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The effect of risk hedging on capital structure

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Résumé

Cet article examine la relation entre les activités de couverture et la situation d'endettement des entreprises, en utilisant l'ensemble de données de l'industrie minière de 2010 à 2019 en Amérique du Nord. L'activité de couverture est représentée par la valeur nette absolue des instruments dérivés divisée par l'EBITDA, et l'effet de levier est représenté par la distance jusqu'au défaut et le ratio de levier. La mesure de la distance jusqu'au défaut est dérivée du modèle de tarification des options de Black-Scholes-Merton et le ratio de levier est calculé par le total du passif divisé par le total de l'actif. Les résultats montrent que le ratio de couverture décalé d'un an a une relation positive avec la distance jusqu'au défaut et qu'il est robuste à l'effet ferme fixe, et soutiennent que davantage d'émissions de dette est associée à la contraction de la distance jusqu'au défaut. La relation entre le ratio de couverture et le ratio de levier indiqué par le résultat d'un modèle de régression est significativement positive mais n'est pas robuste à l'effet ferme fixe. La recherche montre que la participation à la couverture a une relation positive avec la structure du capital, bien que davantage de facteurs devraient être inclus dans l'exploration plus approfondie.

Mots clés : La détresse financière; activités de couverture; la structure du capital; gestion des risques

Méthodes de recherche : Modèle de régression avec une variable explicative principale décalée.

Abstract

This paper examines the relationship between hedging activities and the leverage situation of corporations, using the dataset of the mining industry from 2010 to 2019 in North America. The hedging activity is represented by the absolute net value of derivative instruments divided by EBITDA, and the leverage is represented by the distance to default and the leverage ratio. The measure of distance to default is derived from the Black-Scholes-Merton option pricing model and the leverage ratio is calculated by total liabilities divided by total assets. Results show that hedging ratio lagged by one year has a positive relation with distance to default and it is robust to fixed firm effect, and support that more debt issuing is associated with the contraction of the distance to default. The relation between hedging ratio and leverage ratio indicated by the result of a regression model is not significantly positive as expected, but is significantly positive in simultaneous equations of distance to default and leverage ratio. The research shows that hedging involvement has a positive relationship with capital structure though more factors should be included in the further exploration.

Keywords : Financial distress; hedging activities; capital structure; risk management

Research methods : Regression model with a lagged main explanatory variable.

Table of contents

List of tables and figures

List of abbreviations and acronyms

dd: Distance to default

EBITDA: Earnings before interest, tax, depreciation and amortization.

Preface

This thesis is an original and unpublished work by the author Jiayu Li, a student who register for MSc in Finance at HEC Montreal in 2018. This thesis has been written to fulfill the graduation requirements .

The main idea of this thesis is originally stemmed from my passion for developing better methods to decide a optimal capital structure which maximize the firm size and reduce the market risk with which firms are commonly faced. My understanding of hedging advantages and leverage control was first sparkled in courses of *Topics of Corporate Finance* and *Risk Management.* The details are developed after the comprehension of a rich set of literatures about the risk hedging and the effect it has imposed on companies. The exploration of database allows me to relate hedging activities to capital allocation.

The research of this topic enriches greatly my knowledge and academic capacity. Hopefully, this thesis can add information for further studies.

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1. Introduction

Hedging strategy has become increasingly popular in the topic of corporate management. It can provide a source of protection for a firm's finance from a risky scenario. Hedging activities include the offsetting position in derivative contracts, the purchase of insurance, the diversification of investments, and the operating division of subsidiaries. Derivative hedging benefits firm value more than nonderivative hedging, and different hedging derivatives can generate different results observed by the market, according to Belghitar, Clark and Judge (2007). Derivative instruments are an important part in risk management, and most notional values of payment for hedging activities are designated to sign derivative contracts according to The International Swaps and Derivatives Association. Why do those firms hedge actively by holding derivatives? Previous theoretical research and empirical studies show that hedging can reduce the distress risk of firms, undermine underinvestment problems, increase debt capacities, and consequently enhance the market value of firms. Boyer and Marin (2013) contend that the presence of foreign currency instruments in the operating transactions is related to the decrease of a firm's financial distress cost. Carter, Rogers, and Simkins (2005) find that hedging activities in the airline industry can mitigate underinvestment problems especially in an unfavorable scenario. Graham and Rogers (2002) argue in their article that corporations conduct hedging activities to increase debt capacity and interest tax deductions. Risk management can add firm value by imposing positive effects according to Allayannis and Weston (2001) and Mackay and Moeller (2007). Since benefits from hedging have been recognized to interact with aspects of liabilities, a reasonable hypothesis that hedging activities tend to be associated with the leverage ratio of firms can be put forward.

From the perspective of the traditional theory of capital structure, if the influence of hedging activities on default risk, agency problems between debtholders and shareholders, and debt capacity is robust and predictable in the realistic financial market, an association with leverage should be noticed. The leverage ratio decides the proportion of bonds in the allocation of capital. According to Miller and Modigliani theory, the benefit of issuing debts is tax deduction and the drawback of issuing debts is distress costs in a perfect market. The following trade-off theory enhances the argument by indicating an optimal point where the tax benefit equals the distress cost and the firm value of firms is maximized. If other factors remain constant, more hedging activities should be in line with a new optimal point and with a higher leverage ratio because the distress possibility is reduced (assuming that mangers tend to consider issuing debts when the firm has more liquidation capacity.) This statement is in favor of previous research on the effects or incentives of firms to hedge. It can be deduced that more active engagements in hedging is related to the increase of leverage ratio. The capital structure can be changed or influenced by hedging activities.

From the perspective of corporation valuation, the development or progress of a firm can be simplified as an initial investment and a set of future operating cash flows. The discounted expected cash flow is the market value of firms and the initial investment reflects the capital structure. By this logic, there are only two sorts of decisions to make for managers: the decision on capital and the decision on the control of cash flows, which can generally determine firm value in the market and the financial situation for investors of firms. These two decisions interact with each other and have a simultaneous effect on the development of firms. This paper aims to examine one side of this intertwined relation: the effect of hedging activities on capital structure. Cash flow hedging can manage certain and quantified risk of the firm, decreasing the volatility of cash flows in the future and probability of default at the maturity of bonds (the uncertain fair value hedging is not included in this paper.) The benefit of hedging tends to cause an upward variation of the leverage ratio. The essential part of the effect of hedging on capital structure is the relation between default risk and hedging activities, which will be checked in this paper. The engagement of hedging activities in the reduction of the expected distress risk of firms by reducing the volatility of future cash flows plays an important role in the leverage choice of firms. I have built a structural model to calculate the distance to default of firms, reflecting the default risk such firms are supposed to face. Further study is conducted by relating the variation of the hedging data to the leverage ratio of companies to see the hedging influence on capital structure.

The sample used in this paper includes 2399 firm-year observations from 361 mining companies during the period from 2010 to 2019 inclusive. The fundamental information and market data are from COMPUSTAT and CRSP via the official website of WRDS. I then hand collect information on derivatives usage from their Securities and Exchange Commission (SEC) filings. The hedging data extracted from manual collection and calculation is scaled by EBITDA, which represents the earnings before interest, taxation, depreciation, and amortization, approximating operating free cash flow of companies. Most empirical studies select a binary variable to measure hedging activities instead of a set of numbers. More informational data in this paper can provide a more constructive perspective on the impacts of hedging instruments. Hedging data is lagged by one year to see the change of response variable in the next financial period.

The results of models show that firms with more hedging instruments in their financial statements are less likely to reach the default threshold, and further exploration on hedging data confirms the hypothesis that the change in hedging activities is associated with the increase of leverage ratio as decided by management. Higher hedging ratio is in line with a longer distance to default and a higher leverage. Results obtained from models with distance to default as a response variable are robust when simultaneous model is added to analysis. The relationship between the hedging data and the leverage ratio of corporations is not stable as expected. It can be interpretated by the fact that firms tend to consider more complex aspects when issuing new debts even when hedging activities provide them with more capacity of leverage. For example, it is widely acknowledged that credit rating and transaction costs are important in issuing debts, but these two factors are not included in models.

The rest of this paper is arranged in a classical way. An overview of prior theoretical research and empirical studies on the topic of risk management and capital structure is featured in the next part. The procedure of the data collection and description of the sample are presented in Section 3. Section 4 illustrates the empirical design, the testable hypothesis, and corresponding equations for a regression model. I then present and discuss the results in Section 5. Finally, this work ends with a conclusion and a suggestion for future investigation..

2. Literature review

Previous theories have focused on the exploration of why some firms engage in hedging activities while some others do not. Researchers have studied characteristics of firms related to hedging procedures. Smith and Stulz (1985) particularize three reasons for value-maximizing firms to hedge: tax structure, distress cost, and operational investment. Contracting costs of debt and the relation between hedging and a firm's investment policies are important determinants of hedging decisions. Companies may hedge in response to incentives to mitigate distress and underinvestment problems. In the contrast, Tufano (1996) argues that the characteristics inherent in maximizing firm value are not practically significant, while managerial risk aversion shows significance on whether a firm tends to engage in hedging activities. According to Dionne and Garand (2003), managerial risk aversion, firm size, investment opportunities, financial health, convex tax function and other features are reported to have an impact on hedging decisions in non-financial firms. It can be interpreted that those firms with certain features are more likely to hold derivatives for hedging purposes than other corporations in the industry. Recent studies explore not only incentives to hedge but also how hedging engagement improves a company's financial situation. Furthermore, the questions of whether hedging involvement satisfies a company's initial requirements of avoiding risks or whether hedge adds any value to the company is explained in many analyses.

Many studies from the last two decades suggest that hedging is treated as a financial choice made by managers to maximize firm value. Most profitable companies regard value maximization as an eventual objective of the initial investment and operating cycle. Recent research attempts to prove that a firm's hedging instruments are likely to increase its valuation. As most of the markets worldwide are imperfect, reduction of exposure to a variety of risks is considered an effective way to add value to firms. Furthermore, increasing firm value can be agreed by most stakeholders even though they may have different risk tolerance and financial preference.

Belghitar, Clark, and Judge (2007) provide empirical evidence of the valuation effect of hedging derivatives, especially foreign currency contracts and forward interest contracts.

The results of their study indicate a significantly positive relationship between firm value and hedging instruments used for foreign currency and interest rates. Hedging activities that control different sources of predicted risks not only reduce the odds of future unhealthy scenarios, but also have a positive impact on tax advantage and debt capacity. It can be deduced that increasing the tax shield and debt tolerance benefit firm market value because more cash is left in the firm and more funds are raised for further investment. They also argue that different types of hedging contracts have different impacts on adding to a firm's value. This finding is impressive: It provides isolated samples of a specific hedging team and non-hedging team without selection bias. The conclusion can help us understand the process of how firm value is improved by certain types of hedging instruments. Many other surveys also reach a similar conclusion. Campello, Lin, Ma, and Zou (2011) find that hedging has direct effect on firm financing decision. They also find proof that hedging lowers financial external costs and eases investment spending. Their study adds new thoughts to the body of knowledge of how hedging instruments increase a firm's wealth. Firms are more capable of obtaining external funds and managing anticipated bankruptcy problems under efficient risk management. Managers, therefore, think highly of risk control after signing a loan contract because a negative relation between loan spread and hedging activities can be found in the study. Considering the prestigious image firms wish to present to the public, they attempt not to deceive creditors and other investors. If hedging can generate some default cushion for corporations, they may be more likely to actively invest or develop more projects. Consequently, in the light of creditors, hedging a firm's cash flow can increase the firm market value. Deshmukh and Vogt (2005), on the other hand, provide evidence that hedging can reduce the use of costly external funds by stabilizing internal cash flow. More investment projects can be funded because of less sensitivity to internal cash flow. Though these two articles have different views on the use of external funds, consent can be reached because ultimately, investment opportunity is more available by engaging in hedging activities. By doing so, a firm's value will be increased. The article written by Allayannis and Weston (2001) uses "hedging premium" to describe the value created by hedging programs. They conduct research by investigating firms exposed to foreign currency risk. The hedging premium of these firms is about 4.87% of the firm value. The results demonstrate that firms holding foreign currency derivatives to hedge exchange rates obviously have higher firm valuation than non-hedging firms. Mackay and Moeller (2007) argue that risk management adds value to the firm when price risk has a nonlinear relationship with revenues and costs (a concave relation reflects the production and supply situation.) Boyer and Marin (2014) summarize the ways risk management has become an important part of value maximization. They list theories and empirical studies of hedging's impact on expected cash flow volatility, probability of default, debt capacity and underinvestment issues.

The theories mentioned above show that hedging instruments increase firm market value by affecting many other financial indexes. However, there is another reasonable explanation for hedging on purpose of value maximization. Engagement in hedging instruments can be a factor in the model determining the required return of equity. The findings of Smithson, Associates and Simkins (2005) suggest that the expected return of equity is affected by a corporation's financial risk. That explains how the market value of the firm can be related to financial risk management. Vassalou and Xing (2004) hold the view that default risk is supposed to be a factor predicting return of stock. This can be interpreted by putting default risk into the Fama-French model. Companies with high default risk earn more return than those with low default risk. Therefore, hedging involvement that reduces default risk may prevent companies from benefiting from increasing equity value. However, this conclusion is strictly based on the assumption that the default risk should be related to firm size and book-to-market value. In the paper written by Purnanandam (2008), shareholders' decision will trade off between expected distress costs and value realized by increased risk. Conversely, Jin and Jorion (2006) investigate US oil and gas corporations and find that a hedging premium does not seem to be significant in determining the market value of a firm; it only reduces the sensitivity of equity price.

