Capital Structure, Debt Tax Shield, and Firm Value

-- A Propensity Score Matching Approach

A Thesis Submitted by

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Abstract

The author investigates the effects of capital structure on a firm's market value using a set of econometric methodologies, including OLS, reversed OLS, instrumental variable method, generalized propensity score matching approach, and covariant balancing propensity score matching approach.

The rest of this paper proceeds as follows. In Part B, I briefly explain the classic tax shield evaluation model constructed by Modigliani and Miller in 1963. Part III reviews the precedent literature of debt tax shield evaluation. Part IV introduces sample data and summarizes data characteristics. Part V and VI explain the econometric methodologies and interpret the regression results. Part VII concludes the research results. Part VIII points out potential future improvements to this study.

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I. Introduction

The relationship between a firm's capital structure and its market value has been a central topic of modern corporate finance. According to the theory of debt tax shield, for two firms with identical business size and expected future operation income, the firm with a heavier-levered capital structure usually has a higher market value than a firm with a lower leverage level and the difference in their market values represents the debt tax shield.

The evaluation of the debt tax shield was first comprehensively discussed by Modigliani and Miller in their classic paper (MM, 1963) and by subsequent economists. In this paper I will measure the tax shield of debt using a sample of S&P 500 companies over the period 1980 - 2014. In its emphasis on the relationship between debt and firm value, this paper uses different econometric methodologies to eliminate measurement error and self-selection bias.

The rest of this paper proceeds as follows. In Part B, I briefly explain the classic tax shield evaluation model constructed by Modigliani and Miller in 1963. Part III reviews the precedent literature of debt tax shield evaluation. Part IV introduces sample data and summarizes data characteristics. Part V and VI explain the econometric methodologies and interpret the regression results. Part VII concludes the research results. Part VIII points out potential future improvem ents to this study.

II. Debt Tax Shield and Endogeneity Problems

Under the stylized Modigliani and Miller's setting, there is no personal income tax. The tax benefit of debt refers to the reduction in tax liability due to the interest payment that is deductible from taxable income. For example, a firm with *Debt* (an arbitrary number) dollars of debt makes an annual interest payment of $r \cdot Debt$ where r represents the interest rate of borrowing. Tax payable is calculated by multiplying taxable earnings by corporate tax rate τ, and the interest expense $r \cdot Debt$ is subtracted from taxable earnings, so the interest expense reduces the firm's tax payable by $\tau \cdot r \cdot Debt$ every year. The tax benefit of debt therefore equals the present value of the perpetual annual tax savings, which can be considered as a perpetuity. We assume that the tax benefit of debt has the same level of risk as the underlying corporate debt, and we divide $\tau \cdot r \cdot Debt$ by the interest rate r and get the present value of perpetuity equal to $\tau \cdot Debt$.

The market value of a levered firm can be written as the value of an otherwise identical unlevered firm plus the tax benefit of debt. The tax benefit of debt is referred to as debt tax shield. This relationship can be written as follows.

$$V_L = V_U + \tau Debt \quad (1)$$

V_L represents the market value of a levered firm with a permanent debt amount, and V_U represents the value of an unlevered firm with pure equity financing. The levered and unlevered firms should be identical in any aspect other than the financial structure.

Equation (1) implies that for firms with different capital structures but similar operation characteristics[1], those with higher debt levels usually have greater market values since the marginal corporate tax rate τ is positive. More specifically, as debt increases by $1, the market firm value increases by τ. It also indicates that as the marginal corporate tax rate increases, the tax benefit per unit of debt also increases.

Preceding studies in the debt tax shield have found evidence that firms intend to take advantage of debt financing to increase market values. Masulis (1980 and 1983) discovered a positive coefficient of debt in firm's market value. MacKie-Mason (1990), Trezevant (1992), and Graham (1996, 1999) found evidence that a higher corporate tax rate increases the use of debt financing.

However, there is a measurement problem with most of the empirical studies, because the value of unlevered firm V_U cannot be directly measured. By the definition of Modigliani and Miller, V_U can be calculated using $E(FOI)/\rho$, where $E(FOI)$ represents a firm's expectation of future annual operation income and ρ the firm's pure equity financing cost. The capitalization rate ρ, however, is unobservable and differs with each company and year.

Another problem is self-selection bias. There are many factors that affect the capital structure that influence a firm's market value, and a firm's financing decision is made by the discretion of the firm's management team. Therefore, it is highly possible that people manipulate the firm's financing approach attempting to benefit from its optimal capital structure. For example, a firm with an expectation of stable

[1] Similar operation characteristics refer to similar expectations of future operation income. Here we want to make sure those firms correspond to the same firm value if they were unlevered.

future cash flow that could cover the repayments of interest and principle are more likely to use debt financing. On the contrary, a firm that is faced with liquidity risk would likely cut its leverage ratio to reduce the bankruptcy risks. Because a firm's financial condition also influences the firm's market value, there appears to be a spurious relationship between the firm's debt and market value.

III. Literature Review

Modigliani and Miller (1958, 268) developed their Proposition 1 asserting that, *"The market value of any firm is independent of its capital structure and is given by capitalizing its expected return at the rate ρ_k appropriate to its class."* In the same paper Modigliani and Miller prove Proposition 1 with the no-arbitrage principle, and show that any deviation from Proposition I would result in arbitrage activities that eliminate the discrepancy. In addition, they tested Proposition I with 43 large electric utilities for the years 1947 and 1948 (F. B. Allen, 1954) and 42 oil companies for year 1953 (Robert Smith, 1955), and concluded that the firm value and financial structure are independent with each other.

Modigliani and Miller (1963) corrected the conclusion they drew on "Effects of the Present Method of Taxing Corporations" (Modigliani and Miller, 1958, 272), and suggested that tax advantage of debt financing is greater than they used to believe. To calculate the value of a levered firm, they classify the long-run returns to a firm into two categories and explore the present value of two streams of returns. The first component of returns is an uncertain series of after-tax earnings, which has a present value equal to V_U, the value of an imaginary unlevered company. The second component of returns to the firm is the certain flow of tax savings from the interest payments called the debt tax shield, which has a present value of $\tau \cdot Debt$. Therefore, the market value of a levered firm V_L is equal to the sum of the value of an unlevered firm V_U and the value of the debt tax shield.

Modigliani and Miller's studies of capital structure gave rise to a broad and long-lasting discussion in this topic and other derivative subjects in modern corporate finance. Many researchers analyzed the debt tax shield using different approaches from diversified aspects. Masulis (1980 and 1983) studies exchange offers made during the 1960s and 1970s to test Modigliani and Miller's proposition that the tax benefit of debt increases the firm's market value. He discovered a debt coefficient of approximately 0.40, which is very close to the top statutory corporate tax rate at that time. Long and Malitz (1985), Titman and Wessels (1988), and Fischer, Heinkel, and Zechner (1989) use various forms of debt/equity ratios to test whether non-debt tax shields, such as depreciation or investment tax credits, reduce the tendency of firms to use the debt tax shields. Studies focused on incremental financing decisions (e.g., MacKie-Mason (1990), Trezevant (1992), and Graham (1996, 1999)) find evidence that high marginal tax rates promote the use of debt. Graham (2000) estimates the tax benefit function by calculating the tax rates corresponding to different interest deduction percentages. Then he determines the tax benefit of debt by aggregating the area under the tax benefit function up to the level of actual interest expense. Graham concludes that capitalized tax benefit of debt equals 9.7 percent of firm value.

Additionally, Graham conducts firm-by-firm analysis to determine tax benefit of debt for some well-known firms from a broad spectrum of industries, including Boeing, Intel, Pacific Gas and Electric, Coca-Cola, and so on. He finds that a small portion of the sample firms is located on the downward-sloping part of their marginal tax benefit functions. In another study, Binsbergen, Graham, and Yang (2010) estimated the marginal cost of debt function with a large sample of companies between 1980 and 2007, and derived an equilibrium net benefit of debt of 3.5% of asset value. In a very innovative approach, Doidge and Dyck (2013) studied the debt tax shield by designing a "quasi natural experiment" with Tax Fairness Plan (TFP), which is an unanticipated dramatic change in tax policy, and they document that prospective tax shields add 4.6% to firm value. Following the work of Doidge and Dyck, Faccio and Xu (2014) exploit a series of tax reforms in OECD countries and investigate the value of debt tax shield of different categories of firms; they conclude that debt tax shields are more valuable for high corporate tax payers and more profitable firms. Specifically, Faccio and Xu also used propensity score matching methodology to test and verify the conclusion they got.

On the other hand, precedent researches have proven the existence of intrinsic costs associated with debt financing. The first category of debt cost is the financial distress faced by firms with interest and principal obligations, which is studied by Kraus and Litzenberger (1973) and Scott (1976). The second category of cost is related to agency cost investigated by Jensen and Meckling (1976) and Myers (1977). The third category of risk was discussed by Miller (1977), in which he argues the existence of personal tax might offset tax benefit of debt. Even though there is trade-off between benefits and costs of debt financing, it is generally agreed that firm value increases with the use of debt up to the point where the marginal cost of debt equals the marginal benefit.

This paper focuses on the study of the debt tax shield and is closely related to precedent work of Fama and French (1998) and Kemsley and Nissim (2002). In the paper of Fama and French, they refine Modigliani and Miller's simple model by taking account of the tax effects of firm's equity financing. In tax stories about financing decisions, it is tax disadvantageous to pay dividends in the similar way that it is tax saving to pay interest, so Fama and French use dividend and interest expense to represent the level of debt and equity, and they regress firm value on past, current, and future earnings, investment, and research and development (R&D) expenditures as well as annual dividend and interest expense. To measure the tax effects of debt and equity financing, Fama and French emphasize the control for profitability. In other words, the control variables need to capture all the information about expected net cash flows associated with firm's financing decision, so that the coefficients on dividend and debt variables evaluate pure tax effects. Fama and French also include the two-year change of dependent variables in regressions in order to control for the expected growth of profits. In order to deal with the heteroskedasticity problem of different firm sizes, Fama and French deflate all relevant variables by total book assets.

