBD and those calculated based on Merton's (1974) model and Leland's (1994) model. The *p*-value is reported in the parentheses below each correlation coefficient.

Panel A: Correlation among different measures of default probability

	Default Probability (Merton)	Default Probability (Leland)	Altman's Z-score	Ohlson's O-score
DLI (Merton)	1.0000	0.9377	-0.5461	0.5745
		(<0.0001)	(<0.0001)	(<0.0001)
DLI (Leland)		1.0000	-0.5873	0.6004
			(<.0001)	(<0.0001)
Altman's Z-score			1.0000	-0.6207
				(<0.0001)
Ohlson's O-score				1.0000

Panel B: Correlation among different calculated asset volatilities

	Asset Volatility (LBBD)	Asset Volatility (Merton)	Asset Volatility (Leland)
Asset Volatility	1.0000	0.6976	0.7058
(LBBD)		(<0.0001)	(<0.0001)
Asset Volatility		1.0000	0.8632
(Merton)			(<0.0001)
Asset Volatility			1.0000
(Leland)			

Panel C: Correlation among different calculated RAR

	RAR (LBBD)	RAR (Merton)	RAR (Leland)
RAR (LBBD)	1.0000	0.5534	0.5005
		(<0.0001)	(<0.0001)
RAR (Merton)		1.0000	0.8294
			(<0.0001)
RAR (Leland)			1.0000

Figure 1. The averaged medians and means of industry adjusted risk adjustment ratio (*IRAR*) in each risk decile.

The solid line is the averaged medians based on Merton's (1974) model and dashed line is based on Leland's (1994) model; the dash-dotted line is the averaged means based on Merton's (1974) model and dotted line is based on Leland's (1994) model.