The core part of the valuation effect of hedging lies in the reduction of cash flow volatility and the increase of expected cash flow, which is the direct reason why additional firm value can be created by hedging. Possible bad scenarios can be harmful to stakeholders of corporations, so management always shows strong interest in risk controlling. Though shareholders' behaviour is regarded to be irrelevant to hedging programs because of the assumption that shareholders hold a portfolio which diversifies a firm's specific risk (Dionne and Garand (2003)), they are still associated with agent cost such as risk substitution and underinvestment problem when a company approaches a distressed situation. The falling risk due to risk management can reach alignment of principal and agent to some extent because hedging undermines the exposure of managers regardless of the option or stock compensation adapted (Boyer and Marin (2014)). Hedging also improves the compensation mechanism and performance monitoring according to Ashley and Yang (2004). Therefore, engagement of hedging instruments becomes increasingly popular in financial management to avoid bankruptcy and to generate more intrinsic value.

Since the expected cash flow in the future operating cycle is supposed to be discounted to decide the present value of a firm, all sources of risk except default risk are actually the unexpected shock caused by daily transactions and operations which affect cash flow. Distress occurs when firm value cannot cover the face value of debt. The capital structure of a company is closely associated with risks from market and management. Hedging designed to avoid these risks on cash flow can effectively reduce the odds of distress. Trade-off theory of capital structure indicates an optimal debt ratio which maximizes the firm market value and simultaneously minimizes the required return of the whole company in the presence of tax and distress possibility. However, in reality, other leverage benefits, such as the decrease of free cash flow issue, and other leverage costs, such as underinvestment, should also be taken into consideration (Korteweg (2010)). If analysts include agency costs and other aspects when they decide the leverage ratio in the next financial period, there will still be a balance to consider between the advantages and disadvantages of issuing long-term debt or listing short-term liabilities. Graham and Harvey's (2001) survey of 392 CFOs of U.S. firms shows that the majority of managers consider capital structure decisions to be important to a firm's value and that they have a target for the leverage level. Rajan and Zingales (2003) and Frank and Goyal (2004) build a cross-sectional regression model to find determinants of capital structure, the proxy of firm characters which controls the shift of this balance. Korteweg (2010) illustrates that a median firm can obtain benefit form leverage approximately 5.5% of firm value. As hedging can be an important factor affecting the probability of default, which has a straightforward relationship with debt, it should be added to explain the decision of leverage ratio.

Many articles testify the relationship between leverage and hedging. According to Boyer and Marin (2013), a firm's financial distress can be reduced by participating in currency hedging activities because the distance to default is increased, the equity implied volatility of asset is lower, and the moneyness of the debt is decreased. The offsetting position of financial instruments such as derivatives, options, and swaps can reduce or even totally remove one sort of market risk a company may suffer from. The foundation laid here is that hedging can reduce the volatility of future cash flow and probability of default. The article also adds information to the composition of hedging activity by regarding the setting up of foreign subsidiaries and developing of a foreign currency-based debt as hedging. In consequence, bankruptcy costs and other indirect costs induced by financial distress are less likely to impose significant pressure on companies. As proposed by Stulz (1996), hedging effectively reduces the odds of lower or negative realization. The survey of Bhabra and Yao (2011) indicates that total costs related to bankruptcy are more than 6% of a firm's value during a period of three years. If the possibility of liquidation becomes less disturbing for management, the public image will be greater and the conflicts between debtholders and shareholders will be mitigated when the firm is faced with default. Dionne and Triki (2013) build a theoretical model for leverage ratio and hedging data to find their explanatory determinants simultaneously and suggest in their article that hedging does not necessarily improve the direct debt capacity because commodity hedging derivatives may not have a straightforward impact on debt structure. In contrast, Graham and Rogers (2002) find evidence that corporations conduct hedging activities to increase debt capacity and interest tax deductions, but the attempt to reduce expected tax liability arising from convex tax function is not material. Their studies also show that a firm's active hedge is associated with expected distress cost and firm size. Chen and Wang (2011) argue that risk management interacts with liquidity control. Carter, Rogers, and Simkins (2005) investigate the relationship between hedging activity and investment opportunity in airline companies and find that a hedging position can reduce underinvestment problems especially during a bad economy. Underinvestment issue is a situation when costly equity capital makes projects with positive NPV less feasible. Hedging can reduce the variation of cash flow and collect more internal capital. If managers do not have to remain available fund to meet the obligation of the company, they are more likely to invest in a profitable program.

3. Data Collection and Sample Description

3.1 Sample Formation

To figure out the relationship between hedging data and leverage ratio, the mining industry, with SIC beginning from 1000 to 1499, is selected as the subject of study. Many past pieces of research related to hedging have used the gold mining industry to extract data because the market price for primary products of these firms can suffer from substantial changes during the period; furthermore, there exists a plethora of financial instruments designed as an offsetting position to hedge commodity price risk. The first empirical study conducted by Tufano (1996) explored risk management practice in the gold mining industry, and a subsequent study conducted by Dionne and Garand (2003) revisited and expanded the database Tufano used.

I have chosen a 10-year time horizon from 2010 to 2019 which includes an economic cycle and avoids a severe financial crisis. A rich set of firm-based data from COMPUSTAT is examined and 1977 companies' observations are obtained. After eliminating company data which contains less than two-year information, 1875 companies remain in the dataset. To obtain the merging data of CRSP and COMPUSTAT databases, the ncusip from CRSP's monthly stock file is matched to the first eight characters of the cusip from COMPUSTAT. I use the corresponding cusip from COMPUSTAT as an index to search market data from CRSP. Only 375 companies are left after the exact match and two-year data selection.

Quantifying hedging activities is difficult because there are no strict accounting requirements of GAAP to report the amount defined as hedging. The accounting requirements for derivatives are complex, and judgment is required in certain areas such as cash flow hedge accounting and hedge effectiveness testing. The Financial Accounting Standards Board (FASB) has issued SFAS 119 to mandate the disclosure of derivative contracts and their important details. All derivative instruments, other than those that meet the normal purchase and normal sales exception, are recorded at fair market value under GAAP and are included in consolidated balance sheets as assets or liabilities. I search the 10-K forms for firms in the US and 20-F or 6-K forms for firms located in foreign countries on the official website of the Securities and Exchange Commission (SEC) filings, and I also search financial statements of Canadian companies on The System for Electronic Document Analysis and Retrieval (SEDAR) if the information cannot be found on the SEC. The information related to hedges of the company is always reported in the Item 7, *quantitative and qualitative disclosures about market risk*, and in the footnotes for financial sheets. I read every single line of the paragraph associated with hedging description and extract all information about hedges for further process. I assess each instrument contract such as swap agreements or commodity derivatives to determine whether or not it is qualified for special cash flow hedge accounting. In performing the assessment, I make examinations and assumptions about the timing and amounts of future cash flows related to the forecasted purchases of mineral products and sales of the operating period. Some instruments are not designated as hedge accounting under GAAP, but they are firmly defined as holding derivatives in an attempt of hedging. These instruments are regarded as cash flow hedging even though its gains or losses are not listed on the Income Statement. Also, I include other embedded derivatives from royalty obligations, provisional sales which fixate the product price by provisional payment based upon preliminary assays and quoted mineral prices, and contingent consideration arrangements which manage the potential contingent consideration received if commodity prices exceed a particular number several years in the future. Several empirical studies use binary variables to represent hedging activity because the specific amount of hedging activity is hard to measure. However, the dummy variable only shows the existence of hedging procedures but cannot capture the extent of hedging involvement of a company or provide more information. Other studies extract the notional value of hedging derivatives as a proxy of hedging activities of a company. Allayannis and Ofek (2001) use the dollar notional value of foreign currency derivatives in their model to test the incentives to hold exchange instruments. Gay and Nam (1998) define the dollar notional amount of the firm’s derivative position as the derivative usage. Although the notional amount can indicate the scale and depth of a firm's hedging activities, this variable cannot reflect the long or short position in contracts and the netting effect among hedging derivatives. Graham and Rogers (2002) replace the notional amount with the absolute net value of derivative positions in each category of instruments for most analysis. I calculate the absolute net value of hedging derivatives for further measurement of hedging ratio by hand collecting the number from financial reports of each firm during the decade from 2010 to 2019 inclusive. After deleting the missing data and adding hedging information to the merging data, I obtain 2399 year-firm observations for 362 companies in the mining industry.

The structural model is universally used to provide distance to default and probability of default in the study of risk management. The option view of firms observed by Black and Scholes (1973) allows analysts to regard a firm's assets as the underlying asset and equity value as a European call option under an assumption of a very simple capital structure. It also lays the foundation for exploring credit risk because, with a set of observed data, researchers can compute the number of remaining assets for payment of debtholders if the firm goes bankrupt. This is the point where the public can think about the default problem of a firm. A considerable amount of theoretical research supports the importance of the Black-Scholes formula in deciding the default measure. Moreover, prior studies attest to calculating and modeling unobserved parameters in the Black-Scholes-Merton model such as the KMV method. Scientific results mentioned above ease the burden to gauge default data. In this paper, the risk measure of distance to default will be used as a proxy to capture the leverage situation of a firm, the expected distress cost and liquation ability. Acquiring a risk-free rate is the first step to calculating the distance to default. I download the FRB-H15 table from Federal Reserve Board and extract the average annual rate from the daily one-year maturity treasury bill as the risk-free rate. In order to compute a more accurate result, I use daily market data from CRSP to calculate the volatility of stock return. Other calculations for the rest of the parameters in this model can be derived from fundamental data found on COMPUSTAT.

All dataset built for this paper is checked twice to ensure accuracy, and the process of data collection is conducted by the author and volunteers recruited for final agreement to remove personal judgments. The number calculated by hand is revisited and reviewed twice to three times on average. All data tables are guaranteed to be realistic and calibrated to the same level.

3.2 The Definition of Dependent Variables and Explanatory Variables

3.2.1 Dependent Variables

Distance to default is considered an important measure indicating the leverage situation, a firm's assets, and a firm's systematic risk according to Boyer and Marin (2013). This figure can be readily constructed by building a structural model. As mentioned above, if we see corporation securities as a European call option, the position of bondholders in the investment procedure equals owning the firm and have written a call option to shareholders. Companies face distressed problems if the value of firms cannot outperform the face value of total bonds. This helps create a framework using structural method modeling default. The default model proposed by Merton (1974) provides an approach to calculate the probability of default and distance to default. The model has recently become an important theoretical algorithm to interpret credit risk. In fact, distance to default (dd) is the amount of standard deviation to the barrier where unpaid obligations induce a company to be distressed. It has a close association with the probability of default.

$$Prob(A_T < B|A_T) = N\left[-\frac{\ln\left(\frac{A_T}{B}\right) + \left(\alpha - \delta - \frac{{\sigma_A}^2}{2}\right)}{\sigma\sqrt{T}}\right] = N\left(-\hat{d}_2\right) \qquad (1)$$

In the equation (1), A_T is the market value of firm at the time T; B is the face value of total bonds with a maturity of T; α is the expected return of firm during the given period; δ is the continuous dividend yield of firm; σ_A is the volatility of firm; $\hat{d}_2$ is Black-Scholes term in an actual situation (where the firm's expected return on total assets is used to replace risk-free rate). $\hat{d}_2$is supposed to be dd in the mathematical calculation for the proxy of distress risk in prior articles.

$$dd = \frac{\ln(A_T) + \left(\alpha - \delta - \frac{{\sigma_A}^2}{2}\right) - \ln B}{\sigma\sqrt{T}} \qquad (2)$$

With theoretical models and a rich set of data which includes observed variables from the market and derived data from the calculation, the exact value of dd can be computed. The detailed calculation of dd is presented in Appendix (1).

The second dependent variable is the leverage ratio which reflects the financial decision on capital structure. Leverage is widely regarded as an index implying the allocation of fund resources of corporations. Frank and Goyal (2009) use six ratios to measure leverage and focus on one main measurement (the ratio of total debt to the market value of assets.) Dionne and Triki (2003) use the quantity of the book value of the firm's long-term debt divided by its market firm value. The leverage ratio is an explanatory variable for distance to default and also the dependent value of hedging data. I select total liability divided by market value to measure leverage because some short-term liabilities without interest are also a financial choice made by management during transactions and an obligation affecting subsequent decisions.

3.2.2 Explanatory variables

A hedging ratio is created by using the absolute net value of derivative assets held in an attempt to hedging divided by EBITDA (Earnings before interest, tax, depreciation, and amortization.) EBITDA is a similar amount of free cash flow which indicates to some extent the profitability of firms and operating size of all transactions. The denominator is able to remove the effect of different firm sizes at particular developing stages of the hedging decision. Other independent variables for dd come from Altman's (1973) five parameters extracted to predict the possibility of financial failure. Four of these accounting ratios are selected to build regression models. $\frac{Working\ Capital}{Total\ Assets}$ represents the proportion of net current assets available for operation in the whole financial situation. $\frac{EBIT}{Total\ Assets}$ is an important turnover index in determining profitability of firms in corporate analysis because it can reflect the ability a company shows in creating excessive wealth for shareholders and debtholders. $\frac{Retained\ Earnings}{Total\ Assets}$ indicates the rest of the benefits belonging to shareholders after the distribution of net income for the financial period. $\frac{Sales}{Total\ Assets}$ suggests the realization through recurring operations of firms. I leave out the ratio $\frac{Market\ value\ of\ Equity}{Total\ Liability}$ because it actually reflects the leverage of a firm, and leverage choice has been included in the leverage ratio. Other explanatory variables are composed of firm size and liquidity to control the changes in dependent variables.