The regressions by Fama and French produce no evidence for tax benefit of debt when they control for either pretax or after-tax earnings. Fama and French interpret this result as a consequence of imperfect controls for profitability. They also find evidence that dividends and debt convey information about the firm value that is missed by a wide range of control variables. They conclude that it is probably impossible to solve this condition. Nonetheless, Fama and French's work exposes a rich set of information in financing decisions, which is evidence of signal effects in corporate finance.

Kemsley and Nissim agree with Fama and French in the existence of non-tax correlations between firm value and debt, and they believe that imperfect control for the value of operation leads to biased estimation of the debt tax shield. Adding market-based variables to the right hand side of the regression is expected to control the risk and growth factors and reduce estimation bias. However, Kemsley and Nissim point out that using the market value of firm as dependent variable restricts the effectiveness of market-based measures (e.g., the market-to-book ratio) as control variables.

Kemsley and Nissim's work is basically generated from Modigliani and Miller's tax-adjusted valuation in model (1). In order to address the concerns mentioned above, they develop an alternative approach by switching the dependent variable – firm value V_L, and the independent variable – the unlevered firm value V_U. Also they define V_U using E(FOI)/ρ, the expected after-tax future operating income discounted by proper capitalization rate ρ. The following is the regression model they developed:

$$E(FOI) = \alpha_1 + \alpha_2\rho(V_L - \beta Debt) + \varepsilon \quad (2)$$

In this equation, β, the opposite value of the ratio of the estimated coefficients of *Debt* and V_L, stands for the estimated value of the net debt tax shield rate. Kemsley and Nissim use a sample of 42,505 observations of 2,964 firms over the period of 1963 to 1993. Their estimation for the debt tax shield rate β using equation (2) is -0.483.

Kemsley and Nissim consider the negative sign of β as a signal of insufficient control for capitalization rate ρ, since the capitalization rate ρ in equation (2) is treated as a constant rate for all firms, which is not the case in the real world. In the rest of their work, Kemsley and Nissim treat ρ as a function of growth and of risk such that ρ increases with risk and decreases with expected growth. In order to control for capitalization rate ρ, Kemsley and Nissim use two different approaches. For the first approach, they construct portfolios using years, industries, and market-to-book ratios of operations so that observations in the same portfolio have similar capitalization rates. The second approach includes using a vector of controls for risk and growth to identify a subsample of observations with similar capitalization rates.

With sufficient controls for the capitalization rate, the estimated debt tax shield by Kemsley and Nissim is substantially positive and equal to approximately 40 percent of firm's debt balance, net of personal tax disadvantage. This means for every dollar of debt issued, the firm value increases by 0.4 dollar on average after controlling for operation profit and risk and growth factors. This estimated net debt tax shield is a little smaller than the average corporate tax rate, 0.45, for their sample period. The result provides evidence that corporations capture the bulk of the corporate tax benefit of debt.

IV. Data

In this section I introduce the definition of the variables and explain the way I process the sample data. I also list the characteristics of the variables. At the end of this section I display the distribution of debt, which gives an intuitive description of corporate debt.

In my research I investigate the Standard & Poor's 500 companies over the period 1980 to 2014. The full sample containing 11,784 observations is an unbalanced panel data set because some firms were not added to the Standard & Poor's 500 index until recently. Companies in financial related industries are excluded from the study because financial institutions usually have a higher leverage and a different tax policy than other companies, and therefore the inclusion of financial institutions might contaminate the research outcome.[2] After deleting the financial related companies, each company is assigned a unique ticker identification number *tickerid*.

Figure 1 shows the overall distribution of debt of the non-financial institutions. Note that Figure 1 displays the number of observations in log-scale to make the graph more readable. The mean of debt is $4,455 million with a standard deviation of 17,588. There are 2,906 observations with debt obligations between $0 and 1,000 million, 1,882 observations with debt between $1,000 million to $2,000 million, and the number of observations declines exponentially with debt.

[2] Including industries of Banks, Capital Markets, Consumer Finance, Diversified Financial Services, and Insurance

Figure 1

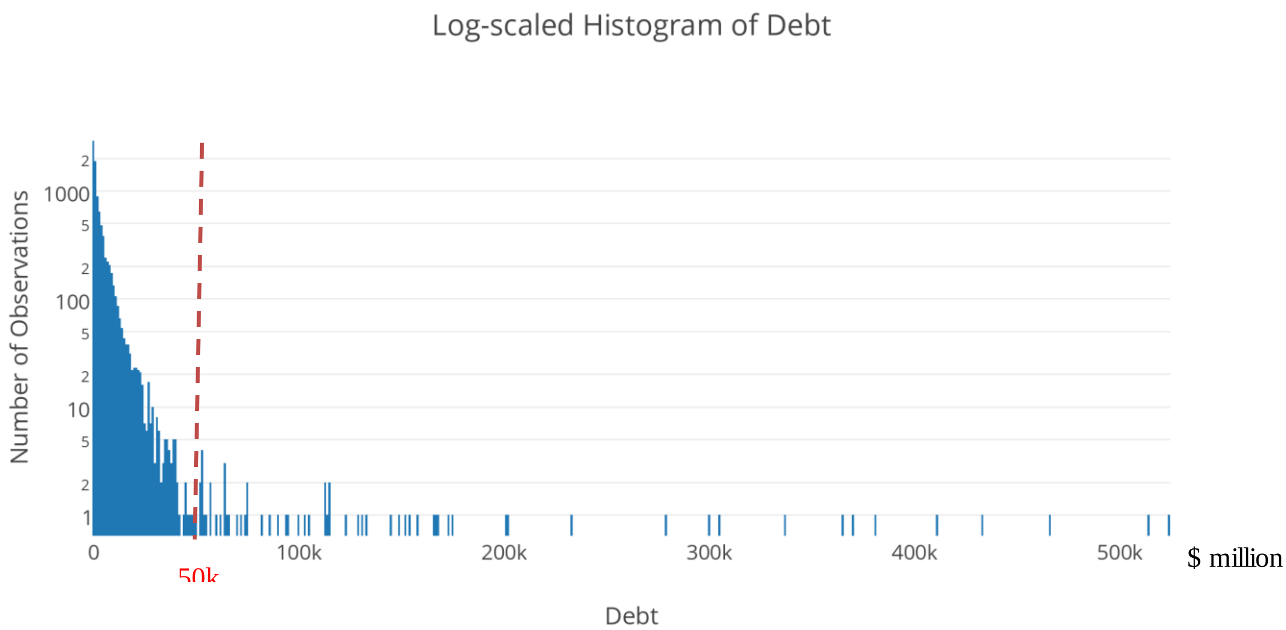
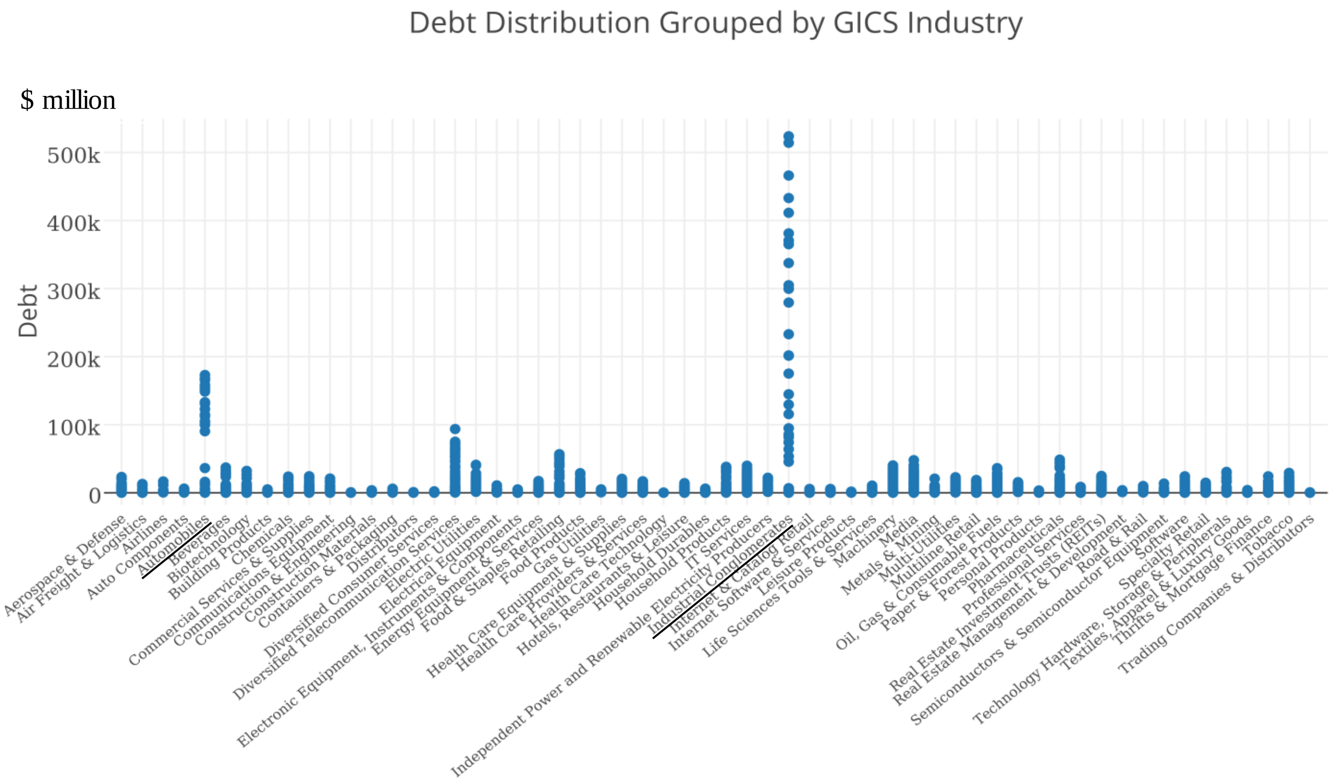


Figure 2 shows the distribution of debt of different GICS industries. It is noticeable that most of the firms' debt values are no more than $50,000 million and that most of the firms with more than $100,000 million debt outstanding belong to the Industrial Conglomerates industry with a maximum debt value equal to $523,762 million and a big standard deviation. It is also noticeable that firms in Automobiles industry are polarized with regard to debt level, with nearly half of observations with debt obligations over $100,000 million.