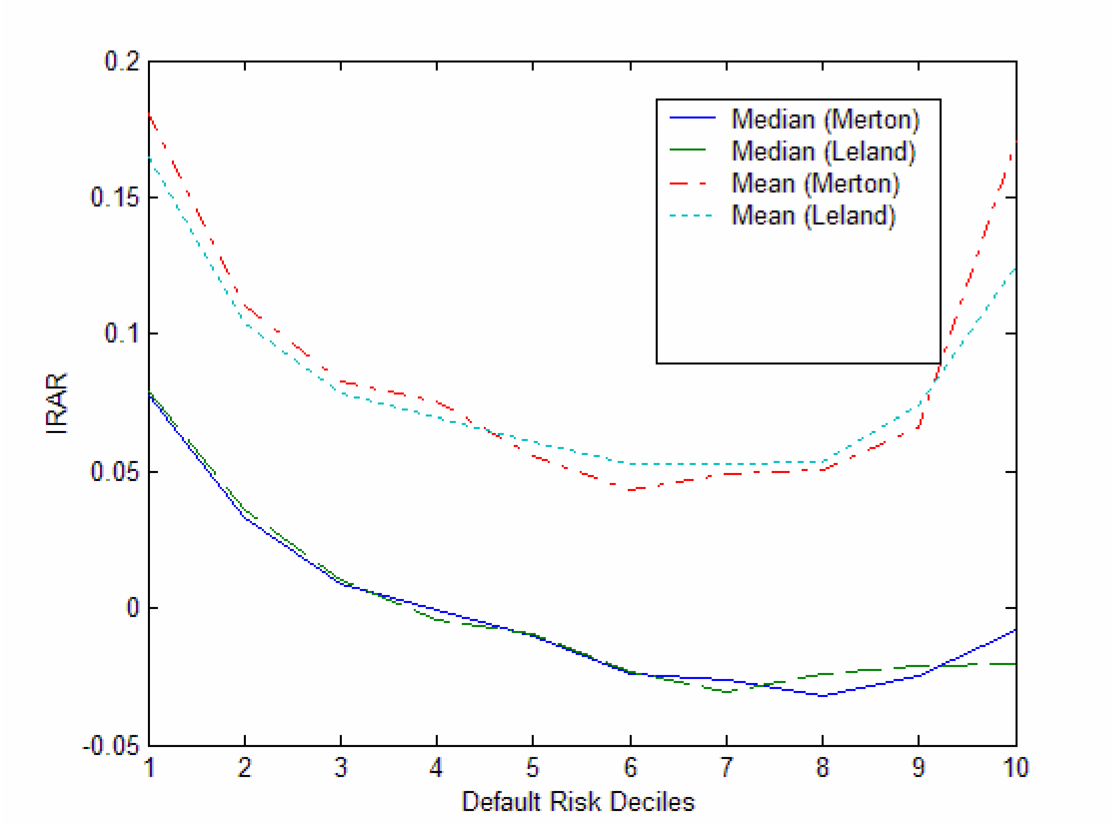
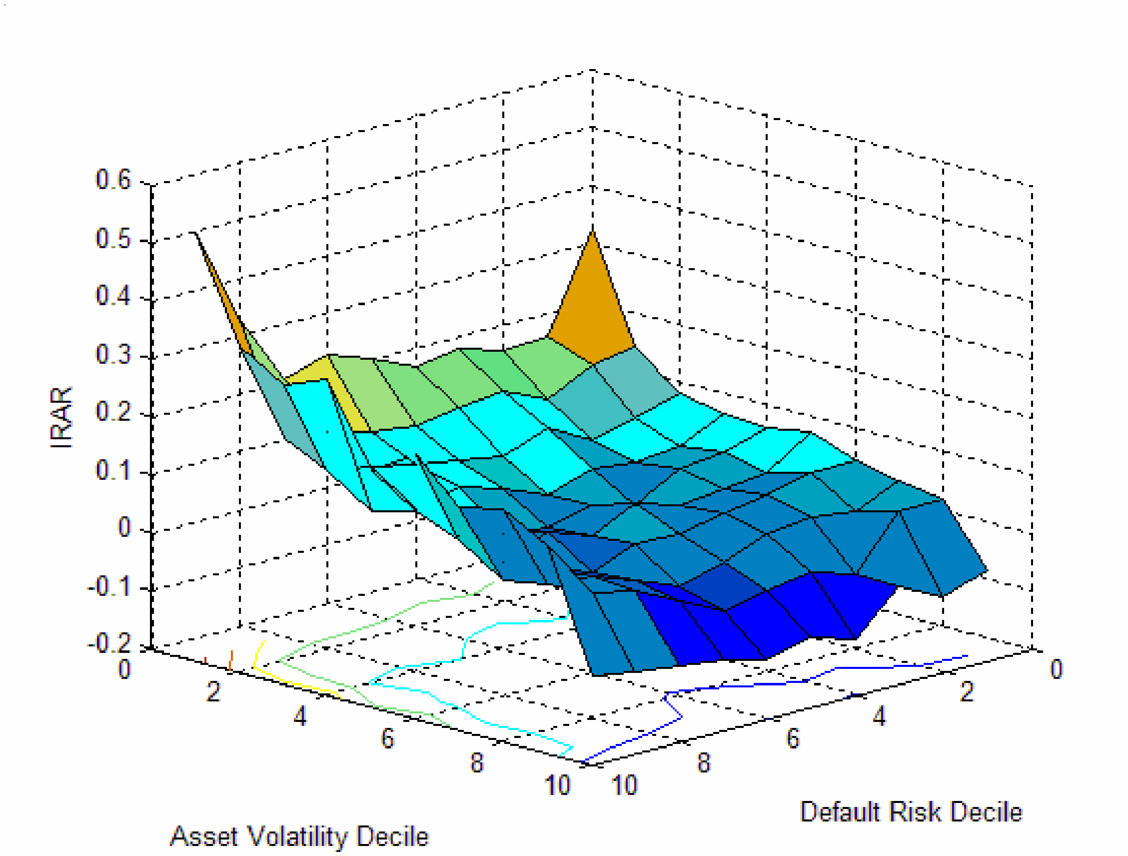


Figure 2. The averaged industry adjusted "risk adjustment ratio" in each default risk and current asset volatility decile.

(A) The relationship of IRAR with asset volatility and default risk based on Merton's (1974) model



(B) The relationship of IRAR with asset volatility and default risk based on Leland's (1994) model