Independent variables for leverage ratio are decided by following the steps set out by Dionne and Triki (2003). Four classical variables are chosen to control the regression model: The book value of property, plant and equipment of a firm is divided by total assets, highlighting the fixed assets which can be used as collateral when signing a loan and initial and subsequent expenditures coming from the invested fund at the launching of the firm; depreciation and amortization of the current year divided by total assets, which can tell the truth about the tax advantage a firm can obtain by possessing property; the firm's selling, general, and administrative expenses divided by the net sales, which shows the distinctive features of daily operations and the nature of how the company runs the business; operation incomes divided by sales, which provide information about the incomes from operating transactions and capacity for solvency. Other variables for controlling include firm size and market-to-book ratio. Table 1 summarizes the definition of dependent and independent variables in the paper.

Hedging activities are expected to reduce the default risk and increase the dd. Leverage ratio is predicted to have a negative relation with dd because more debt induces more distress consideration. Four ratios from Altman's five accounting variables are supposed to show positive association with dd. Firms with greater economic scale can better deal with distress problem, so firm size has a positive relation with dd. High MtoB ratio shows that the company is growing, the dd, therefore, will decrease because the company does not stabilize its operation and needs to raise funds by debt. On the other hand, ideally, hedging can improve the debt capacity and increase the leverage ratio. Also, collateral assets ($\frac{\text{BV of pp\&eq}}{Total\ Assets}$) can increase the leverage of firms.

Table 1. Variable description

Variables	Definition	Predicted sign for dependent variables	
		dd	Leverage ratio
Hedging ratio	Absolute net value of derivatives hold for hedging divided by EBITDA.	+	+
Leverage ratio	Book value of total liabilities divided by market value of firm	-	
$\frac{Working\ Capital}{Total\ Assets}$	Working capital divided by book value of total assets (COMPUSTAT).	+	
$\frac{EBIT}{Total\ Assets}$	Earnings before interest and tax divided by book value of total assets (COMPUSTAT).	+	
$\frac{Retained\ Earnings}{Total\ Assets}$	Retained earnings divided by book value of total assets (COMPUSTAT).	+	
$\frac{Sales}{Total\ Assets}$	The amount of net sales divided by book value of total assets (COMPUSTAT).	+	
Size	Natural logarithm of total assets (COMPUSTAT).	+	+
Liquidity	Cash and short-term investments divided by current liabilities (COMPUSTAT).	+/-	
MtoB	Market to book ratio (COMPUSTAT).	-	+/-
$\frac{\text{BV of pp\&eq}}{Total\ Assets}$	The firm's book value of property, plant and equipment divided by the book value of total assets (COMPUSTAT).		+
$\frac{Operating\ income}{Sales}$	The firm's operating income divided by its sales (COMPUSTAT).		-
$\frac{\text{Dep \& Amt}}{Total\ Assets}$	Depreciation and amortization divided by the book value of total assets (COMPUSTAT).		-
$\frac{\text{Sga}}{Sales}$	The firm's selling, general, and administrative expenses divided by the sales net of returns , allowances and discounts. (COMPUSTAT).		-

$\frac{\text{Dep \& Amt}}{Total\ Assets}$ (non-debt taxation saving) and $\frac{\text{Sga}}{Sales}$ (special overhead for every firm) are predicted to decrease leverage ratio because adequate tax advantage and less cash inflow make debts less attractive. Operating income ratio is expected to have a negative relation with leverage ratio.

1.3 Sample description

As presented in Table 2 and Figure 2, distance to default across the period experienced a slight increase from 71.58 to 80.35 in the first three years and a subsequent decrease to 41.19 in the next three years. The mean of distance to default for all years is 64.99, indicating companies in the mining industry are relatively far from the default point, though the means of EBIT and retained earnings of firms in the sample remain negative across the decade. The leverage ratio went up gradually from 0.38 to 0.46 for the period. Figures for hedging instruments show fluctuation during the period, and it should be noted that hedging activities are active in 2015 and 2016 even though firms obtain negative free cash flow (EBITDA is minus, and hedging data is absolute value in the sample.) In terms of other explanatory variables, $\frac{Retained\ Earnings}{Total\ Assets}$ shows a general downward from 2011 to 2019; the rest of four accounting ratios from Altman's five credit measurement shows stable ups and downs without any significant change. Other explanatory variables such as $\frac{\text{BV of pp\&eq}}{Total\ Assets}$, $\frac{\text{Dep \& Amt}}{Total\ Assets}$ and sgaA fluctuated during the period, but the figure for $\frac{Operating\ income}{Sales}$ experienced a strong variation process and reached a bottom at -1.52 in 2015. Moreover, it is evident that firm size shows a gradual upward trend through the decade. Market-to-book ratio climbed to its peak at 5.47 in 2015 and decreased to 1.33 sharply in 2017, suggesting a short expansion in the first half of the decade in this industry. The liquidity ratio stabilized at about 1 for the given time horizon except for 1.68 in 2011. Three independent variables for leverage ratio did not see remarkable variation during the time interval.

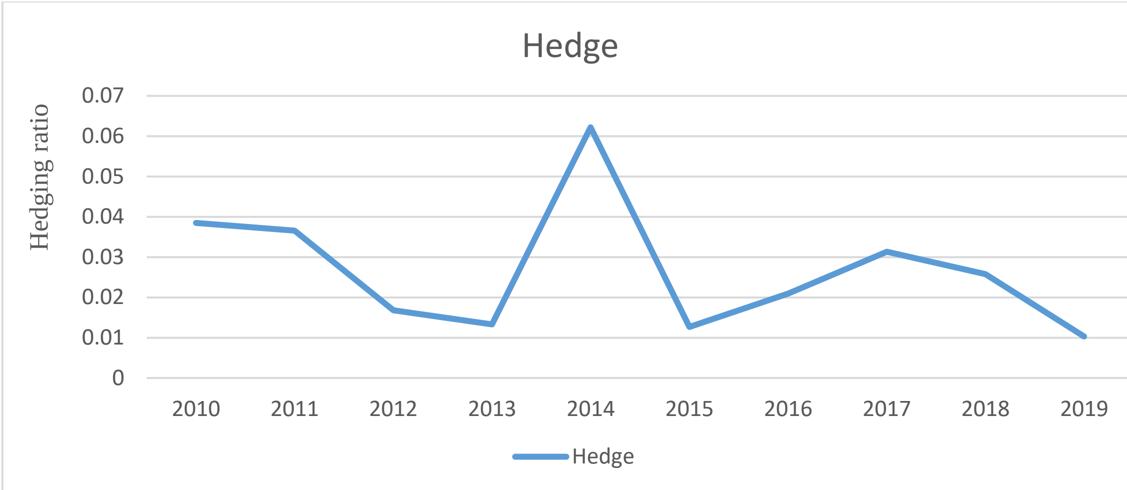

Figure 1. The evolution of the hedge measure across the period

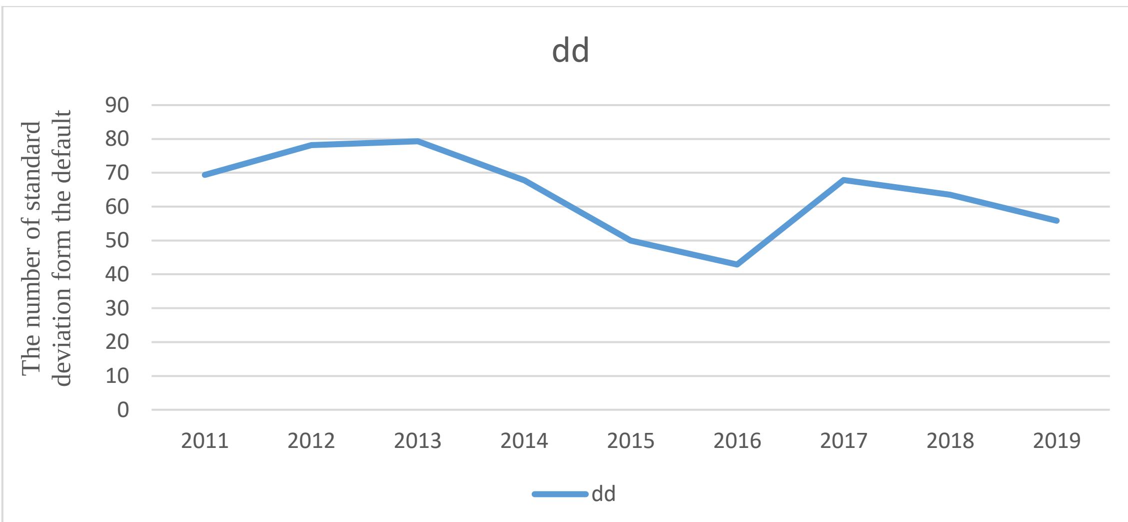

Figure 2. The evolution of the dd measure across the period

Table 2. Sample statistics

Means for variables of years										
	All sample	2011	2012	2013	2014	2015	2016	2017	2018	2019
dd	64.98	71.58	79.46	80.34	69.51	50.64	41.19	66.28	65.89	56.39
Leverage	0.381	0.296	0.333	0.355	0.369	0.430	0.430	0.415	0.409	0.465
Hedge	0.013	-0.015	0.005	0.039	0.086	-0.100	-0.107	0.079	0.319	0.015
$\frac{Working\ Capital}{Total\ Assets}$	0.072	0.040	0.107	0.093	0.072	0.059	0.074	0.044	0.072	0.039
$\frac{EBIT}{Total\ Assets}$	-0.085	0.000	-0.045	-0.067	-0.070	-0.425	-0.111	-0.045	-0.043	-0.055
$\frac{Retained\ Earnings}{Total\ Assets}$	-0.958	-0.296	-0.413	-0.602	-0.830	-1.774	-1.594	-1.266	-1.245	-1.430
$\frac{Sales}{Total\ Assets}$	0.347	0.381	0.345	0.346	0.354	0.203	0.295	0.351	0.415	0.411
Size	6.897	6.746	6.841	6.827	6.968	6.822	6.922	7.027	7.044	7.058
Liquidity	1.264	1.677	1.337	1.379	1.105	1.200	1.394	0.992	1.189	0.994
MtoB	2.597	2.894	3.040	2.167	2.344	5.474	1.443	1.326	3.245	1.503
$\frac{\text{BV of pp\&eq}}{Total\ Assets}$	0.683	0.649	0.673	0.684	0.689	0.692	0.701	0.694	0.692	0.706
$\frac{Operating\ income}{Sales}$	-0.667	-0.470	-0.870	-0.414	-0.802	-1.527	-0.613	-0.179	-0.712	-0.382
$\frac{\text{Dep \& Amt}}{Total\ Assets}$	0.075	0.069	0.063	0.063	0.069	0.095	0.083	0.073	0.089	0.083
$\frac{\text{Sga}}{Sales}$	0.785	0.723	1.022	0.756	0.661	0.412	0.861	0.343	0.770	0.317

Notes: The data is adjusted to remove extreme value by hand because the same standard such as truncation at 5% cannot applied to all variables. However, the adjustment is not material by only eliminating 2-3 rows of data.

The difference of independent variables between hedgers and non-hedgers is presented in Table 3. Except $\frac{Sales}{Total\ Assets}$ and MtoB, other variables show apparent differences between hedgers and non-hedgers. This provides evidence that these independent variables and control variables can explain why hedging can make difference for the financial health of companies.

Table 3 The difference between hedgers and non-hedgers

	Hedgers	Non-hedgers	Difference t stats	Difference p-value
$\frac{Working\ Capital}{Total\ Assets}$	0.045	0.121	-7.570	0.000
$\frac{EBIT}{Total\ Assets}$	-0.012	-0.130	7.185	0.000
$\frac{Retained\ Earnings}{Total\ Assets}$	-0.159	-1.781	10.261	0.000
$\frac{Sales}{Total\ Assets}$	0.371	0.350	1.519	0.130
Size	7.988	5.785	29.757	0.000
Liquidity	0.757	1.947	-8.862	0.000
MtoB	2.665	2.452	0.218	0.828
$\frac{\text{BV of pp\&eq}}{Total\ Assets}$	0.741	0.625	13.039	0.000
$\frac{\text{Dep \& Amt}}{Total\ Assets}$	0.083	0.066	4.254	0.000
$\frac{\text{Sga}}{Sales}$	0.144	1.649	-4.211	0.000
$\frac{Operating\ income}{Sales}$	-0.095	-3.104	4.956	0.000

4. Econometric models

4.1 Construction of Linear Regression Models

The objective of this paper is to provide an interpretation of hedging activities on capital structure, especially the hedging management of derivative instruments. In the theoretical analysis, default risk can be represented by simulating the situation where the value of assets cannot cover the book value of liabilities, and distance to default is widely used to stand for the distress condition and financial leverage of firms. The central feature of this paper lies in the explicit fact that all sorts of hedging activities are designated to eventually reduce the odds of bankruptcy. Therefore, firms hedging their market risks by derivative instruments are less likely to fall into distressed problems. By this logic, if default risk is mitigated by hedging, companies can spare more capacity for issuing debts in attempts to further exploitation. The final result of this chain will land on an increasing leverage ratio. That is how hedging activities impose positive effects on capital structure. In addition, drawbacks of debt are undermined and benefits of debt such as tax savings from interest expenses are outlined by engaging in hedges. Hedging ratio and leverage ratio are straightforward financial decisions formulated by corporate management, while the distance to default is a nature determined by companies' managerial methodology. Distance to default, hence, is a more precise measure to capture the leverage situation because the leverage ratio is more related to the personal behavior of managers and a more accessible measure to understand debt capacity. However, leverage decision can directly affect distance to default because more debt naturally causes more default risk; a leverage ratio can therefore decide the point where a company is distressed. That is why distance to default can capture the leverage situation of firms. In an imaginary theoretical world, if we hold leverage ratio as a constant, the distance to default is determined by factors affecting free cash flows of firms; if we hold other factors stable, the distance to default is determined by the leverage ratio of a firm. In reality, all parameters mentioned above are not a constant in every scenario. If we do not consider changes of leverage ratio during the period, reduction of cash flow volatility realized by hedging can increase the distance to default point; if we do not take hedging activities into account, the change of leverage ratio can cause corresponding variation of distance to default. In a given period, the relation of distance to default and hedging ratio, and the relation of distance to default and leverage ratio are examined separately. Moreover, the relation of hedging decision and leverage decision is further explored to see if more hedging can influence the management decision on leverage.