Figure 2



In this session I describe the definition of several important variables. V_L represents the market value of the firm, which equals to the sum of the market value of common equity (*Equity*), book value of debt (*Debt*) and preferred stock (*Preferred*), calculated as

$$V_L = \text{Equity} + \text{Debt} + \text{Preferred},$$

where *Equity* is derived from the current market capitalization and *Debt* is the sum of long term borrowing and short term borrowing. The after-tax earnings variable *FOI*, future operation income, is defined as *EBITA*(1 - tax_rate)*, where *EBITA* stands for earnings before interest, tax, and amortization and is directly available from a firm's financial profile. As to the tax rate, I use the top corporate statutory federal tax rate[3] of the year as *tax_rate* for all firms, and panel B in Table 3 shows the tax rates from year 1980 to 2014. The expectation of future operation income, *E(FOI)*, is calculated by taking an average of annual *FOI* over the subsequent five years. The financial leverage ratio *Leverage* is defined as *total_assets* divided by *total_common_equity* and serves as an indicator of firm's capital structure.

I also generate two variables *Hier* and *debt_index* as comprehensive measures of a firm's capital structure. *Hier* is an indicator of a firms' relative leverage level and is determined in the following way: one could compare a firm's leverage ratio with its industry median leverage level,[4] and assign "1" to its *Hier* value if the firm's leverage is above the industry median level, and assign "0" otherwise.

Before analyzing the sample data, I firstly trim the data by deleting the observations with negative values of *Asset*, *E(FOI)* or V_L, which accounts for slightly above 1% of the overall sample. Secondly, I drop the observations with a leverage ratio above 17, which accounts for less than 10 percent of overall observations. Thirdly, I trim the dataset by deleting observations with more than 9 billion dollars of debt to exclude potential outliers. Several firms in specific years had extremely high debt levels and the distribution of corporate debt is very dispersed in the right part of distribution. Finally, I deal with missing values in variables E(FOI), V_L, Debt and Asset, since these variables are the most relevant in later regression. Table 1 tabulates

[3] See Thomas L. Hungerford, *Corporate tax rates and economic growth since 1947*. (2013)

[4] The industry categorization is determined by the Global Industry Classification Standard (GICS).

the missing values of E(FOI), V_L, Debt and Asset. We can see from Table 1 that observations containing missing values in E(FOI) account for more than half of the sample while observations containing any missing values in V_L, Debt or Asset account for roughly 10 percent of the sample. The proportion of missing values in V_L, Debt or Asset is quite small and we can delete the observations containing missing values in these variables.

Table 1

Missing-value Patterns

Percent	Debt	Asset	V_L	E(FOI)
41%	1	1	1	1
46%	1	1	1	0
5%	1	0	0	1
4%	1	0	0	0
1%	1	1	0	1
1%	1	1	0	0
<1%	0	1	0	0
<1%	0	1	0	1
<1%	1	0	1	0
<1%	0	0	0	1
<1%	1	0	1	1
<1%	0	0	0	0

After dropping observations with any missing value in V_L, *Debt* or *Asset*, there are 6,962 observations left. By the definition of *E(FOI)*, it is an average of the operation income of the following five years. There is an intrinsic problem with the definition of *E(FOI)* because for observations from year 2010 to 2014 (and for most observations in year 2009[5]), the value of *E(FOI)* is missing due to unavailable information of future operation income. Therefore I drop all observations from year 2009 to 2014, which account for 1,612 observations.

Considering that there still is a significant amount of observations containing missing values in *E(FOI)*, I decide to test whether the missed *E(FOI)* values are randomly distributed across other observables. The way to achieve this goal is to generate a dummy variable *foi_dummy* indicating whether *E(FOI)* is missing or not and regress the dummy variable on other observable variables. The regression results are shown in Table 2. As we can see, the R^2 of this regression is 0.2340. The coefficients of *Debt*, *EV*, and *mktcap* are statistically significant at 1% level. However, it is also noticeable that the coefficient of V_L is not significantly different from zero. This insignificant coefficient of V_L indicates that conditional on the other observables, the missing values of *E(FOI)* are randomly distributed across different levels of the firms' market value. Therefore, although the missing values are correlated with some of the observables, they are conditionally random with respect to the dependent variable (*E(FOI)*). Thus, I deleted the missing observations in *E(FOI)*.

Table 2

Missing Value Indicator Regression Result

Dummy variable foi_dummy is an indicator of whether E(FOI) is a missing value for this observation. If E(FOI) is not missing, foi_dummy = 0. Otherwise, foi_dummy =1. The table below

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[5] For most companies, the financial data of 2014 was not released by Bloomberg at the time I collected data, and these companies intrinsically have missing data in E(FOI) for year 2009. The fact is only 2 out of 320 observations have non-missing E(FOI) data in year 2009.

shows the regression results of foi_dummy on other variables.

foi_dummy	Coefficient	P>t
Debt	$-6.1e^{-05}$	0.001***
EV	$1.83e^{-05}$	0.005***
V_L	$2.26e^{-05}$	0.193
Asset	$5.65e^{-07}$	0.854
debt_index	0.010	0.399
mktcap	$-4.3e^{-05}$	0.006***
EBITA	$1.14e^{-05}$	0.223
EV_to_EBITA	$-1e^{-04}$	0.156
tt_equity	$1.95e^{-06}$	0.734

After deleting the observations containing any missing values in E(FOI), V_L, Debt or Asset, the new dataset contains 3,253 observations of 334 firms. In Panel A of Table 3, I summarize the important statistics of the variables *V_L*, *E(FOI)*, *Debt*, *Asset*, *Leverage*, *Hier,* and *debt_index*.

As we can see from Panel A in Table 3, the mean and standard deviation of *Hier* are both 0.5. This fact indicates that half of the firms have leverage levels that are above the median of the industries they belong to, and the other half of the firms have leverage levels below the industrial median level. I also generate a comprehensive debt index *debt_index* using Principal Component Analysis (PCA) that takes as input *long_borrow, short_borrow, Debt, Hier,* and *Leverage*.

Panel B of Table 3 summarizes the top federal statutory corporate tax rate from year 1980 to 2014. Besides federal tax, state and local governments may also impose corporate taxes ranging from 0% to 12%, the top marginal rates averaging approximately 7.3% (See appendix 1). A corporation may deduct its state and local income tax expense when computing its federal taxable income, generally resulting in a net effective tax rate of approximately 40% (KMPG. *Corporate Tax Rates Table*)[6]. The total effective tax rate may vary significantly by the location of the corporation.

Table 3

Descriptive Statistics

Panel A

Panel A summarizes the statistical characteristics of 3,253 observations from 346 firms in total. For each of the 334 firms, there is unique ticker identification *tickerid*. V_L represents the market value of the firm with a permanent level of debt *Debt*. *FOI* represents the firm's future operation income, which is defined as *EBITA*(1- tax_rate)*. *E(FOI)* is the expectation of *FOI*, calculated as an average of future operation income over subsequent five years. *Debt* is the sum of long-term and short-term debt. The values of V_L, *E(FOI)*, *Debt*, and *Asset* are expressed in million dollars. The financial ratio *Leverage* is defined as *total_asset* divided by *total_common_equity*. Variables *Hier* and *debt_index* are newly generated indicators of the firm's capital structure. All variables are measured in units of million dollars.

Variable	Obs.	Mean	Std. Dev.	Min	Max
V_L	3253	14843	30717	15.13	601029

[6] http://www.kpmg.com/global/en/services/tax/tax-tools-and-resources/pages/corporate-tax-rates-table.aspx

E(FOI)	3253	846.2	1571	0.156	32142
Debt	3253	2157	2366	0	8993
Asset	3253	8806	11600	12.97	216203
Leverage	3253	2.780	1.533	1.086	16.53
Hier	3253	0.494	0.500	0	1
debt_index	3253	0.0828	1.718	-2.251	15.81

Panel B

Corporate tax rate *tax_rate* represents top corporate statutory federal tax rate and is identical for all firms in a specific year.

Year	tax_rate
From 1980 to 1986	0.46
Year 1987	0.4
From 1988 to 1992	0.34
From 1993 to 2014	0.35

The overall distribution of debt after trimming data is shown in Figure 3, and the distribution of debt among different GICS industries after deleting extreme and missing data is displayed in Figure 4.