This paper conducts three regression models to explore effects of hedging on distance to default and leverage ratio. Hypotheses for these econometric models are as follows:

Hypothesis 1: Hedging ratio has a positive relationship with distance to default.

Hypothesis 2: Leverage ratio has a negative relationship with distance to default.

Hypothesis 3: Hedging ratio has a positive relationship with leverage ratio.

In attempts to test whether a natural relationship between hedging ratio and leverage situation exists in companies in the mining industry, linear regression models are designed using selected explanatory variables. Merton's (1974) option view of firms is an important theoretical foundation for the calculation of distance to default, and the opinions and assumptions of Miller-Modigliani (1958) on capital structure hold in this model. It is reasonable to consider the distance to default computed form Merton's default model as a meaningful index to indicate the leverage behind current capital structure which is comprehended through Miller-Modigliani's theory. Market value of assets and the volatility of assets' value are an unobserved but necessary parameter in the structural model. The cash flow from reoccurring operations determines the valuation of firm's total assets and certainly the volatility of assets' deviation from normal average. Therefore, it can be deduced that financial ratios reflecting the operating cash flows are related to the valuation of corporation securities and explanatory power of distance to default. Altman's five accounting variables indicating the operation turnover of firms can be a reasonable measure of whether adequate free cash flows inside firms during the operation cycle. Also, it is interesting to think about the effects of hedging ratio and leverage ratio on distance to default simultaneously because hedging choice and debt choice are indeed two factors influence the default risk level. Finally, I examine whether the hedging decision is associated with the increase of debt capacity and the corresponding increase of the leverage ratio. However, deciding the capital structure of a firm is a complex procedure for management since the benefit allocation among stakeholders of firms needs to be negotiated and many other factors should be included. Three examples can be listed to explain it: (1) substantial transaction costs are always ignored in many theoretical models and simulations; (2) managerial risk aversion causes different decisions on leverage ratio in different market environments; (3) consideration over the developing stages the company stays and the public images the company chooses is inevitable for capital structure. Those three factors cannot be extracted from database or measured accurately because financial behavior is tough to quantify, and financial regulation does not require related information in firms' public statements. Consequently, the effect of hedging ratio on leverage index may not meet requirements of robustness.

The three equations for a regression model take the form below.

Model 1:

$$dd_{i,t} = \beta_0 + \beta_1 * Hedge_{i,t-1} + \beta_2 * \frac{Working\ Capital_{i,t}}{Total\ Assets_{i,t}} + \beta_3 * \frac{EBIT_{i,t}}{Total\ Assets_{i,t}} + \beta_4 * \frac{Sales_{i,t}}{Total\ Assets_{i,t}} + \beta_5 * Size_{i.t} + \beta_6 * Liquidity_{i,t} + YearDummy + \epsilon_{i,t}$$

Model 2:

$$dd_{i,t} = \beta_0 + \beta_1 * Leverage_{i,t-1} + \beta_2 * \frac{Working\ Capital_{i,t}}{Total\ Assets_{i,t}} + \beta_3 * \frac{EBIT_{i,t}}{Total\ Assets_{i,t}} + \beta_4 * \frac{Retained\ Earnings_{i,t}}{Total\ Assets_{i,t}} + \beta_5 * Size_{i,t} + \beta_6 * Liquidity_{i,t} + \beta_7 * MtoB_{i,t} + YearDummy + \epsilon_{i,t}$$

Model 3:

$$Leverage_{i,t} = \beta_0 + \beta_1 * Hedge_{i,t-1} + \beta_2 * \frac{BV\ of\ pp\&eq_{i,t}}{Total\ Assets_{i,t}} + \beta_3 * \frac{Operating\ income_{i,t}}{Sales_{i,t}} + \beta_4 * \frac{Dep\&Amt_{i,t}}{Total\ Assets_{i,t}} + \beta_5 * \frac{Sga_{i,t}}{Total\ Assets_{i,t}} + \beta_6 * Size_{i,t} + \beta_7 * MtoB_{i,t} + YearDummy + \epsilon_{i,t}$$

As this paper focuses on the effects of hedging activities on leverage ratio, hedging data is lagged by one year to see if the hedging decision can influence financial default estimators of following year. In an attempt to examine the influence of leverage decision on distance to default, the leverage ratio is constructed from the time horizon of last year for every firm-year observation in the dataset. In the Model 1, I select three of the five Altman credit risk measures. The ratio (Working Capital)/(Total Assets) and the ratio EBIT/(Total Assets) are considered as important ratios indicating the operating cash flow scaled by companies' total assets in Altman's article (1968). Though the coefficient of Sales/(Total Assets) is less attractive than other variables in Altman's article, it is crucial to default risks of firms because sales reflecting the quality and quantity of transaction orders can directly affect the reputation of firms in the public eye. I omit the other two measures because of their being less sensitive to free cash flows. Furthermore, due to the half of non-hedgers in the sample, Heckman's (1989) two-stage model should be introduced to correct the endogeneity error in Model 1. I choose firm size, liquidity ratio, dividend declaration, market exploitation, tax loss carry forward, and long-term debt ratio as determinants of hedging ratio according to the article of Dionne and Garand (2003). By building a Probit model with those determinants, inverse-Mills ratio can be calculated and subsequently used in the Model 1. The detailed process of Heckman's two-stage model is presented in Appendix (2).

Similar to Model 1, Model 2 is composed of leverage ratio of last year and another three of five Altman's default risk measures. Retained earnings can show greater explanatory power in the determination of leverage ratio. It is because retained earnings is the actual internal fund of the company. The reason why I do not consolidate Model 1 and Model 2 into one joint model is that hedging choice and debt ratio choice are supposed to show some causal relationship as presented in Model 3. In terms of Model 3, three explanatory variables are selected from past literature. The available collateral value of firms, the taxation advantages from depreciation and amortization, and the distinctive expenses decided by operation nature are standard determinants in the leverage related studies. As the data for research comes from the same industry, the consideration of difference for industry can be ignored. Moreover, as all data is coming from companies located in North America and thus allowing a relatively stable and similar market environment, I do not need to take country elements into accounts separately. However, the time interval of the dataset is from 2010 to 2019 inclusive. The changes of economic trends also cause variation of financial data of firms. Nominal year dummies should be included in regressions to remove the effect of time passage.

4.2 Correlation Matrix

Before conducting regression models, a correlation check should be considered for better understanding explanatory variables in the model.

As we can see in Panel A of Appendix (A), distance to default, the main variable to test hypotheses, is positively correlated with hedge ratio and previous hedge ratio lagged by one year. The result of correlation is in line with the projection of Table 1. This fact suggests that hedging engagement has favorable effects on increasing the distance to default for companies. The ratio, working capital divided by book value of total assets, is positively related to distance to default, demonstrating that the cash flow addition is associated with the reduction of odds of distress and the increase in the possibility of firms to build better credit reputation. EBIT divided by total assets and net sales divided by total assets are intertwined with a correlation at 0.83 because the EBIT is calculated by sales subtracted by the cost of production. However, the number for sales cannot be replaced by other figures computed to indicate earnings since sales separated from the income statement can reflect lots of information about the market shares and business propensity in the future. That part of declaration has been considered an important signal for investors. Control variables also show positive correlation with distance to default. It can be interpreted that companies with greater business size have more realizable cash flow in the future operating cycle and have more stable development pace for different economic environments. Liquidity ratio has the highest correlation with distance to default. It can be explained by the fact that the solvency of a firm is directly associated with the distress problem the firm will be faced at the maturity of debts.

It should be noticed that hedging ratio is negatively correlated (-0.04) with the previous hedging ratio of the last financial year. This phenomenon may be related to the hedging costs which are neglected by assumptions of prior research. In addition, previous hedging ratio shows a greater correlation with distance to default than current hedging ratio. A financial decision on hedging activities can cause more changes of distress for next year than for the current year.

Panel A of Appendix (A) also illustrates correlation between distance to default and explanatory variables in regression model 2. In line with the expectation of Table 1, leverage ratio and lagged leverage ratio show a negative correlation with distance to default. It is a common relation between leverage decision and how far corporations from the default points in option view the model. More debts issued during the financial period can induce more default risks in next years. Leverage ratio for current year is strongly correlated with lagged leverage at one year. A positive 0.89 is found by research results, suggesting the fund collection by issuing long-term debts in next one financial period is not active and the changes from value of last year to current value for total liabilities are not material. The main explanatory variable, lagging leverage, does not present significant correlation with other independent variables of Model 2. The ratio indicating retained earnings is positively correlated with distance to default as anticipated. It can be interpreted that more actual cash flows after allocation to debtholders and shareholders are related to more distance to default point. It also has a relatively close relation with working capital ratio and EBIT ratio with a correlation of 0.46 and 0.49. MtoB ratio is positively correlated with response variable, which is contrary to previous expectations. Companies with a higher MtoB ratio are regarded as growth companies in the stage of initial expansion. However, greater MtoB ratio also indicates more market value of equity, suggesting a favorable public opinion on companies.

As the Panel B of Appendix (A) shows, the hedge ratio lagged by one year and current hedge ratio both show positive correlation with leverage ratio as predicted. The correlation between hedge ratio and lagging hedge ratio becomes -0.02 slightly different from -0.04 in the correlation matrix of Model 2. However, the same conclusion can be reached in that a negative correlation exists between hedge ratio and that for last year. $\frac{\text{BV of pp\&eq}}{Total\ assets}$ is positively correlated with leverage ratio and show great importance in the relationship of leverage ratio with explanatory variables. The $\frac{\text{Dep \& Amt}}{Total\ assets}$ is positively correlated with leverage ratio, but the expected sign for this figure is negative. A possible explanation for the positive sign is that more depreciation and amortization also means more fixed assets and intangible assets in companies which is a healthy signal for the development of companies. $\frac{\text{Sga}}{Sales}$ is negatively correlated with the response variable as anticipated. Correlation with other control variables are in line with previous anticipation.

5. Results and Robust Check

5.1 Results of Regression Models

The sample for Model 1 is composed of hedgers' corporate data in the mining industry form 2011 to 2019 inclusive. The calculation of distance to default and lagging hedge requires data from last year so that the beginning year of the ten-year time horizon is omitted during the sample formation. In order to remove the treatment effect, I calculate inverse-Mills ratio from a Probit model, which constructs determinants of hedging activities, and add this ratio to the Model 1 as an explanatory variable. Inverse-Mills ratio can summarize the features of non-hedgers and outstand the difference between hedgers and non-hedgers. There are 913 firm-year observations in the hedgers' sample.

The results indicated in Panel A of Table 4 support the positive relation between hedging involvement and distance to default. The significant coefficient at 0.09 assures that actively engaging in hedging activities such as signing a derivative contract can effectively increase the distance to default point. As the distance to default calculated by Black-Scholes-Merton model measures the leverage because the face value of total debts and market value of equity are important parameters to build the model and simple capital structure hypothesis is included in the model, it can be interpreted that more hedging instruments can influence the allocation of debts and equity in the financial decision on fund collection. In terms of other explanatory variables, three ratios form Altman's five accounting variables show a positive sensitivity of distance to default to a change in those three independent variables. Although the change of units for dependent variable is slight when explanatory variables fluctuate, the increase or decrease can be confirmed by running the model. However, the p-value for $\frac{Sales}{Total\ Assets}$ is 0.69, showing that the coefficient of this variable is not significant at 1% significance. It can be noticed that firm size has the strongest explanatory power in the model with a coefficient of 1.02. The coefficient for liquidity is contrary to the correlation between distance to default and liquidity ratio. That is because the control variable in the model provides synergy for regression.

Table 4. Results of Models

	Coefficient	SE	tStat	p-value
Panel A dd				
Lagging hedge	0.0934	0.0235	3.5619	0.0003
$\frac{Working\ Capital}{Total\ Assets}$	0.1472	0.0349	4.2475	0.0000
$\frac{EBIT}{Total\ Assets}$	0.0460	0.0239	3.8748	0.0001
$\frac{Sales}{Total\ Assets}$	0.0138	0.0354	0.3889	0.6975
Size	1.0229	0.1151	11.0050	0.0000
Liquidity	0.1513	0.0375	2.5819	0.0010
Goodness of fit	Adj R^2=0.689			
Panel B dd				
Lagging leverage	-0.4926	0.0287	-18.1590	0.0000
$\frac{Working\ Capital}{Total\ Assets}$	0.1753	0.0377	4.1221	0.0000
$\frac{EBIT}{Total\ Assets}$	0.1081	0.0197	6.4666	0.0000
$\frac{Retained\ Earnings}{Total\ Assets}$	-0.1002	0.0259	-4.2564	0.0000
Size	0.4779	0.0803	7.0128	0.0000
Liquidity	0.1167	0.0190	5.4594	0.0000
MtoB	-0.0095	0.0141	-0.6744	0.5001
Goodness of fit	Adj R^2=0.668			
Panel C Leverage				
Lagging hedge	-0.0439	0.0149	-2.9423	0.0033
$\frac{\text{BV of pp\&eq}}{Total\ Assets}$	0.1730	0.0247	6.9919	0.0000
$\frac{Operating\ income}{Sales}$	-0.0577	0.0348	-1.6563	0.0978
$\frac{\text{Dep \& Amt}}{Total\ Assets}$	0.1217	0.0320	3.7988	0.0001
$\frac{\text{Sga}}{Sales}$	-0.0678	0.0573	-1.1831	0.2369
Size	0.2684	0.0565	4.7467	0.0000
MtoB	-0.0085	0.0116	-0.7386	0.4603
Goodness of fit	Adj R^2=0.821			

Note: This table presents the coefficients and the p-values of a firm fixed effect regression model to explain the relation between distance to default and the value of companies' hedging instruments. In Models 1 and 2, the dependent variable is the distance to default (dd) calculated with the structural model in previous equations presented in Section 3. Lagging leverage is calculated by total liabilities divided by total market value of assets. In Model 3, the response variable is leverage ratio, which is defined as the book value of total liabilities divided by the market value of assets (book value of total liabilities plus market value of equity); the main explanatory variable is hedging ratio lagged by one year and hedging ratio is calculated by absolute net value of derivative assets held to hedge risks and EBITDA; other determinants are decided form prior classic explanatory variables of leverage ratio and important control variables for firms. Firm and Year dummies are also included in the regression, but not reported.

As shown in Panel B of Table 4, previous leverage ratio evidently has a negative and significant relation with distance to default. The estimator of coefficient is modelled to be -0.49 with a significantly small p-value at 1% significance. It can be directly explained by the fact that more issuance of debts can cause companies to be faced with increasing credit risk. Three explanatory variables quoted from Altman's five accounting ratios show different explanatory powers for distance to default. The coefficient estimated for $\frac{Working\ Capital}{Total\ Assets}$s 0.18 and the p-value of the estimator is 0.00. That result shows that the changes caused by working capital divided by total assets is positive and the relationship is significant at 1% significance. Likewise, $\frac{EBIT}{Total\ Assets}$ presents a positive sensitivity of distance to default and the result is statistically significant at 1% significance. In contrast, the ratio for retained earnings divided by total assets shows a negative coefficient for the model, against the prediction in Table 1. But the result is not statistically significant at 1% significance. It can be deduced that retained earnings of current year cannot increase the distance to default. In terms of control variables, the coefficient for liquidity is 0.11 in line with the coefficient estimated in Model 1. The figure for size still shows a positive and significant sensitivity of response variable. The result of firm size is robust in different models. It can be observed that the expansion stage a corporation stays really matters in the consideration of default problems. Indeed, companies with more assets have a longer distance to default point in the mining industry. However, MtoB fails to explain distance to default in Model 2, with a nonmaterial estimated coefficient and an insignificant p-value. There are 1810 firm-year observations for the Model 2 sample.

The regression results shown in Panel A and Panel B of Table 4 demonstrate that hedging decision and leverage decision are both related to the increase in the distance to default of corporations separately. To explain it, hedging ratio and leverage ratio are lagged with 1 year to see the changes of distance to default of the next year. The positive sensitivity of distance from the default situation to hedging ratio and leverage ratio can account for the slightly increasing response variable if we assume that a staggered financial period can represent causality of two incidents. Further exploration of hedging activities' effect on capital structure is completed by constructing a model with leverage on the left side as a dependent variable and hedging data on the other side as determinants as presented in the Panel C.

The coefficient estimated for hedging ratio is -0.044 at 1% significance. This can be interpreted by the fact that the relation between the hedging decision and the leverage decision is complex because both of these two ratios are a reflection of managerial behavior which cannot be affected by many aspects of operation. It is of interest that the sign of coefficient opposite the original regression model when firm fixed effect is added as a nominal explanatory variable. Some specific companies may adjust their capital structure to less debt scenario if they hedge their sources of risk in the last financial year. Since industry is a time invariant within firms, the firm fixed effect includes the industry fixed effect. As a result, the firm fixed effects model has a more robust specification (controls for more unobservable factors including time invariant industry-level intangible variables.) Therefore, the previous hedging ratio can induce effects on distance to default, but it is not sure to affect the leverage ratio directly because of some specific firm characters not observed in financial reports.. Collateral value indicated by $\frac{\text{BV of pp\&eq}}{Total\ Assets}$ shows that firms with more collateral assets are supposed to have higher leverage ratio. The coefficient of $\frac{\text{BV of pp\&eq}}{Total\ Assets}$ is significant at 1% significance, so the estimation for this index in Model 3 can be a reliable consideration. $\frac{\text{Dep \& Amt}}{Total\ Assets}$represents the non-debt tax shield for companies and it is expected to have a negative relation with the leverage ratio in Table 1. However, the coefficient for this value is a statistically significant positive at 0.12. $\frac{Operating\ income}{Sales}$which illustrates operating income scaled by sales and$\frac{\text{Sga}}{Sales}$ which illustrates selling, general and administrative expenses divided by sales are in line with the expected sign in Table 1. They both show negative sensitivity of response variable, but an insignificant p-value. Size is a positive determinant with a coefficient at 0.27, suggesting that firms with larger scales in the market tend to raise funds by debt. The estimator of MtoB is negative and insignificant in Model 3, showing less reasonable explanatory powers for the change of leverage ratio of firms in this industry.

5.2 Robustness Check

Results from Table 4 reveal an endogenous phenomenon with the effects of economic parameters that hedging activities impose, especially with the offsetting position in derivative contracts, for they can be related to the increasing leverage ratio and longer distance to default of next financial period. Indeed, the increase of leverage ratio can cause contraction of distance to default because of more pressure from repayment of increasing liabilities. It should be logical that financial leverage is a choice made by management but distance to default is a representation of financial situation decided by the joint effects of operating issues of firms. The results shown above can support the assertion that more hedging activities are in line with longer distance to default, and that hedging involvement is supposed to relate to the upward change of debt capacity. However, whether the model is robust for different conditions or whether the relation between the hedging ratio and distress problems can be seen as reasonable evidence for further decision still needs to be tested. I conducted a 3SLS simultaneous model to simulate the process where the company make hedging decision and leverage decision simultaneously, showing a stronger relationship between distance to default and leverage ratio with hedging ratio as endogenous variable.

The coefficient estimator for lagging hedge, presented in Panel A of Table 5, is in contrary to the estimation of Panel A of Table 4 that indicates the result of single equation. The figure for coefficient is -0.32 compared to 0.09 of regular regression model, and it is not significant at 10% significance. This is because previous hedging dominates as a main variable in single equation regression and supports as an endogenous control variable in the equation system. Leverage represents an important negative coefficient estimated, illustrating that less liabilities in the company are related longer distance to default. $\frac{Working\ Capital}{Total\ Assets}$ shows a negative coefficient (-0.06), illustrating that more working capital scaled by total assets is not a stable determinants of distance to default. In contrast, $\frac{EBIT}{Total\ Assets}$ ratio shows a positive sensitivity at 0.04 of dependent value as modelled in single equation regression. The control variable, firm size, still presents a great explanatory power with a significant p-value at 1% significance. The estimator for

Table 5. Simultaneous model for dd and leverage ratio

	Coefficient	SE	tStat	p-value
Panel A dd				
Lagging hedging	-0.3212	0.3627	-0.85	0.396
$\frac{Working\ Capital}{Total\ Assets}$	-0.0625	0.1218	-0.51	0.608
$\frac{EBIT}{Total\ Assets}$	0.0444	0.0613	0.72	0.469
$\frac{Retained\ Earnings}{Total\ Assets}$	0.0005	0.1020	-0.01	0.996
Size	0.7127	0.1620	4.40	0.000
Liquidity	0.0596	0.0432	1.38	0.167
MtoB	-0.0171	0.0168	-1.02	0.310
Leverage	-0.9119	0.6147	-1.48	0.138
Goodness of fit	Adj R^2=0.691			
Panel C Leverage				
Lagging hedge	0.7236	0.3792	1.91	0.056
$\frac{\text{BV of pp\&eq}}{Total\ Assets}$	0.0504	0.0616	0.82	0.413
$\frac{Operating\ income}{Sales}$	-0.1729	0.1307	-1.32	0.186
$\frac{\text{Dep \& Amt}}{Total\ Assets}$	0.2297	0.0862	2.66	0.008
$\frac{\text{Sga}}{Sales}$	-0.1849	0.1504	-1.23	0.219
Size	0.6294	0.1445	4.35	0.000
MtoB	-0.0072	0.0223	-0.32	0.746
dd	-0.5981	0.1984	-3.01	0.003
Goodness of fit	Adj R^2=0.393			

Note: This table represents the result of simultaneous model for the relationship of distance to default and leverage ratio. Three-stage least-squares regression is adopted to estimate the coefficients of variables. Hedging ratio is set as endogenous variable. There are 1559 observations in the panel data. The year and firm fixed effects are included in the equation system.

liquidity ratio gives similar results to firm size, showing a positive sign of coefficient in line with the estimation of single equation regression. In summary, the result of the Panel A of Table 5 shows sign of multilinearity because the relationship among explanatory variables is interacted in the calculation and financial comprehension.

The other regression in the equation system shows the relationship with leverage ratio as dependent variable and distance to default as explanatory variable. The coefficient estimator for hedging ratio is 0.72 at 1% significance, which is contrary to the results of single equation regression model presented in Table 4. This can be interpreted by the fact that the hedging decision can be related to the increase of leverage ratio under the consideration of simultaneous effect of distance to default and leverage ratio. It is reasonable that the sign of coefficient estimated for distance to default is significantly negative in line with the relation indicated by the other equation because more debt in the firm tend to increase the possibility of bankruptcy and consequently support the contraction of the distance to default. Some companies in the mining industry may adjust their capital structure to more debt scenario if they hedge their sources of risk in the last financial year. I fail to find the positive relation between hedging ratio and leverage ratio in the single equation regression because year and firm fixed effect is added in regression models which induce more specific characteristics of companies. Therefore, the previous hedging ratio can induce effects on distance to default, but it is not sure to affect the leverage ratio directly because of some specific firm features not observed in financial reports. With regard to other explanatory variables, the estimator of collateral value is positive as shown in Table 4 and the estimator of depreciation and amortization scaled by total assets is significantly positive, suggesting the robustness of relationship. Similarly, the coefficients estimated for operating ratio $\frac{Operating\ income}{Sales}$ and $\frac{\mathrm{Sga}}{Sales}$ is negative but not significant at 10% significance. The control variable indicated by firm size shows a material coefficient at 0.63 and a significant p-value at 1% significance. Whereas the estimated coefficient for MtoB is still negative and insignificant.

In summary, the negative relation between distance to default and leverage ratio is robust when simultaneous model is included. The sensitivity of hedging ratio towards leverage ratio is affected by year and firm features but shows positive sign when considering distance to default and leverage ratio simultaneously. The model constructed to estimate the relationship between previous hedging ratio and leverage ratio seems to robust with stable coefficients of other explanatory variables.

In the construction of Model 1, including hedging ratio contributes 0.005 marginal R squared to the fitness of regression model and 0.006 marginal adjusted R squared. Adjusted R squared represents the fitness of model without the effect of adding a nonimportant or unrelated explanatory variable. This indicates the effective explanatory power of hedging data for distance to default. Likewise, hedging ratio increases the fitness of Model 3 by adding 0.0019 R squared and 0.0023 adjusted R squared. If the hedging ratio increase by one standard deviation, the distance to default of the company tend to show a upward trend by 0.099 standard deviation. The leverage ratio of the company will decrease by 0.047 according to the results of Model 3 if hedging ratio increases by one standard deviation.

6. Conclusion

This paper aims to find the effect of hedging activities on capital structure in the US mining industry in the last decade. Capital structure is measured by direct leverage ratio and indirect distance to default. Leverage ratio is total liability divided by market value of assets; it indicates the strategy companies adopt on capital allocation, with distance to distress barrier being an endogenous variable reflecting the nature of default risks and the leverage situation. Hedging activities include the offsetting position in derivative contracts and other sorts of contracts reported by companies to hedge operating risks of cash flow. I calculate a hedging ratio by using absolute net value of hedging instruments scaled by EBITDA. This measurement of hedging activities provides more information than simple binary variables for exploration of risk management. I examine the relation between hedging ratio and leverage index including direct and indirect representatives through regression models with market data and fundamental data from authoritative databases on websites.

The results of the regression models indicate a positive relationship between hedging ratios and distance to default, suggesting that firms that hedge their risks by signing contract for control of future cash flows tend to have longer distance to default. Less possibility of default allows companies to increase their debt capacity. Therefore, the leverage decision of firms changes in line with the increase of hedging ratio. Prior research shows that hedging has a significant effect on the improvement of underinvestment problems and a reduction in distress probability with the consequent increase in firm value. The ultimate objective of hedging is to prevent companies from bankruptcy and to ensure their gradual growth. Corporations are likely to consider expansion via debt financing when bankruptcy is not a threat for current operations.