Figure 3

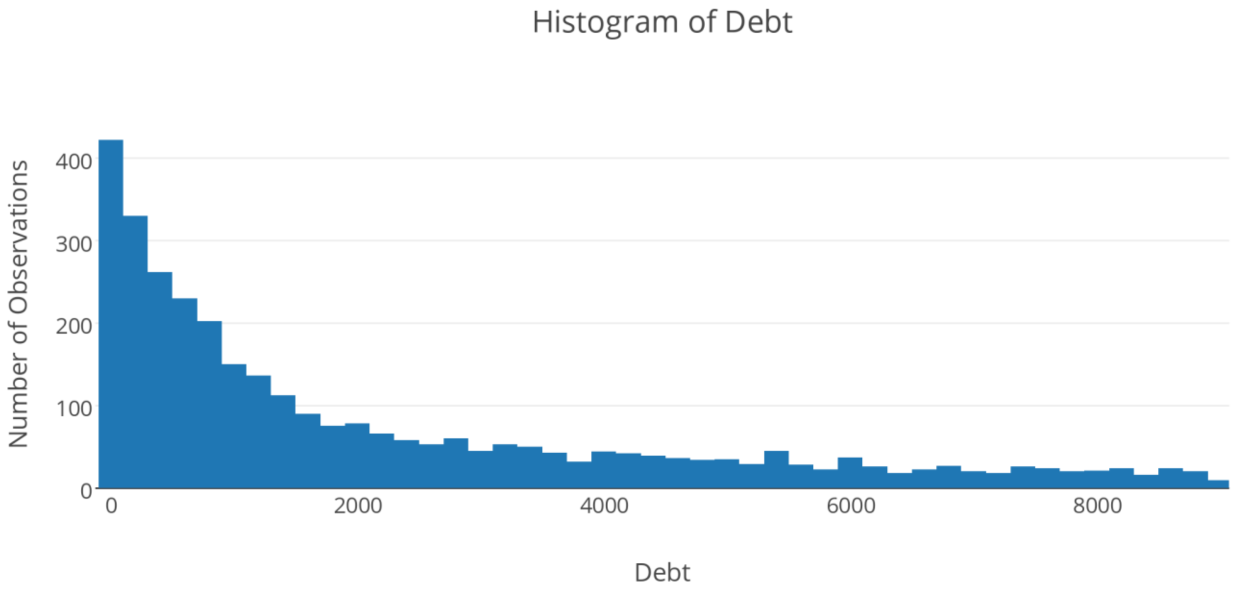

Figure 4

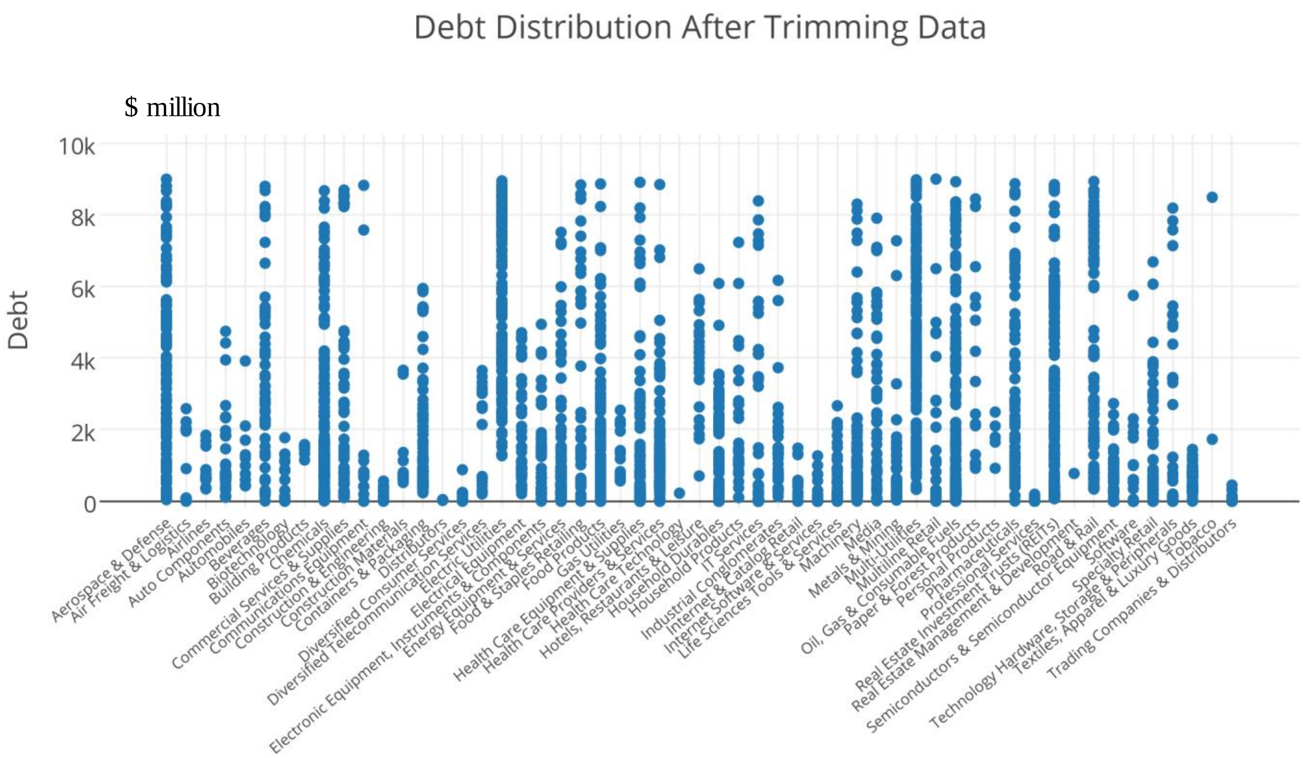

Table 4 displays the pairwise correlations between V_L, *E(FOI)*, *Debt* and *Asset*. In the upper triangle, I list the correlation coefficients of the absolute value of variables, while in the lower triangle I list the pairwise coefficients between these variables deflated by the value of *Asset* and the absolute value of *Asset*.

Table 4

Correlations among Undeflated Variables and among Deflated Variables

In the upper triangle of Table 4, the numbers represent correlations between undeflated (absolute value of) row and column variables. In the lower triangle of Table 4, the numbers represent correlations between corresponding row and column variables deflated by asset (except for the last row, where the row variable is undeflated asset). The sample size is 3,253 observations.

	V_L	E(FOI)	Debt	Asset
V_L	1	0.850	0.620	0.795
E(FOI)	0.619	1	0.423	0.661
Debt	0.114	-0.0650	1	0.930
Asset	-0.0848	-0.157	0.0618	1

It is noticeable in Table 4 that the undeflated V_L, *E(FOI)*, *Debt* and *Asset* are positively correlated with each other; however, the pairwise correlations among deflated V_L, *E(FOI)*, *Debt* and undeflated *Asset* drop significantly.

V. Econometric Methodology

A. OLS Regression with Panel Data

Based on Modigliani and Miller's classic model (1) and substituting *E(FOI)/ρ* for V_U, we have the linear equation to estimate the value of debt tax shield as below:

$$V_L=\alpha_1 + \alpha_2 E(FOI)/\rho + \alpha_3 Debt + \varepsilon, \qquad (3)$$

where α_3 measures the marginal effect of *Debt* on V_L. Under the assumptions by Modigliani and Miller, there is no personal income tax or financial distress costs, and the coefficient of *Debt* measures the pure debt tax shield rate. Modigliani and Miller proved theoretically that α_3 should be positive and equal to the marginal corporate tax rate.

When treating the pure equity capitalization rate ρ as a constant, equation (3) could be transformed into the following linear equation:

$$V_L = \alpha_1 + \alpha_2 E(FOI) + \alpha_3 Debt + \varepsilon, \qquad (4)$$

where α_2, the coefficient of *E(FOI)*, is equal to the reciprocal of capitalization rate ρ. The OLS regression results of the panel data[7] are shown in Table 5.

Table 5

OLS Regression Results with Panel Data

The OLS method regresses the market value of firm V_L on expected future operation income *E(FOI)* and *Debt* of the panel data. This regression is based on Modigliani and Miller's classic firm valuation model with the assumption of a constant capitalization rate ρ.

$$V_L = \alpha_1 + \alpha_2 E(FOI) + \alpha_3 Debt + \varepsilon$$

[7] The panel data sets *year* as time variable and uses *tickerid* as group variable.

	α_1	α_2	α_3	R^2	Obs.
Mean	2779.46	9.59^{***}	1.83^{***}	0.6645	3,253
t-statistic	1.34	3.58	4.0		

From Table 5 we find the OLS estimation of α_1 is not significantly different from 0 at the 10% level. This result is in compliance with Modigliani and Miller's original model (1) where the constant is equal to zero. The implicit estimation of ρ is the reciprocal of estimated α_2, which equals 0.1043 (10.43%). This capitalization rate falls within a reasonable range of the market capitalization rate during recent decades. The estimated debt tax benefit rate, α_3, is significantly positive with an estimation of 1.83. This rate is much higher than the statutory corporate tax rate, and there probably exists some bias in the OLS estimation due to endogeneity problems.

As a transformation of equation (1), Kemsley and Nissim exchanged the dependent variable and independent variables to produce the nonlinear equation (2). When treating capitalization rate ρ as a constant, equation (2) could be linearized and written as follows:

$$E(FOI) = \gamma_1 + \gamma_2 V_L + \gamma_3 Debt + \varepsilon, \quad (5)$$

where the estimated rate of debt tax shield (i.e., β) could be calculated as the opposite of the coefficient of *Debt* over the coefficient of V_L (i.e., $-\gamma_3/\gamma_2$). The outcomes of regression (5) are shown in Table 6.

Table 6

Reversed Regression Results with Panel Data

This regression model is based on the model of Kemsley and Nissim (2002). They reversed the dependent variable V_L and independent V_U, and assume a constant capitalization rate ρ for all firms to linearize the equation. The estimated debt tax shield β is equal to the opposite of the ratio of coefficients of *Debt* and V_L ($-\gamma_3/\gamma_2$).

$$E(FOI) = \gamma_1 + \gamma_2 V_L + \gamma_3 Debt + \varepsilon$$

	γ_1	**γ_2**	**γ_3**	**β**	**R^2**	**Obs.**
Mean	296.95***	.025**	.081	-3.21	0.6977	3253
t-statistic	3.33	1.99	1.52	0.88		

The estimated debt tax shield rate β has a negative value (-3.21), which is very different from the OLS estimation in the previous part. Kemsley and Nissim get a significantly negative net debt tax shield without controlling for capitalization rates, and they explain it as a biased estimation due to imprecise measurement of V_U. Similarly, we get a negative but insignificant coefficient of debt using Kemsley and Nissim's estimation model.

Despite the simplicity of equation (4) and (5), the capitalization rate ρ is not a constant in the real world. Actually, ρ as firm's capitalization rate is a function of year and firm characteristics. For example, ρ decreases with growth rate and increases with risk (Kemsley and Nissim, 2002). Since the firm's capitalization rate ρ is unobservable and imprecisely captured, it gives rise to the measurement error of V_U. Although many researchers used to try various proxies to capture ρ with a final goal of measuring V_U, such as Fama and French, they usually get either insignificant or negative coefficients on debt and end up concluding that it is necessarily impossible to employ proxies to precisely measure V_U. This measurement error might be captured by *Debt* and contaminate the estimation of debt tax shield.

Due to limit of information, we cannot decide the direction of bias in the estimated debt coefficient caused by measurement error of V_U. Imagine a firm with an above-average growth rate g, then its capitalization rate ρ will be lower than average. In our model (4) this firm will be underestimated in V_U. On the other hand, according to Gordon Growth Model, the firm with an above-average growth rate g usually has a higher market value V_L. Therefore, if the firm's amount of debt has a significant correlation with its growth rate g, there will be a consistent bias in the estimation of the coefficient α_3.

B. Instrumental Variable (IV) Approach

In order to remove the measurement error with unlevered firm value V_U, in this section I employ an instrumental variable for V_U and evaluate the debt tax shield. The ideal instrumental variable for V_U should be an exogenous variable that is not directly related to firm's market value V_L. Besides, since V_U is the value of an imaginary unlevered firm with identical operation income with the levered firm, V_U is independent of the levered firm's capital structure. Therefore, the ideal instrumental variable should also be uncorrelated with firm's leverage ratio in the same way as V_U. The book value of total assets (*Asset*) satisfies the exogeneity requirement because the book value of total assets is not directly correlated with the firm's market value V_L. The definition of asset by International Accounting Standards (IAS) is "a resource controlled by the enterprise as a result of past events and from which future economic benefits are expected to flow to the enterprise". According to the definition of asset by IAS, the book value of total asset is generally stable and unlikely to be influenced by management decision or firm's market value. When it comes to independence from a firm's capital structure, total assets is the sum of debt and equity, and is uncorrelated with the debt to equity ratio. In this sense, a firm's book value of total assets satisfies the requirements for an instrumental variable of V_U.

In the two stage least squares (2SLS) regression, the first-stage equation regresses the endogenous variable (V_U) on all of the exogenous variables (*Asset* and *Debt*):

$$V_U = \pi_1 + \pi_2 \text{ Asset} + \pi_3 \text{ Debt} + \varepsilon, \quad (4)$$

where V_U is represented by *E(FOI)* with bias. Panel A of Table 7 shows the regress result of the first-stage equation (4).

As we can see from Panel A in Table 7, the F-statistic of the first-stage regression equals 103.81 with a p-value of 0. Specifically, the t-statistic of the coefficient of *Asset*, π_2, is 41.50 with a p-value of 0. This indicates that *Asset* is significantly correlated to V_U and therefore is a strong instrumental variable for the endogenous variable V_U.

In the second-stage of 2SLS, we substitute the expected value of $\widehat{V_U}$ using model (4) for V_U in the classic model (1). The second-stage regression model is:

$$V_L = \alpha_1 + \alpha_2 \widehat{V_U} + \alpha_3 \text{ Debt} + \varepsilon \quad (5)$$

The two-stage least squares (2SLS) estimated coefficients are listed in Panel B, Table 7 below:

Table 7

Panel A

First-stage Regression Results of 2SLS

First-stage regression model: $V_U = \pi_1 + \pi_2$ Asset + π_3 Debt + ε, where unobservable variable V_U is imperfectly represented by *E(FOI)*.

First-stage	π_1	π_2	π_3
Mean	384.95	0.120^{***}	-0.197^{***}
t-statistic	0.99	50.73	-18.34

F(30, 2889) = 129.30, p-value = 0

Panel B

Second-stage Regression Results of 2SLS

Second-stage regression model: $V_L = \alpha_1 + \alpha_2 \widehat{V_U} + \alpha_3$ Debt + ε, where V_U is substituted by $\widehat{V_U}$ predicted in the first-stage.

Second-stage	α_1	α_2	α_3	R^2	N
Mean	-2432.65	15.20^{***}	0.71^{***}	0.7124	3253
t-statistic	-0.24	29.90	2.81		

The estimated constant $\widehat{\alpha_1}$ has a t-statistic of 0.24, so we cannot reject the null hypothesis that α_1 is equal to zero at a significant level of 10%. This outcome provides support for a zero constant in MM's classic model. The implied value of ρ is equal to the reciprocal of 15.20, which is equal to 0.0658 (6.58%). The estimated coefficient of debt tax shield is 0.71. This value is closer to MM's estimation than the previous OLS and reversed OLS regression results, probably because the IV method has reduced the measurement error of V_U effectively.

The IV regression results generally comply with the proposition of MM's classic firm valuation model. However, this estimation of debt tax shield rate is still a little more than the statutory corporate tax rate[8] from year 1980 to 2014. According to Kemsley and Nissim (2002), the noncompliance rises from insufficient control for the nontax correlations between debt and firm's market value, and such nontax dimensions include firm's growth rate *g*, financial distress, signaling and size effects. The following section discusses how to control for the non-tax dimension using the matching approach.

C. The Generalized Propensity Score Matching (GPSM) Approach

A firm usually has access to different capital resources to finance its business activities. When the management members make a financial decision, they usually take into consideration a variety of factors from the firm's current financial condition, to the capitalization costs, to the firm's potential opportunities and threats. We can imagine that firms capable of paying back interests and principles on future due dates have a greater probability of using debt financing than firms currently obsessed by liquidity concerns. However, these factors that influence a firm's financial decision and market value might not be completely captured by V_U, which is measured by the present value of the expected future operation profitability.

Take an example of two firms with equal expectations of future operation profitability but different capital structures. If we simply attribute the entire difference in the market value of two firms to the discrepancy in their capital structure, it would be problematic because the firm with more debt might be the one with an expectation

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[8] The highest statutory corporate tax rate happened during 1980 and 1986, which is equal to 0.46.

of adequate cash flow in the future. Since firms in a robust financial condition have higher market values than firms with liquidity issues, this gives rise to a spurious relationship between debt and the market value of a firm. Another possible scenario is that the firm with adequate capital-raising resources might want to use other financing methods to avoid bankruptcy risks associated with debt obligations. These possible non-tax correlations between a firm's debt and market value complicate the estimation of debt tax shield, which is reflected in the coefficient of *Debt*.

Therefore, when determining the tax benefit of debt, we need to employ an econometric approach to control for all nontax dimensions connecting firm's capital structure and market value. The difficulty is that some of the relevant variables are insider information that are not available for outsiders or not well quantified for quantitative analysis. A commonly used way to address the unobserved heterogeneity problem is the Differences-In-Differences (D-I-D) method. With D-I-D method, we don't need to find the controls for the relevant unobserved variables, as long as the counterparties have similar patterns of evolution if there was no intervention.

Akin to the logics behind the D-I-D method, the matching approach matches the treated and untreated units on observables and makes assumption that the counterparties are independent of potential outcomes conditional on the observables $\boldsymbol{X}$, that is:

$$E[Y_0|\boldsymbol{X}, d = 1] = E[Y_0|\boldsymbol{X}, d = 0],$$

where Y_0 represents the potential outcome of units not receiving treatment for both the treated (d=1) and the untreated (d=0). This condition is known as the weak unconfoundedness assumption. When this assumption holds, matching method can yield an unbiased estimate of the treatment impact.

The propensity score matching (PSM) approach by Rosenbaum and Rubin (1983) is a commonly used matching method to deal with the self-selection problem with binary treatment variable. Instead of creating a match with the exact values of observed variable vector $\boldsymbol{X}$, the propensity score matching (PSM) approach matches on the basis of the propensity score (R), which measures the probability of an observation being in the treatment group:

$$R(\boldsymbol{X}) = \Pr(d = 1|\boldsymbol{X}),$$

with d = 1 represents being in the treatment group. Otherwise, d = 0 and the observation is in the control group. In order to get an unbiased estimation, when applying the PSM approach we also assume the independence of potential outcomes conditional on the propensity score R.

In the first part of our matching analysis, we use the PSM method to figure out the effect of a higher-than-median debt ratio on firm's market value deflated by total asset. The procedure goes as follows: Firstly, the generated dummy variable *Hier* is an indicator of whether the firm's leverage ratio is above or below its industrial median level. This indicator is considered as a treatment variable standing for the comparative leverage level. Secondly, we use a logit model to estimate $\widehat{Hier}$ as a function of observable firm characteristics (including market capitalization, WACC, EBITA, future operation income, etc.). Among the observable firm characteristics, *DebtIndex* is generated using short-term borrowing, long-term borrowing, leverage ratio, and

WACC using the Principal Component Analysis (PCA) approach, and serves as a comprehensive debt index that takes into account various debt characteristics. Thirdly, we use the predicted value from logit regression, $\widehat{Hier}$, to generate the propensity score R for all observations. Then we stratify and match observations according to their propensity score R, and then compare the treated observations with controlled ones within the same strata to derive the treatment effects on V_L, which represents the firm's market value V_L deflated by Asset. The result of PSM analysis is shown in Table 8 below.