The faultiness of this paper is that the relation between increasing hedging ratio and higher leverage ratio is not robust. This is because a specific firm may face more challenges of issuing debts such credit rating and transactions, which is not included in the models found in this paper. Furthermore, managerial risk aversion is not considered in this paper because of the complex definition and collection of financial behavior. Future research should add more controlling variables reflecting credit ratings and transaction costs.

Bibliography

Allayannis, George, and Eli Ofek. “Exchange Rate Exposure, Hedging, and the Use of Foreign Currency Derivatives.” *Journal of International Money and Finance* 20, no. 2 (2001): 273–96.

Allayannis, George, and James P Weston. “The Use of Foreign Currency Derivatives and Firm Market Value.” *The Review of Financial Studies* 14, no. 1 (2001): 243–76.

Altman, Edward I. “Predicting Railroad Bankruptcies in America.” *The Bell Journal of Economics and Management Science* 4, no. 1 (1973): 184–211.

Ashley, Allan S., and Simon S. M. Yang. “Executive Compensation and Earnings Persistence.” *Journal of Business Ethics* 50, no. 4 (2004): 369–82.

Belghitar, Yacine, Ephraim Clark, and Amrit Judge. “The Value Effects of Foreign Currency and Interest Rate Hedging: The UK Evidence.” *International Journal of Business* 13, no. 1 (2008): 43.

Bhabra, Gurmeet S., and Yuan Yao. “Is Bankruptcy Costly? Recent Evidence on the Magnitude and Determinants of Indirect Bankruptcy Costs.” *Journal of Applied Finance & Banking* 1, no. 2 (2011): 39–68.

Black F., and Scholes M. “The Pricing of Options and Corporate Liabilities.” *Journal of Political Economy* 81, no. 3 (1973): 637–57.

Bolton, Patrick, Hui Chen, and Neng Wang. “A Unified Theory of Tobin's-Q, Corporate Investment, Financing, and Risk Management.” *Journal of Finance -New York-* 66, no. 5 (2011): 1545–78.

Boyer, M. Martin and Monica Marin. “Financial Distress Risk and the Managing of Foreign Currency Exposure.” *Quarterly Journal of Finance* 3, no. 1(2013): 2

Boyer, M. Martin and Monica Marin “How Risk Management Adds Value.” *In Investment Risk Management, H.K. Baker and G. Filbeck (Eds)*- Chapter 3, (2014): 42-58.

CAMPELLO, M., C LIN, Y MA, and H ZOU. “The Real and Financial Implications of Corporate Hedging.” *Journal of Finance* -New York- 66, no. 5 (2011): 1615–47.

Carter, David A., Daniel A. Rogers, and Betty J. Simkins. “Does Hedging Affect Firm Value? Evidence from the Us Airline Industry.” *Financial Management* 35, no. 1 (2006): 53–86. doi:10.1111/j.1755-053X.2006.tb00131.x.

Smithson, Charles, and Betty J Simkins. “Does Risk Management Add Value? A Survey of the Evidence.” *Journal of Applied Corporate Finance* 17, no. 3 (2005): 8–17. doi:10.1111/j.1745-6622.2005.00042.x.

Deshmukh, Sanjay, and Stephen C. Vogt. "Investment, Cash Flow, and Corporate Hedging." *Journal of Corporate Finance* 11, no. 4 (2005): 628–44. doi:10.1016/j.jcorpfin.2005.02.004.

Dionne, Georges, and Martin Garand. "Risk Management Determinants Affecting Firms' Values in the Gold Mining Industry: New Empirical Results." *Economics Letters* 79, no. 1 (2003): 43–52. doi:10.1016/S0165-1765(02)00286-0.

Dionne, G., and T. Triki. "On Risk Management Determinants: What Really Matters?" *European Journal of Finance* 19, no. 2 (2013): 145–64.

Frank, Murray Z., and Vidhan K. Goyal. "Capital Structure Decisions: Which Factors Are Reliably Important?" *Financial Management* 38, no. 1 (2009): 1–37. doi:10.1111/j.1755-053X.2009.01026.x.

Gay, Gerald D., and Jouahn Nam. "The Underinvestment Problem and Corporate Derivatives Use." *Financial Management* 27, no. 4 (1998): 53–69.

Graham, J., and D. Rogers. "Do firms hedge in response to tax incentives? " *The Journal of Finance* 57 (2002): 815–39.

Graham, John R., and Campbell R. Harvey. "The Theory and Practice of Corporate Finance: Evidence from the Field." *Journal of Financial Economics* 60, no. 2 (2001): 187.

Heckman, J. J. "Sample Selection Bias as a Specification Error" *Econometrica* 47 (1979): 153_161.

JIN, Y., and P. JORION. "Firm Value and Hedging: Evidence from US Oil and Gas Producers." *Journal of Finance* -New York- 61, no. 2 (2006): 893–919.

KORTEWEG, ARTHUR. "The Net Benefits to Leverage: The Net Benefits to Leverage." *The Journal of Finance* 65, no. 6 (2010): 2137–70. doi:10.1111/j.1540-6261.2010.01612.x.

MACKAY, PETER, and SARA B. MOELLER. "The Value of Corporate Risk Management." *The Journal of Finance* 62, no. 3 (2007): 1379–1419.

Merton, Robert C. "On the Pricing of Corporate Debt: The Risk Structure of Interest Rates*." *The Journal of Finance* 29, no. 2 (1974): 449–70. doi:10.1111/j.1540-6261.1974.tb03058.x.

Modigliani, Franco, and Merton H. Miller. "The Cost of Capital, Corporation Finance and the Theory of Investment." *The American Economic Review* 48, no. 3 (1958): 261–97.

Papanastasopoulos, G., "Using Option Theory and Fundamentals to Assessing Default Risk of Listed Firms." *International Journal of Accounting, Auditing and Performance Evaluation* no. 4(2007), 305_331.

Purnanandam, Amiyatosh. “Financial Distress and Corporate Risk Management: Theory and Evidence.” *Journal of Financial Economics* 87, no. 3 (2008): 706–39. doi:10.1016/j.jfineco.2007.04.003.

Rajan, R., and L. Zingales. “Banks and Markets: The Changing Character of European Finance.” *Working Paper Series* 9595, no. 9595 (2003).

Smith, Clifford W, and Rene M Stulz. “The Determinants of Firms' Hedging Policies.” The Journal of Financial and Quantitative Analysis 20, no. 4 (1985): 391–405.

Stulz, Rene M. “Rethinking Risk Management.” Journal of Applied Corporate Finance 9, no. 3 (1996): 8–25. doi:10.1111/j.1745-6622.1996.tb00295.x.

Tufano Peter. “Who Manages Risk? An Empirical Examination of Risk Management Practices in the Gold Mining Industry.” *Journal of Finance* 51, no. 4 (1996):1097–1137.

Vassalou, M, and Y Xing. “Default Risk in Equity Returns.” *Journal of Finance* -New York- 59, no. 2 (2004): 831–68.

Appendix A: Correlation Table

Panel A

	dd	Lagging Hedge	Hedge	$\frac{Working\ Capital}{Total\ Assets}$	$\frac{EBIT}{Total\ Assets}$	$\frac{Sales}{Total\ Assets}$	$\frac{Retained\ Earnings}{Total\ Assets}$	Size	Liquidity	MtoB	Lagging Leverage	Leverage
Dd	1.000											
Lagging Hedge	0.010	1.000										
Hedge	0.007	-0.040	1.000									
$\frac{Working\ Capital}{Total\ Assets}$	0.187	0.003	0.000	1.000								
$\frac{EBIT}{Total\ Assets}$	0.127	0.010	0.008	0.148	1.000							
$\frac{Sales}{Total\ Assets}$	0.009	0.004	0.002	0.024	0.827	1.000						
$\frac{Retained\ Earnings}{Total\ Assets}$	0.100			0.461	0.485		1.000					
Size	0.138	-0.000	-0.018	0.038	0.209	0.084		1.000				
Liquidity	0.248	-0.001	-0.000	0.175	-0.012	-0.064	-0.044	-0.198	1.000			
MtoB	0.006			0.008	-0.063		-0.018	-0.055	0.003	1.000		
Lagging Leverage	-0.561			-0.159	0.049		0.099	0.322	-0.233	-0.044	1.000	
Leverage	-0.635	0.015	0.005	-0.207	0.020		0.097	0.329	-0.255	-0.049	0.892	1.000

Panel B

	leverage	Lagging Hedge	Hedge	$\frac{\text{BV of pp\&eq}}{Total\ Assets}$	$\frac{Operating\ income}{Sales}$	$\frac{\text{Dep \& Amt}}{Total\ Assets}$	$\frac{\text{Sga}}{Sales}$	Size	Liquidity
Leverage	1.000								
Lagging Hedge	0.015	1.000							
Hedge	0.005	-0.022	1.000						
$\frac{\text{BV of pp\&eq}}{Total\ Assets}$	0.232	0.006	0.018	1.000					
$\frac{Operating\ income}{Sales}$	0.023	0.001	0.001	0.025	1.000				
$\frac{\text{Dep \& Amt}}{Total\ Assets}$	0.195	-0.033	-0.018	0.129	0.018	1.000			
$\frac{\text{Sga}}{Sales}$	-0.053	-0.003	-0.002	-0.058	-0.904	-0.022	1.000		
Size	0.176	0.015	-0.007	0.138	0.054	-0.128	-0.108	1.000	
Liquidity	-0.050	0.000	0.000	-0.049	-0.000	0.040	0.002	-0.061	1.000

Appendix B: Calculation of Distance to Default

The Merton default model (Merton 1974) analyses corporation securities as options, where the bond value at maturity is the minimum of firm value or face value of debts, and the share value is the maximum of zero or the firm value subtracted by face value of debts. This is the framework of a structural approach to modelling default risk. Assumptions should be made to build the model: 1) the market imperfection is neglected; 2) risk-free interest rate is constant and time continuous; 3) Bonds issued are zero-coupon bond; 4) the assets of the firm are lognormally distributed follow a Geometric Brownian motion.

$$\frac{dMVA_T}{MVA_T} = r * dt + \sigma_A * dZ$$

Where MVA_T is the market value of firms' total assets at time T; σ_A is the volatility of market value of firms' total assets; Z is the standard Brownian motion.

According to option value from Black-Scholes pricing calculation adjusted by dividend (the valuation is used by Boyer and Marin (2013) and Papanastasopoulos (2007)), the share value at the maturity is:

$$MVE = MVA * e^{-\delta T} N(d_1) - Be^{-rT} N(d_2) + \left(1 - e^{-\delta T}\right) MVA \qquad \text{(A.1)}$$

Where MVE is the market value of stocks, which is constructed by the mean monthly price of financial year. δ is the continuous dividend yield and is defined as the sum of the previous year's common and preferred dividends divided by the market value of assets. B, the strike price of options, is the promised payments for total debts in Black-Scholes model, but B is defined as the firm's current liabilities plus one-half of firms' long-term liabilities in corporation model. r is risk-free rate which is extracted from T-bill rate at one-year maturity. T is assumed as one year in the model. d_1 is calculated by the formular $\frac{\ln\frac{MVA}{B} + (r - \delta + \frac{\sigma_A{}^2}{2})}{\sigma_A \sqrt{T}}$ and d_2 equals $(d_1 - \sigma_A \sqrt{T})$. Ito's lemma derives the relation between volatility of underlying assets and the implied volatility and modelling assets.

$$\sigma_E = \sigma_A \frac{MVA}{MVE} N(d_1) e^{-\delta T} \qquad \text{(A.2)}$$

Where σ_E is the volatility of share price and I compute it by using the daily return of stocks of firms over the fiscal year.

The unknown MVA and σ_A can be calculated by equations A.1 and A.2. To remove the size difference of firms' assets, the standardized MVA which is defined as x*MVE is used in the model. With the exact MVA and σ_A for every firm each year, distance to default can be calculated by replacing the risk-free rate with actual return of firms' asset (previous net incomes divided by market value of total assets).

Appendix C: Heckman's Two-stage Model

Heckman's two-stage model can eliminate the bias caused by self-selection. I divide the database into hedgers and non-hedgers to testify the relation between hedging activities and distance to default, but the endogenous factors affecting whether the firm adopts hedging activities can cause a biased coefficient. Therefore, inverse-Mills ratio is calculated by a Probit model to correct the building process of models.

$$hedging = \beta_0 + \beta_1 * size + \beta_2 * leverage + \beta_3 * liquidity + \beta_4 * TLCF + \beta_5 * MtoB + \beta_6 * dividend$$

Where hedging data is a binary variable defined as 1 when the firm conducts hedging activities in the year and 0 when the firm does not engage in hedging activities. Size is the natural logarithm of total assets and leverage is the book value of the firm's long-term debt divided by the market value of total assets; the liquidity is defined as cash and short-term investments divided by current liabilities; TLCF is natural logarithm of tax loss carry forward; MtoB is market to book ratio and dividend represents the dividend ratio which is calculated by the sum of the previous year's common and preferred dividends divided by the market value of assets.

The inverse-Mills ratio derived from the model is significant in Model 1.

Matlab code

Thesis

```
% data=raw compustats data imported from compdata.xlsx

% crspdata=raw crsp data imported from crspcusip.xlsx

data=readtable("compdata.xlsx");

comp=unique(data.gvkey);
```

Dada mining of compustat and crsp

First selection: remove all COMPUSTAT dada less than 2 years

```
num_comp=length(comp);

for i=1:num_comp

    indk=find(data.gvkey==comp(i));

    if length(indk)<2

       data(indk,:)=[];

    end

end

clear i

clear indk

clear num_comp

num_aft=unique(data.gvkey);

cusip=unique(data.cusip);

% in the beginning, 1977 companies are constructed, after deleting
missing

% data, 1875 companies remain.

clear comp

clear num_aft
```

Translate to PERMCO/PERMNO

```
compcusip=cell(length(cusip),1);

for i=1:length(cusip)

    charcusip=char(cusip(i));

    indc=find(string(data.cusip)==string(cusip(i)));
```

```
    if length(charcusip)<8

       compcusip(i)=cellstr(charcusip);

data.cusip(indc)=replace(data.cusip(indc),cusip(i),cellstr(charcusip));

    else

    compcusip(i)=cellstr(charcusip(1:8)); % extract the first 8 digits of
cusip

data.cusip(indc)=replace(data.cusip(indc),cusip(i),cellstr(charcusip(1:8)
));

    % replace original cusip data with compcusip

    end


end

clear i

clear indc

clear charcusip

%writecell(compcusip,'mycusip.txt')

% mycusip.txt is the index used for looking for crsp data
```

Second selection: CRSP data

```
crspdata=readtable('crspcusip.xlsx');

crspper=unique(crspdata.PERMNO);

for i=1:length(crspper)

    indq=find(crspdata.PERMNO==crspper(i));

    t=crspdata(indq,:);

    t.year=floor(t.date/10000);

    if length(unique(t.year))<2 % deleting data with less than 2-year
information

        crspdata(indq,:)=[];

    end

end

clear t
```

```
clear i

clear indq

crspdata=rmmissing(crspdata);


afterper=unique(crspdata.PERMNO);
% there are 385 companies during the market data resourse, after
selection,

% there are 376 companies remaining.


crspcusip=unique(crspdata.NCUSIP);


crspdata.year=floor(crspdata.date./10000);
k=0;

for i=1:length(afterper)

    indd=find(crspdata.PERMNO==afterper(i));

    T=crspdata(indd,:);

    Tdata=grpstats(T(:,{'PERMNO','PRC','SHROUT','year'}),'year','mean');

    Tdata.equity_value=Tdata.mean_PRC.*Tdata.mean_SHROUT; % calculate
eauity value for each year

    n=length(Tdata.year);

    mktdata(k+1:k+n,:)=Tdata(:,["mean_PERMNO","year","equity_value"]); %
save informaiton in mktdata

    k=k+n;

end


clear i
clear indd

clear T

clear Tdata

clear k

clear n

clear crspper

clear afterper
```

```
clear cusip
```

Merge COMPSTATS ans CRSP

```
% compcusip is first 8 digits of cusip form compustat
% mktdata contains equity value form crsp for each year, no need to use
% crsp data any more except for matching cusip
for ii=1:length(compcusip)
    indc=find(string(crspdata.NCUSIP)==string(compcusip(ii)));
    indcom=find(string(data.cusip)==string(compcusip(ii)));
    if isempty(indc) % remove unmatching data
       data(indcom,:)=[];

    end
end


clear ii
clear indc
clear indcom
mercom=unique(data.gvkey);


mercusip=unique(data.cusip);


h=0;
for j=1:length(mercusip)
    indj=find(string(crspdata.NCUSIP)==string(mercusip(j)));
    perm=unique(crspdata.PERMNO(indj));
    indmc=find(string(data.cusip)==string(mercusip(j))); % match cusip
form compustat and crsp


    indm=find(mktdata.mean_PERMNO==perm);
    Tmkt=mktdata(indm,:);


    Tcomp=data(indmc,:);
```

```
    maindata=innerjoin(Tcomp,Tmkt,"LeftKeys","fyear","RightKeys","year");
    g=length(maindata.fyear);

    Maindata(h+1:h+g,:)=maindata;
    h=h+g;

end
clear j
clear h
clear g
clear indj
clear indm
clear indmc
maincom=unique(Maindata.gvkey); %382
mainper=unique(Maindata.mean_PERMNO); %375
cik=Maindata.cik;
save Maindata % Maindata is dataset with merged crsp and compustat
permno=Maindata.mean_PERMNO;
% find(Maindata.gvkey==108326)
clear permno
clear cik
clear Tmkt
clear Tcomp
clear perm
clear maindata
```

Find why there are 375 PERMNO but 382 gvkeys

```
for i=1:length(mercom)
    indn=find(Maindata.gvkey==mercom(i));
    mercom(i,2)=unique(Maindata.mean_PERMNO(indn));
end
clear indn
```

```
clear i



[M N]=hist(mercom(:,2),unique(mercom(:,2)));
indcount=find(M==2);

repeper=N(indcount);

clear M

clear N

clear indcount

% find(mercom(:,2)==91069)

%  in=find(Mainhedg.mean_PERMNO==10353) this problem will be solved when

%  merged with hedg data, but permno 91069 conresponds two gvkeys because

%  old(2010-2012)and new(2014-2017) company

clear repeper

clear mercom

clear mercusip

clear mainper

clear maincom
```

Hedging data

```
hedg=readtable('hedging data.xlsx');

indsort=find(Maindata.currtr~=1);

forcom=Maindata.gvkey(indsort); % in order to find gvkey which doesnot
have agreed curcd and curncd

clear indsort

hedg.currtr(isnan(hedg.currtr))=1;

hedg.netValue=hedg.netValue.*hedg.currtr; % standardize all data in US
dollar

hedg(:,5)=[];

hedg(:,2)=[];



Mainhedg=innerjoin(Maindata,hedg);
clear crspcusip
```

```
clear forcom




hedgcom=unique(Mainhedg.gvkey);
hedgper=unique(Mainhedg.mean_PERMNO);% there are 362 companies in the
sample

Mainhedg.hedg=abs(Mainhedg.netValue)./Mainhedg.ebitda; % define hedg
ratio
```

Extract risk free rate and std of equity

```
dailyper=unique(Mainhedg.mean_PERMNO);

% writecell(num2cell(dailyper),'dailyper.txt');

dailyequity=readtable('dailyperm.xlsx'); % download daily market data



dailyequity.year=floor(dailyequity.date./10000);
dper=unique(dailyequity.PERMNO); % check

dailyequity.RET=str2double(dailyequity.RET);

% calculate std of equity for each year using daily data

sdaily=grpstats(dailyequity(:,{'PERMNO','year','RET'}),["PERMNO","year"],
'std' );

sdaily=rmmissing(sdaily);

sMainhedg=innerjoin(Mainhedg,sdaily,"LeftKeys",["fyear","mean_PERMNO"],"R
ightKeys",["year","PERMNO"]);

sMainhedg.equity_value=sMainhedg.equity_value./1000; % make equity value
in millions US dollars

 clear dailyper

 clear dailyequity

 clear sdaily

sMainhedg(:,1860)=[];



% import the risk free rate
riskfree=readtable('FRB_H15.csv');
```

```
riskfree.rate=str2double(riskfree.MarketYieldOnU_S_TreasurySecuritiesAt1_yearConstantMaturity_Quo)./100;

riskfree(:,1:2)=[];

riskfree.datayear=floor(riskfree.datadate./10000);

riskfree=rmmissing(riskfree);

Riskfree=grpstats(riskfree(:,2:3),"datayear","mean");



% import the imr excel
% imr is calculated by constrcting Probit model in Python

imr=readtable('imr.xlsx');



% constract variables for regression
sMainhedg.imr=imr.x0;

sMainhedg.strick=sMainhedg.lct+(0.5*sMainhedg.dltt);

sMainhedg.ts=sMainhedg.lt.*sMainhedg.txt./sMainhedg.pi;

sMainhedg.MtoB=sMainhedg.equity_value./sMainhedg.seq;

sMainhedg.wta=sMainhedg.wcap./sMainhedg.at;

sMainhedg.rta=sMainhedg.re./sMainhedg.at;

sMainhedg.ebita=sMainhedg.ebit./sMainhedg.at;

sMainhedg.saleta=sMainhedg.sale./sMainhedg.at;

sMainhedg.DEratio=sMainhedg.lt./sMainhedg.equity_value;

sMainhedg.liquidity=sMainhedg.che./sMainhedg.lct;

sMainhedg.divr=(sMainhedg.dvc+sMainhedg.dvp)./(sMainhedg.lt+sMainhedg.equity_value);

sMainhedg.size=log(sMainhedg.at);

sMainhedg.leve=sMainhedg.dltt./(sMainhedg.lt+sMainhedg.equity_value);

sMainhedg.detax=sMainhedg.txdi./sMainhedg.at;

sMainhedg.inc=sMainhedg.tie./sMainhedg.ebit;

indt=find(sMainhedg.lt==0);

sMainhedg.divr(indt)=(sMainhedg.dvc(indt)+sMainhedg.dvp(indt))./sMainhedg.at(indt);

sMainhedg.leve(indt)=sMainhedg.dltt(indt)./sMainhedg.at(indt);

sMainhedg.dpat=sMainhedg.dp./sMainhedg.at;
```

```
sMainhedg.collat=sMainhedg.ppent./sMainhedg.at;

sMainhedg.slg=sMainhedg.xsga./sMainhedg.sale;

sMainhedg.deratio=sMainhedg.lt./(sMainhedg.lt+sMainhedg.equity_value);

sMainhedg.ope=sMainhedg.oiadp./sMainhedg.sale;

clear indt


% match lagged data
for i=1:length(hedgcom)

    ind=find(sMainhedg.gvkey==hedgcom(i));

    tempshe=sMainhedg(ind,:);

    if max(unique(diff(tempshe.fyear)))==1

    tempshe.pridvr(1)=NaN;

    tempshe.deratio(1)=NaN;

    tempshe.prihedg(1)=NaN;

    tempshe.priimr(1)=NaN;

    tempshe.priNI(1)=NaN;

    tempshe.pridvr(2:end)=tempshe.divr(1:end-1);

    tempshe.deratio(2:end)=tempshe.lt(1:end-
1)./(tempshe.equity_value(1:end-1)+tempshe.lt(1:end-1));

    tempshe.prihedg(2:end)=tempshe.hedg(1:end-1);

    tempshe.priimr(2:end)=tempshe.imr(1:end-1);

    tempshe.priNI(2:end)=tempshe.ni(1:end-1);

    sMainhedg.pridvr(ind)=tempshe.pridvr;

    sMainhedg.prideratio(ind)=tempshe.deratio;

    sMainhedg.prihedg(ind)=tempshe.prihedg;

    sMainhedg.priimr(ind)=tempshe.priimr;

    sMainhedg.prioNI(ind)=tempshe.priNI;

    else nnt(i)=unique(tempshe.gvkey); % nnt means companies which do not
have consecutive data

    end

end

nntt=find(nnt~=0); % gvkey 10221 PERMNO 66739  and 108326 PERMNO 92893
```

```
ind1=find(sMainhedg.gvkey==10221);

tempshe1=sMainhedg(ind1,:);

tempshe1.pridvr(1)=NaN;

tempshe1.pridvr(7)=NaN;

tempshe1.deratio(1)=NaN;

tempshe1.deratio(7)=NaN;

tempshe1.prihedg(1)=NaN;

tempshe1.priimr(1)=NaN;

tempshe1.prihedg(7)=NaN;

tempshe1.priimr(7)=NaN;

tempshe1.priNI(1)=NaN;

tempshe1.priNI(7)=NaN;

tempshe1.deratio(2:6)=tempshe1.lt(1:5)./(tempshe1.equity_value(1:5)+temps
he1.lt(1:5));

tempshe1.deratio(8:end)=tempshe1.lt(7:end-
1)./(tempshe1.equity_value(7:end-1)+tempshe1.lt(7:end-1));

tempshe1.prihedg(2:6)=tempshe1.hedg(1:5);

tempshe1.priimr(2:6)=tempshe1.imr(1:5);

tempshe1.prihedg(7:end-1)=tempshe1.hedg(7:end-1);

tempshe1.priimr(7:end-1)=tempshe1.imr(7:end-1);

tempshe1.priNI(2:6)=tempshe1.ni(1:5);

tempshe1.priNI(7:end-1)=tempshe1.ni(7:end-1);

sMainhedg.pridvr(ind1)=tempshe1.pridvr;

sMainhedg.prideratio(ind1)=tempshe1.deratio;

sMainhedg.prihedg(ind1)=tempshe1.prihedg;

sMainhedg.priimr(ind1)=tempshe1.priimr;

sMainhedg.prioNI(ind1)=tempshe1.priNI;

ind2=find(sMainhedg.gvkey==108326);

tempshe2=sMainhedg(ind2,:);

tempshe2.pridvr(1)=NaN;

tempshe2.pridvr(7)=NaN;

tempshe2.deratio(1)=NaN;
```

```
tempshe2.deratio(7)=NaN;
tempshe2.prihedg(1)=NaN;
tempshe2.prihedg(7)=NaN;
tempshe2.priimr(1)=NaN;
tempshe2.priimr(7)=NaN;
tempshe2.priNI(1)=NaN;
tempshe2.priNI(7)=NaN;
tempshe2.pridvr(2:6)=tempshe2.divr(1:5);
tempshe2.pridvr(8:end)=tempshe2.divr(7:end-1);
tempshe2.deratio(2:6)=tempshe2.lt(1:5)./(tempshe2.equity_value(1:5)+temps
he2.lt(1:5));
tempshe2.deratio(8:end)=tempshe2.lt(7:end-
1)./(tempshe2.equity_value(7:end-1)+tempshe2.lt(7:end-1));
tempshe2.prihedg(2:6)=tempshe2.hedg(1:5);
tempshe2.prihedg(8:end)=tempshe2.hedg(7:end-1);
tempshe2.priimr(2:6)=tempshe2.imr(1:5);
tempshe2.priimr(8:end)=tempshe2.imr(7:end-1);
tempshe2.priNI(2:6)=tempshe2.ni(1:5);
tempshe2.priNI(8:end)=tempshe2.ni(7:end-1);
sMainhedg.pridvr(ind2)=tempshe2.pridvr;
sMainhedg.prideratio(ind2)=tempshe2.deratio;
sMainhedg.prihedg(ind2)=tempshe2.prihedg;
sMainhedg.priimr(ind2)=tempshe2.priimr;
sMainhedg.prioNI(ind2)=tempshe2.priNI;
clear ind
clear ind1
clear ind2



clear i
clear tempshe
clear tempshe1
```

```
clear tempshe2
clear nnt
clear nntt
save sMaindata.mat
```