Table 8

PSM Estimated Treatment Effect of Higher-than-Average Leverage Level

Specification (1) uses a set of firm characteristics as matching observables including: market capitalization, price-to-sales ratio (the ratio of a stock's last price divided by sales per share), WACC, EBITA, *E(FOI)*, *EV*, *Asset*, GICS industry, and year. Specification (2) includes firm characters: *E(FOI)* deflated by *Asset*, *EV* deflated by *Asset*, *Asset*, *Debt_Index*, and year.

VL	Specification (1)	Specification(2)
ATE of Hier	-0.083	0.044
t-statistics	(-0.95)	(0.64)

Table 8 shows the outcomes of the PSM method using two different specifications of firm's observable characteristics. As we can see from Table 8, there is no explicit evidence found in the results showing a comparatively high leverage level within a specific industry increases or decreases a firm's market value to book asset ratio. One of the reasonable explanations would be that the dependent variable

V_L is essentially a function of firm's leverage and book-to-market ratio of equity[9], and an increase in the leverage ratio will result in convergence of V_L toward 1. In this way, the embedded relationship between V_L and capital structure complicates the PSM analysis and obfuscates the treatment effect of a comparatively high leverage level.

Although not in favor of, the result of PSM analysis is not in contradiction of MM's debt tax shield model that we are trying to test, since the relative leverage level within an industry is not a straight indicator of a firm's absolute debt amount. Also, analyze the impact of $\widehat{Hier}$ within each industry would make more sense; however, numbers of observations in single industry categories are too small to conduct the PSM analysis.

Hirano and Imbens (2004) generalized the methodology of traditional PSM approach to the application of continuous treatment variable. The extended matching approach is named as the Generalized Propensity Score Matching (GPSM) approach. In the second part of our matching analysis, we use the GPSM approach to mitigate the self-selection bias in firm's capital structure and to measure the value of debt tax shield.

Similar to the PSM method, the basic idea of GPSM is to estimate a propensity score "*R*" as a function of the continuous treatment variable and a vector of observable covariates ***X***. Hirano and Imbens start the GSPM method with balancing

[9] VL = V_L/Asset = (market_capitalization+Debt)/(book_value_of_common_equity+Debt) = (1+leverage)/(book_to_market ratio +leverage). For simplicity of expression, we ignore the preferred equity term in V_L.

The market-to-book ratio is a common proxy for risk (Fama and French, 1992) and for expected growth in operating earnings (Penman, 1996).

the distribution of the treatment variable conditional on the covariates $\boldsymbol{X}$. Following Hirano and Imbens, in our study we assume that the treatment *Debt* conforms to a normal distribution with a mean $\boldsymbol{\beta}'\boldsymbol{X}_i$ and variance σ^2 conditional on the covariates including *DebtIndex*, *EV*, *E(FOI)* and *Asset*, expressed as follows:

$$Debt_i \mid \boldsymbol{X}_i \sim N\left\{\boldsymbol{\beta}'\boldsymbol{X}_i, \sigma^2\right\} \tag{6}$$

We estimate the vector of parameters $\boldsymbol{\beta}$ and the variance σ^2 by maximum likelihood estimation (MLE). The propensity score R is estimated using the exponential algorithm:

$$\hat{R}_i = \frac{1}{\sqrt{2\pi\hat{\sigma}^2}} exp\left(-\frac{1}{2\hat{\sigma}^2}(Debt_i - \hat{\boldsymbol{\beta}}'\boldsymbol{X}_i)^2\right) \tag{7}$$

The propensity score R needs to satisfy the balancing property stating that within strata with the same value of $r(d_0, \boldsymbol{X})$, the probability that *Debt* is equal to a specific amount d_0 is independent of the covariate set $\boldsymbol{X}$. The balancing property of propensity score can be expressed as follows:

$$\boldsymbol{X} \perp 1\{Debt = d_0\} \mid r(d_0, \boldsymbol{X}). \tag{8}$$

After testing the conditional independence of propensity score *R*, the next step of GPSM is to write the conditional expectation of firm's market value $E(V_L|Debt, \hat{R})$ as a polynomial function of its two arguments, treatment *Debt* and the estimated propensity score $\hat{R}$. Specifically, the conditional expectation model contains an interaction term *Debt* * $\hat{R}$:

$$E(V_L|Debt, \hat{R}) = \alpha_0 + \alpha_1 Debt + \alpha_2 Debt^2 + \alpha_3\hat{R} + \alpha_4\hat{R}^2 + \alpha_5 Debt \cdot \hat{R} \tag{9}$$

We estimate these parameters in (9) using OLS regression and present the estimated coefficients in Table 9. It is worth mentioning that the coefficients in Table 9 are only intermediate results with no direct meaning.

Table 9

The Conditional Expectation Function of V_L

The regression model is: $E(V_L|Debt,\hat{R}) = \alpha_0 + \alpha_1 Debt + \alpha_2 Debt^2 + \alpha_3\hat{R} + \alpha_4\hat{R}^2 + \alpha_5 Debt \cdot \hat{R}$

	α_0	α_1	α_2	α_3	α_4	α_5
Mean	12,554.75	13.96	-0.001	-92,226.34	175,395.2	-18.14
t-statistic	6.19	12.26	-6.90	-4.70	4.00	-7.89

After deriving the conditional expectation of dependent variable $E(V_L|\ Debt,\ \hat{R})$, the final step of GPSM approach is to estimate the dose-response function $V_L(Debt)$ by deriving the firm market value corresponding to each level of debt. The firm market value V_L corresponding to a specific debt amount "d" is calculated by averaging the estimated conditional expectation function $E(V_L|\ d,\ \hat{R})$ over all possible propensity scores $\hat{R}$ at that debt level "d". Note that we average the conditional expectation function over the propensity score function at a specific debt level rather than over the entire range of the propensity score at all debt levels.

It is important to know the assumption and implication of the GPSM approach. Hirano and Imbens (2004, 2-4) state and prove the bias removing feature of the generalized propensity score. Put simply, the balancing property of generalized propensity score implies the weak unconfoundedness of the treatment assignment (Hirano and Imbens, 2004, 3), which is a sufficient condition to ensure an unbiased estimation of the treatment outcome. In conclusion, the GPSM approach generates a dose-response function that removes non-tax effects of debt caused by the covariate dissimilarities associated with changes in debt value.

The treatment variable *Debt* is distributed between the value 0 and 9,000 (million dollars). To draw the dose-response curve, I pick 17 different debt values, estimate their corresponding dose-response values using the GPSM method individually, and then connect all the points with a smoothed line. With a goal of analyzing the region where the debt tax shield rate is close to the corporate tax rate, I select debt points more intensively between $9,000 million and $10,000 million, and estimated the corresponding firm market values corresponding to selected debt amounts.

Table 10 lists all of the debt values I selected and their corresponding dose-response firm value V_L using the GPSM method. The unit of measurement is one million dollars. In addition, Stata automatically calculates the slope of the dose-response curve named "diff_dose_response" at selected debt points. "diff_dose_response" is calculated by estimating the dose-response at (selected debt value + $1) value of debt and subtracting V_L at "selected debt value + $1" by V_L at "selected debt value".

Table 10

Debt and Corresponding Dose-Response Market Value V_L and Slope

Debt level (Million)	dose_response (V_L)	diff_dose_response (Slope)
1000	12447.61	8.651367
2000	23325.01	8.242188
3000	33597.76	7.5
4000	42599.1	6.582031
5000	50324.93	5.574219
6000	56806.17	4.503906
7000	62062.5	3.40625
8000	66104.26	2.28125
9000	68936.46	1.140625
9200	69357.98	.90625

9400	69731.2	.6796875
9600	70056.15	.4453125
9800	70332.81	.21875
10000	70561.2	-.015625
11000	70978.98	-1.179688
12000	70189.43	-2.351563
13000	68191.68	-3.53125

In order to properly interpret these results, we must be clear that the estimated "diff_dose_response" measures the marginal effects of $1 increase in debt financing on the firm's market value. The marginal effect of debt is quite different from the estimated debt coefficients in the OLS or IV methods. The debt coefficients estimated by OLS and IV represent the average effects of debt on a firm's market value. Thus, the value of debt tax shield could be measured by multiplying debt coefficient with debt amount. On the other hand, the marginal effects of debt estimated by GPSM method pertain to specific debt levels and cannot be applied to evaluate the debt tax shield.

Figure 5

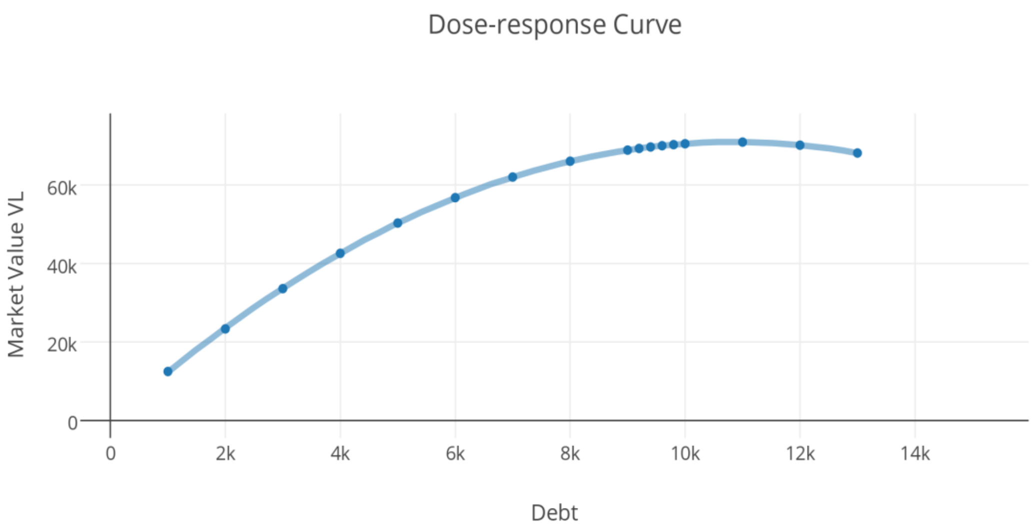


Figure 5 draws the dose-response curve by connecting the picked points using a smoothed line. From Figure 5 we can see the dose-response curve is a parabola going downwards, with a positive but deminishing slope between 0 and $10,000 million of debt, and a downward slope beyond $10,000 million of debt. Specifically, at debt value around $9,400 million, the marginal effect of debt on a firm's market value is around 0.68, while at debt value around $9,600 million, the marginal effect of debt is approximately 0.45. Since the statutory corporate tax is around 0.4, marginal effect of debt at debt levels from $9,400 million to $9,600 million is very close to the corporate tax rate.

Figure 6

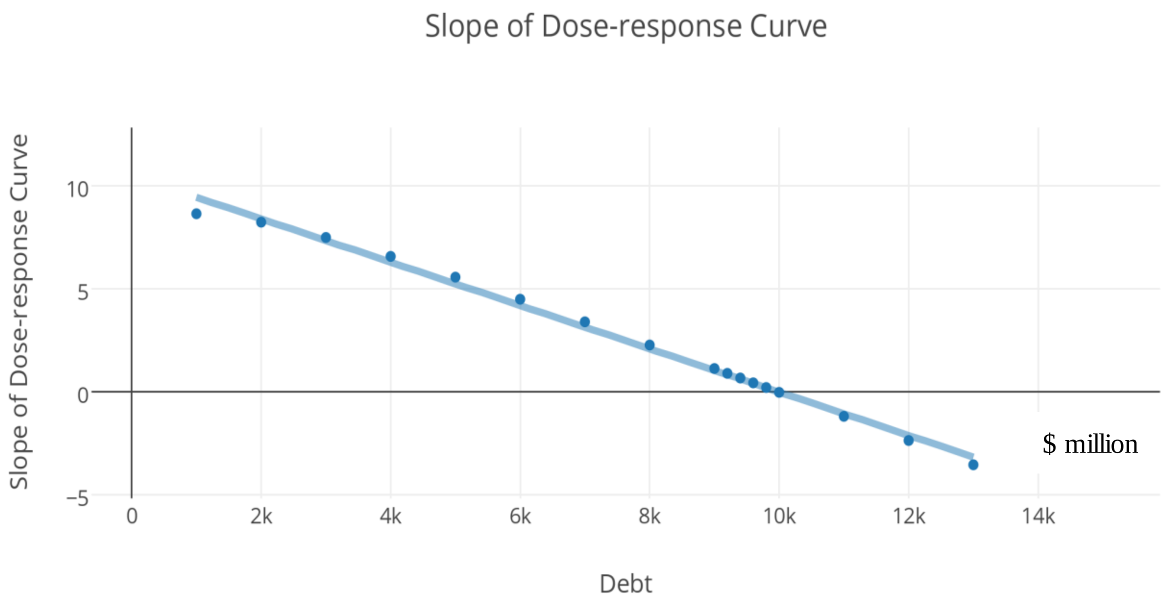


Figure 6 describes the slope of the dose-response curve. The vertical value of a point in Figure 6 represents the slope of the dose-response curve in Figure 5, which stands for the effect of one dollar's increase in debt on a firm's market value while keeping other characteristics unchanged. We can see from Figure 6 that the marginal effect of debt is roughly a downward-sloping straight line. Specifically, the marginal effect of debt financing on a firm's market value deminishes to zero around debt level of $10,000 million, with a negative marginal effect on firm value when the debt amount exceeds $10,000 million. The slope of the dose-response curve lies between 0.22 and 0.68 at debt levels between $9,400 million and $9,600 million. In other words, firms with debt obligation amounts within this range are supposed to benefit from the tax shield rates equal to the marginal corporate tax rate. For firms with lower debt levels, the tax shield rate is expected to exceed the corporate tax rate, while for firms with debt levels higher than $9,600, the tax benefit of debt disappears and even turns into a net cost of debt. This outcome is exactly the same as the result of Figure 5.

Since the dose-response function gives the estimated firm's market value at each specific debt amount, and the derivative of the dose-response function represents the marginal effect of debt controlling for non-tax factors, we conclude that the derivative of dose-response function represents the marginal debt tax shield. One possible explanation for the declining tax shield rate might be the increasing cost of debt financing. For example, a firm with a small amount of (or zero) debt outstanding may be able to issue new bonds backed by equipment or other assets owned by the firm. Such collateral backed bonds are senior debts that usually have a lower cost than unsecured bonds or second lien debt issued against the same collateral. This explains the high marginal benefit brought by debt at the left part of the dose-response function. As the firm's outstanding debt goes up, the cost of borrowing climbs and the pure benefits of debt decline. It is even possible to have a negative effect on the firm's market value when the firm depletes its borrowing credit and other financing sources and has to issue high-yield bonds to attract investors. Under that condition, the firm's market value will decrease with new debt.

Table 11 gives us a detailed list of the debt distribution of 3,253 observations. Over 90 percent of the observations have a debt value below $6,060 million, and enjoy a marginal debt benefit at a rate of 4.5. This rate means that for two firms with identical business size as well as future profit expectation, the market value of the heavier leveraged firm is higher than that of the less leveraged firm. Specifically, the firm with a debt level of $6,060 million has a market value of 4.5 dollars less than that of the identical firm with 1 dollar more in debt.

Table 11

Percentiles and Statistics of Debt

	Debt Percentiles
1%	0
5%	.41
10%	44
25%	340
50%	1138
75%	3368
90%	6060
95%	7479

99%	8672
Mean	2157
Std.Dev.	2366
Skewness	1.215
Kurtosis	3.416

Although the GSPM method addresses the self-selection bias, it has one shortcoming. Just like other matching approaches, the GSPM method has been criticized for matching observations based on the observables and ignoring any potential unobservable elements. The GSPM method assumes that the selection of treatment level is based solely on observable covariates, which is questionable in the real world. When a firm makes a financial decision, it is likely that unobservable factors also have an influence on its final choice. Nevertheless, when it comes to financial analysis, the Mosaic theory might give us some inspiration. The Mosaic theory suggests that by combining publicly accessible information we can form a mosaic of publicly inaccessible information. According to the Mosaic theory, it is possible to reduce the deficiency caused by the unobservable variables by collecting and combining observable covariates. Thus, as we enlarge the set of observable covariates, it's highly likely that we have included most of the relevant information in making corporate financial decisions, either observable or unobservable.

D. Covariate Balancing General Propensity Score (CBPSM) Approach

Although the GPSM approach reduces self-selection bias under the covariant balancing condition, there is no easy way to balance the covariates. When performing the GPSM approach to evaluate debt tax shield, the balancing property of propensity score is satisfied at a significance level lower than 0.01, meaning it is very likely the balancing property has been violated so that the GPSM cannot fully eliminate estimation bias associated with the covariates.

In order to balance the observed covariates across continuous treatment values, I follow the covariate balancing propensity score (CBPS) methodology developed by Fong and Imai (2014), which extended the covariate balancing propensity score (CBPS) methodology to continuous treatment regime. Specifically, CBPS estimates the propensity score in a way such that the resulting association between the treatment and covariates is minimized. To accomplish this goal, Fong and Imai (2014, 14-16) first centered both the continuous treatment variable and each covariate by subtracting their respective sample means, and then balanced covariates such that weighted correlation between these two centered variables is minimized.

Table 12 lists the Pearson correlation coefficients between each of the covariates and the treatment variable *Debt*. The correlation coefficients of original (unweighted) variables are listed in comparison with the coefficients of the weighted ones. From Table 12 we find that the original Pearson correlation displays a substantial lack of balance of the covariates. After weighting on the covariate balancing propensity score, the correlation coefficients reduce by a large extent, demonstrating the effectiveness of the CBPS method.

Table 12

Correlations between the Covariates and Debt

The second column of Table 12 lists the original Pearson correlation coefficients between each covariate and the treatment variable *Debt*. The third column of Table 12 lists the Pearson correlation coefficients after adjusting for the weights derived from the covariate balancing propensity score.

	Pearson Correlation with Debt	
	Original	**Balanced**
E(FOI)	0.38108296	0.33760724
EV_to_EBITA	-0.03737813	-0.03364143
EBITA	0.38615667	0.37543573
tt_equity	0.49355800	0.42756722
EV	0.36315920	0.27212121
Asset	0.70879004	0.63312812
Debt_index	0.93097536	0.61892195
lvrg	0.32437198	0.22592234
mktcap	0.26630027	0.21176967

After balancing the covariates, we estimate the marginal effect of corporate debt on the market value of firm using the panel linear regression model, which controls for the covariate balancing propensity score as well as firm and year fixed effect. The panel data regression results are displayed in Table 13. The estimated coefficient of debt over the full sample is 1.29, and the estimated capitalization rate ρ is approximately 7.19% (the reciprocal of estimated coefficient of $E(FOI)$, 13.90). Both estimators are significantly different from zero.