Sample Description

```
datasample=sMainhedg(:,["gvkey","fyear",'DEratio','MtoB','hedg','wta','rta','ebita','saleta','liquidity','size','leve','dpat','collat','slg','deratio','ope']);
% MtoB
av=min(datasample.MtoB);
indav=find(datasample.MtoB==av);
datasample(indav,:)=[];
clear av
clear indav
% slg
av1=max(datasample.slg);
indav1=find(datasample.slg==av1);
datasample(indav1,:)=[];
av1=max(datasample.slg);
indav1=find(datasample.slg==av1);
datasample(indav1,:)=[];
av1=max(datasample.slg);
indav1=find(datasample.slg==av1);
datasample(indav1,:)=[];
indf=find(datasample.slg==inf);
datasample(indf,:)=[];
clear indf
clear indav1
clear av1
% liquidity
indf=find(datasample.liquidity==inf);
datasample(indf,:)=[];
```

```
clear indf
% rea
ra=min(datasample.rta);
indra=find(datasample.rta==ra);
datasample(indra,:)=[];
ra=min(datasample.rta);
indra=find(datasample.rta==ra);
datasample(indra,:)=[];
ra=min(datasample.rta);
indra=find(datasample.rta==ra);
datasample(indra,:)=[];
ra=min(datasample.rta);
indra=find(datasample.rta==ra);
datasample(indra,:)=[];
% ope
indf=find(abs(datasample.ope)==inf);
datasample(indf,:)=[];
op=min(datasample.ope);
indop=find(datasample.ope==op);
datasample(indop,:)=[];
op=min(datasample.ope);
indop=find(datasample.ope==op);
datasample(indop,:)=[];
op=min(datasample.ope);
indop=find(datasample.ope==op);
datasample(indop,:)=[];
clear op
clear indop
clear indf
clear ra
clear indra
```

```
mmy=nanmean(table2array(datasample,1));
mmg=grpstats(datasample,'fyear');


indh=find(datasample.hedg~=0);
indn=find(datasample.hedg==0);

hedgtable=datasample(indh,:);

nhedtable=datasample(indn,:);

for i=1:15

    aveh(i)=nanmean(table2array(hedgtable(:,2+i)));

    aven(i)=nanmean(table2array(nhedtable(:,2+i)));

    [h,p,ci,stats] =
ttest2(table2array(hedgtable(:,2+i)),table2array(nhedtable(:,2+i)));

    diffpv(i)=p;

    tsta(i)=stats.tstat;

end


clear aveh
clear aven

clear i

clear h p

clear indh

clear indn

clear diffpv

clear tsta

clear hedgtable

clear nhedtable


% the evolution of hedg measure across the period
year=unique(datasample.fyear);

for i=1:length(year)

    indy=find(datasample.fyear==year(i));
```

```
    ddt=sort(datasample.hedg(indy));
    Y=prctile(ddt,[5,95]);
    ddt(ddt<Y(1) | ddt>Y(2))=[];

    meanhedg(i)=nanmean(ddt);
end
clear i
clear year
clear ddt
clear Y
clear indy
```

Prepare data for Probit model

```
protable=sMainhedg(:,["gvkey","fyear","hedg","leve","size","liquidity","d
etax","MtoB","divr"]);
protable2=sMainhedg(:,["gvkey","fyear","hedg","leve","size","liquidity","
tlcf","MtoB","divr"]);
% save table for porbit model in Python
writetable(protable,'probitdata.xlsx');
writetable(protable2,'probitdata2.xlsx');
```

Calculate distance to default (KMV)

```
ddtable=rmmissing(sMainhedg(:,["gvkey","fyear","equity_value","pridvr","s
trick","std_RET",'prioNI','prideratio','prihedg','priimr','deratio','MtoB
','hedg','imr','wta','rta','ebita','saleta','liquidity','size','lt']));


% calculate distance to default
for i=1:length(ddtable.gvkey)
    indt=find(Riskfree.datayear==ddtable.fyear(i));
    E=ddtable.equity_value(i);
D=ddtable.strick(i);
r=Riskfree.mean_rate(indt);
d=ddtable.pridvr(i);
sde=ddtable.std_RET(i);
```

```
[mva,sda]=KMVoptSearch(E,D,r,d,sde);

ddtable.mva(i)=mva;

ddtable.sta(i)=sda;

end

clear D

clear d

clear E

clear r

clear i

clear indt

clear mva

clear sda

clear sde

ddtable.retasset=ddtable.prioNI./ddtable.mva;

ddtable.dd=(log(ddtable.mva./ddtable.strick)+ddtable.retasset-
ddtable.pridvr-0.5*ddtable.sta.^2)./ddtable.sta;


%calculate sample description for dd
mmyd=mean(ddtable.dd);

mmgd=grpstats(ddtable(:,["fyear","dd"]),'fyear');

clear mmgd

clear mmg

clear mmy

clear mmyd


% the evolution of dd measure across the period
year=unique(ddtable.fyear);

for i=1:length(year)

    indy=find(ddtable.fyear==year(i));

    ddt=sort(ddtable.dd(indy));

    Y=prctile(ddt,[5,95]);

    ddt(ddt<Y(1) | ddt>Y(2))=[];
```

```
    meandd(i)=nanmean(ddt);
end
clear i
clear year
clear ddt
clear Y
clear indy
```

Regression

```
ddtable=rmmissing(ddtable);
indf=find(ddtable.dd==inf);
ddtable(indf,:)=[];
clear indf
save ddtable.mat
% divide data into hedgers and nonhedgers
indh=find(ddtable.prihedg~=0);
indn=find(ddtable.prihedg==0);
hedgtable=ddtable(indh,:);
nhedtable=ddtable(indn,:);
clear indh
clear indn
```

Sample Correlation

```
covsample=corr([ddtable.dd,ddtable.prihedg,ddtable.hedg,ddtable.wta,ddtab
le.ebita,ddtable.saleta,ddtable.size,ddtable.liquidity]);

covsample2=corr([ddtable.dd,ddtable.prideratio,ddtable.deratio,ddtable.wt
a,ddtable.ebita,ddtable.rta,ddtable.size,ddtable.liquidity,ddtable.MtoB])
;

covsample3=corr([sMainhedg.deratio,sMainhedg.prihedg,sMainhedg.hedg,sMain
hedg.collat,sMainhedg.collat,sMainhedg.dpat,sMainhedg.slg,sMainhedg.size,
sMainhedg.MtoB]);
```

model 1 and model 2

```
hedgtable=rmmissing(hedgtable);
indf=find(hedgtable.dd==inf);

hedgtable(indf,:)=[];

clear indf

% truncate the hedgtable

S=hedgtable;

Y=prctile(S.prihedg,[5 95],1);

a=find(S.prihedg<Y(1));

b=find(S.prihedg>Y(2));


S([a,b],:)=[];
clear Y

clear a

clear b

% standardize the hedgtable

S.prihedg=zscore(S.prihedg);

S.size=zscore(S.size);

S.liquidity=zscore(S.liquidity);

S.priimr=zscore(S.priimr);

S.imr=zscore(S.imr);

S.wta=zscore(S.wta);

S.ebita=zscore(S.ebita);

S.rta=zscore(S.rta);

S.MtoB=zscore(S.MtoB);

S.saleta=zscore(S.saleta);

S.dd=zscore(S.dd);

save S.mat


% regression without fixed firm effect
mod1=fitlm(S,'dd ~fyear+prihedg+size+liquidity+imr+wta+ebita+saleta')
```

```
% regression with fixed firm effect

S.gvkey = nominal(S.gvkey);

S.fyear = nominal(S.fyear);

mod12=fitlme(S,'dd
~fyear+gvkey+prihedg+size+liquidity+imr+wta+ebita+saleta')



ddtable.dd=zscore(ddtable.dd);
ddtable.prideratio=zscore(ddtable.prideratio);

ddtable.wta=zscore(ddtable.wta);

ddtable.ebita=zscore(ddtable.ebita);

ddtable.rta=zscore(ddtable.rta);

ddtable.size=zscore(ddtable.size);

ddtable.liquidity=zscore(ddtable.liquidity);

ddtable.MtoB=zscore(ddtable.MtoB);

% regression without fixed firm effect

mod2=fitlm(ddtable,'dd~fyear+prideratio+MtoB+size+liquidity+wta+ebita+rta
')

% regression with fixed firm effect

ddtable.gvkey = nominal(ddtable.gvkey);

ddtable.fyear = nominal(ddtable.fyear);

mod22=fitlme(ddtable,'dd~fyear+gvkey+prideratio+MtoB+size+liquidity+wta+e
bita+rta')
```

Mode 3

```
dftable=sMainhedg(:,["gvkey","fyear","deratio","DEratio","prihedg","hedg"
,"imr","MtoB","size","oiadp","collat","dpat","slg",'sale']);
dftable=rmmissing(dftable);



dftable(inf,:)=[];
clear inf

indop=find(dftable.ope==min(dftable.ope));

dftable(indop,:)=[];

clear indop % three times
```

```
indz=find(dftable.prihedg~=0);
dfntable=dftable(indz,:);



S1=dfntable;
covsample3=corr([S1.deratio,S1.prihedg,S1.hedg,S1.collat,S1.ope,S1.dpat,S1.slg,S1.size,S1.MtoB]);
% winsorize data sample
S1.prihedg=winsor(S1.prihedg,5,95);
S1.deratio=winsor(S1.deratio,5,95);
% standardize data sample
S1.deratio=zscore(S1.deratio);
S1.DEratio=zscore(S1.DEratio);
S1.prihedg=zscore(S1.prihedg);
S1.imr=zscore(S1.imr);
S1.MtoB=zscore(S1.MtoB);
S1.size=zscore(S1.size);
S1.ope=zscore(S1.ope);
S1.collat=zscore(S1.collat);
S1.dpat=zscore(S1.dpat);
S1.slg=zscore(S1.slg);
S1.hedg=zscore(S1.hedg);


% regression without fixed firm effect
mod3=fitlm(S1,'deratio~fyear+prihedg+size+collat+dpat+slg+ope+MtoB+imr')
% regression with fixed firm effect
S1.gvkey = nominal(S1.gvkey);
S1.fyear = nominal(S1.fyear);
mod32=fitlme(S1,'deratio~fyear+gvkey+prihedg+size+collat+dpat+slg+ope+MtoB+imr')
```

Function for the data

```
function F=KMVfun(EtD,r,d,ste,x)
 d1 = (log(x(1)*EtD)+(r-d+0.5*x(2)^2))/x(2);
 d2 = d1-x(2);
 F = [x(1)*exp(-d)*normcdf(d1)-exp(-
r)*normcdf(d2)/EtD+x(1)*(1-exp(-d))-
1;x(1)*normcdf(d1)*x(2)*exp(-d)-ste];
end
```

```
function [mva,sta]=KMVoptSearch(E,D,r,d,ste)
EtD=E/D;
x0=[1,1];
mvastaX=fsolve(@(x)KMVfun(EtD,r,d,ste,x),x0);
mva=mvastaX(1)*E;
sta=mvastaX(2);
end
```

```
function [Z]=winsor(X,p1,p2)
Y=prctile(X,[p1 p2],1);
X(X<Y(1))=Y(1);
X(X>Y(2))=Y(2);
Z=X;
end
```

Python code

```
import pandas as pd

import numpy as np

import statsmodels.api as sm

import scipy

from statsmodels.discrete.discrete_model import Logit, Probit, MNLogit

from sklearn.linear_model import BayesianRidge, LinearRegression, ElasticNet
```

```
from sklearn.svm import SVR

from sklearn.ensemble.gradient_boosting import GradientBoostingRegressor  # 集成算法

from sklearn.model_selection import cross_val_score  # 交叉验证

from sklearn.metrics import explained_variance_score, mean_absolute_error, mean_squared_error, r2_score

import matplotlib.pyplot as plt

import seaborn as sns

probittable = pd.read_excel('probitdata2.xlsx')

probittable[np.isnan(probittable)] = 0

probittable[np.isinf(probittable)] = 0

labf_part = probittable[probittable.columns[-1]].values

y=probittable['hedgind']

X=probittable.iloc[:,3:-1]



probit_model = Probit(y, sm.add_constant(X))

result = probit_model.fit()

result.summary()

hedgpredict=result.predict()

imr=scipy.stats.norm.pdf(hedgpredict)/scipy.stats.norm.cdf(hedgpredict)
```

```
imr.to_excel(imr.xlsx)

imr=pd.DataFrame(imr)

imr.to_excel('imr.xlsx')
```

stata code

```
reg3 (dd gvkey fyear prihedg MtoB size liquidity wta ebita rta deratio i.gvkey* i.fyear)
(deratio gvkey fyear prihedg size collat dpat slg ope MtoB dd i.gvkey* i.fyear)
```