Table 13

Panel OLS Regression Results with CBPS

	Debt	E(FOI)
Coefficient	1.29**	13.90***
t-value	1.98	41.50

The outcomes of the GPSM approach in Part C shows that the marginal effect of debt on firm's market value is not a constant as debt amount changes. The relationship between a firm's debt and market value is estimated to be a downward parabola function. The regression results with a quadratic term of debt are displayed in Table 14.

Table 14

Panel OLS Regression Results with CBPS and Square Term

	Debt	$Debt^2$	E(FOI)
Coefficient	1.79**	$-4.61e^{-5}$	13.86***
t-value	2.01	-0.82	40.95

The marginal effect of corporate debt on firm's market value is represented by the derivative of the estimated firm valuation function with respect to debt, which produces ($1.79-4.61*Debt*10^{-5}$). Table 15 tabulates the marginal effect of debt on firm's market value at different debt levels.

Table 15

Marginal Effect of Debt on Market Value at Different Debt Levels

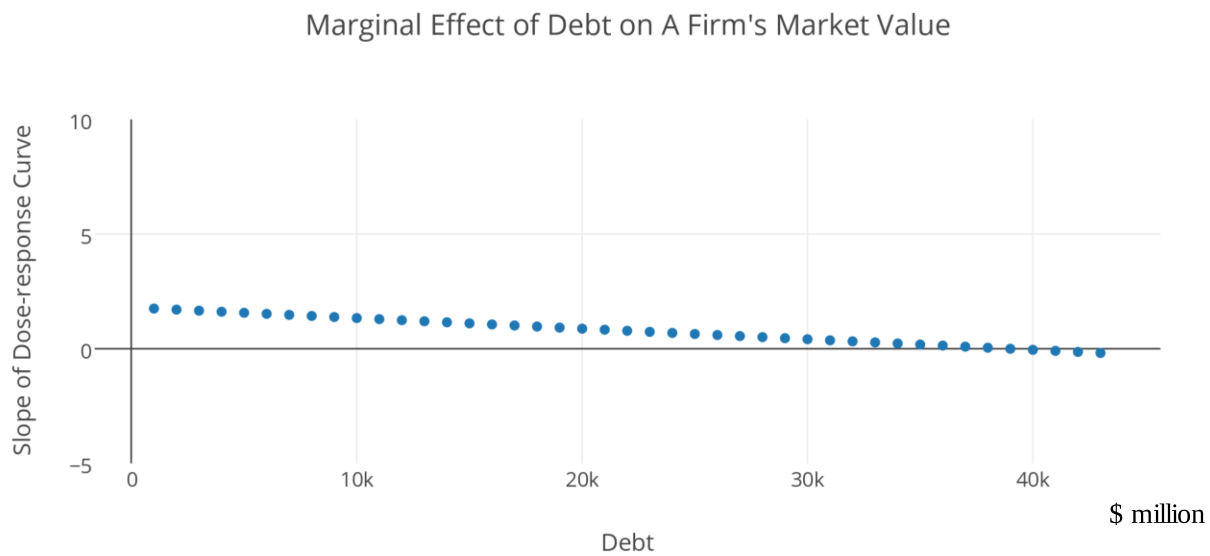
Debt Level (Million)	Marginal Effect of Debt on Market Value

1,000	1.740663
2,000	1.694526
3,000	1.648389
4,000	1.602252
5,000	1.556115
6,000	1.509978
7,000	1.463841
8,000	1.417704
9,000	1.371567
10,000	1.32543
11,000	1.279293
12,000	1.233156
13,000	1.187019
14,000	1.140882
15,000	1.094745
16,000	1.048608
17,000	1.002471
18,000	0.956334
19,000	0.910197
20,000	0.86406
21,000	0.817923
22,000	0.771786
23,000	0.725649
24,000	0.679512
25,000	0.633375
26,000	0.587238
27,000	0.541101
28,000	0.494964
29,000	0.448827
30,000	0.40269
31,000	0.356553
32,000	0.310416
33,000	0.264279
34,000	0.218142
35,000	0.172005
36,000	0.125868
37,000	0.079731
38,000	0.033594
39,000	-0.01254
40,000	-0.05868

The estimated marginal effect of debt with CBPS generally has the same pattern with the outcome of GPSM in Part C. The marginal effect on firm’s market value constantly declines with the corporate debt value, and peak of market value is achieved at approximately 39,000 million dollars. At debt amount around 28,000 million dollars, the marginal increase in firm's market value per unit of debt is estimated to be approximately 0.49, which is the estimated net effective tax rate.

Figure 7 displays the marginal effect of debt on a firm's market value at different debt levels. As we can see from Figure 7, marginal effect of debt on a firm's market value, which is the slope of dose-response curve, declines as debt level increases. Also the debt tax shield rate deceases

Figure 7



By comparing the graphs derived from the GPSM and CBPS approaches, it is easy to notice that the CBPS estimated marginal effect of debt on a firm's market value is of smaller absolute value than the GPSM estimated marginal effect. This indicates that the dose-response curve derived from CBPS approach is smoother than that derived from GPSM approach. Since CBPS supplement GPSM approach in covariate balance, it is reasonable to believe that the marginal effect of debt doesn't change abruptly. At the mean of all the debt amounts, $2,157 million, the marginal effect of debt is about 1.69.

VI. Econometric Results

The simple OLS regression produces an estimation of 1.83 for the coefficient of debt on firm's market value. Following Kemsley and Nissim's variable-reversing model, we get an estimated debt tax shield rate of -3.21, not statistically significant though. These outcomes of regression indicate the insufficiency of controls for non-tax dimension relationship between corporate debt and firm's market value. Therefore we employ the instrumental variable and generalized propensity score matching approaches to capture that potential relationship in order to estimate the value of corporate debt tax shield.

Employing the book value of total asset as an instrumental variable for the value of an imaginary unlevered firm, the 2SLS regression estimates the debt tax shield rate to be 0.71. This estimation is much closer to the effective corporate tax rate in recent three decades, which is a sum of federal and state taxes.

The propensity score matching approach matches the firms on a set of firm characteristic observables including asset, market cap, market-to-book ratio, etc. The propensity score is generated in a way such that when conditioning on the propensity score, the distribution of debt is independent of the covariates. Based on the propensity score, the firms with identical characteristics are compared with each other to analyze the marginal effect of debt on firm's market value. The average treatment effect of an above-median leverage level is not significantly different from zero. The dose-response curve produced by the generalized propensity score matching (GPSM) approach is a downward parabola curve connecting firm's market value with corporate debt amount. The slope of the dose-response curve represents the marginal effect of debt on the market value of firm. Therefore, the downward sloping dose-response curve indicates a diminishing tax shield rate with an increasing debt value. The marginal effect of debt on a firm's market value is estimated to be 0.45 around debt of $9,600 million.

The covariate balancing generalized propensity score supplements the generalized propensity score matching method by calculating the propensity score that minimizes the correlations between the covariates and debt. Using the propensity score generated by the covariate balancing approach, we estimate the overall debt coefficient to be 1.29 with the simple linear OLS regression. After adding debt square to the OLS regression, we get significant estimation coefficients for both debt and debt square, and conclude that the market value of firm conforms to a downward parabola function of debt. This result generally complies with the dose-response function estimated by the generalized propensity score matching approach. The marginal effect of debt at mean level of debt ($2,157 million) is equal to 1.69, and the marginal effect of debt is equal to 0.49 at the debt level of $28,000 million.

VII. Conclusions

In this paper I use different econometric approaches to evaluate the corporate debt tax shield. The instrumental variable method employs the book value of total asset as an exogenous instrumental variable for the unobservable unlevered firm value and determines a debt tax shield rate of 0.71. The generalized propensity score matching (GPSM) approach reduces self-selection bias and estimates a quadratic relationship between firm's market value and debt. The covariate balancing propensity score (CBPS) approach supplements the generalized propensity score by fixing the covariate imbalance problem of the GPSM approach, and the CBPS method estimates the marginal effect of debt on a firm's market value to be 0.49 at the debt amount of $28,000.

VIII. Future Improvements

Although the propensity score matching approach reduces the endogeneity problem associated with corporate capital structure, there still exists a problem of selection on unobservables. The mosaic theory of materiality can be used to demonstrate the unobservable features could be predicted by the observables to some extent. However, the predict power and accuracy is still under discussion.

Another issue is with the instrumental variable of V_U, the book value of total asset. As I stated in Part V(B), the book value of total asset is expected to be an exogenous instrumental variable of V_U because it can only influence a firm's market value V_L through V_U. However, potential violations of the exogeneity might exist. For example, firms can employ different inventory methods such as "last in first out (LIFO)", "first in first out (FIFO)", etc. Different inventory methods will result in different book value of total asset. Meanwhile, inventory value influences a firm's liquidity ratios so that it influences the firm's market value. This dimension of relationship between book value of total asset and market value is not through V_U, since V_U is merely influenced by the liquidity ratio.

There are also issues with the sample data set. The missing data in the sample data set will influence the outcomes if the missing values are non-random. Another issue is, since I derive the expected future operation income from ex post realization that is the average operation income of the following five years, there is survivorship bias and measurement error in the expected future operation income (Kemsley and Nissim, 2002).

Appendix 1

Average State Top Corporate Tax Rate (Year 2000 to 2014)

Year	Average top marginal state corporate rate
2000	7.350%
2001	7.321%
2002	7.112%
2003	7.141%
2004	7.356%
2005	7.312%
2006	7.218%
2007	7.216%
2008	7.248%
2009	7.237%
2010	7.459%
2011	7.546%
2012	7.495%
2013	7.463%

2014	7.390%

Source: State tax statutes, forms, and instructions; Tax Foundation.

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