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FINANCIAL DISTRESS IDENTIFICATION: APPLICATION OF BLACK-SCHOLES-MERTON MODEL

Japneet Kaur*

Abstract *Financial distress is characterized by the inability to fulfill the financial obligations on time due to lack of liquidity. Corporate failures in the recent decade have highlighted that big sized companies are as vulnerable as the small and medium sized companies. In view of this rising awareness, it becomes imperative for the investors to consider the default probabilities of the companies before making any investment decisions.*

The paper aims to determine the probability of default among the NSE Nifty-500 companies for a period of ten years commencing from commencing from financial year 2007-08 to financial year 2016-17. The contingent claims model developed by Black-Scholes and extended by Merton has been applied to compute the probabilities of the select companies. R Studio (version 3.4.3) has been used to analyze the data. The results demonstrated that approximately 4 percent of the companies of the total companies were found to be financially distressed.

Keywords: *Financial Distress, Black-Scholes-Merton Model, Probability of Default*

INTRODUCTION

Financial distress indicates a situation when a company is unable to honor the financial obligations of the creditors when due due to insufficient cash flow, leading to bankruptcy in some of the cases (Bae, 2012). Such a condition leads to huge economic losses for the company, government, and investors. Prediction of financial distress in a way is important, as it gives a signal to the stakeholders and the investors of the company, as regards to the worthiness of their investments. Moreover, corporate failures and scandals in the recent decade such as Enron, Worldcom, Parmalat, Satyam, and Philipp Holzmann have highlighted the necessity to.study bankruptcy prediction of public and private sectors which can help one to understand the company's financial well-being.

There is abundant literature that studies financial distress from financial, economic, and accounting perspective. With few exceptions, accounting-based measures have been majorly used to predict the likelihood of financial distress. Beaver (1966), Altman (1968), Ohlson (1980), and Zmijewski (1984) used accounting information to the assessment of distress risk in a static model. These accounting-based models test the usefulness of information contained in the financial statements of a company to provide an adequate assessment of the financial distress risk. Beaver (1966) examined the predictive ability of financial ratios to detect financial health of the U.S. listed companies. He used a univariate approach and classified the firms into failed and non-failed categories. He found that the financial ratios could predict companies approaching towards failure at least five years before actual failure. However, he suggested that all the ratios could not predict in the same manner. Altman (1968) developed an overall sore, known as Z-score, and analyzed on a sample of 33 bankrupt and 33 non-distressed public firms. He used a combination of five financial ratios to discriminate between financially distressed and non-distressed companies. Similarly, Ohlson (1980) developed O-score incorporating four financial ratios as predictor variables for estimating the probability of default within one year. Past literature is evident of the fact that Z-Score and O-score have been widely used by academicians for estimating the likelihood of bankruptcy in the companies (Mohammed, 2016; Alkhatib and Bzour, 2011; Agarwal and Taffler, 2007; Hillegeist *et al*., 2004; Subramanyam, 1996; and Stone, 1991).

Despite the widespread applicability of the accounting-based models, they have been criticized for using ex-post information and not taking into account volatility of assets (Outecheva, 2007). Market-based models overcome these obstacles as these models consider contemporaneous market information on the firm's liability structure as well as market prices of its assets. These models consider asset volatility and market value of assets crucial to compute distress risk. In particular, Black-Scholes (1973) and Merton (1974) model as a market model, has been found to be superior over the accounting models in terms of assessing the probability

* Research Scholar, University Business School, Panjab University, Chandigarh, India. Email: kaursjapneet@gmail.com

of default (Wu *et al*., 2010; Gharghori *et al*., 2006; and Hillegeist *et al*., 2004). The present chapter applies Black-Scholes (1937) and Merton (1974) model in a pursuit to assess the default probabilities of the NSE *Nifty*-500 companies.

The present chapter has been bifurcated into four sections. Section 2 elaborates on review of related literature. Section 3 discusses the research design covering sample selection procedure, variable specification and tools of analysis. Section 4 reports descriptive statistics of the sample followed by analysis and results in Section 5. Finally, Section 6 presents a summary of the results and concludes.

REVIEW OF LITERATURE

There is a strand of literature that studies the likelihood of financial distress. Researchers have adopted various measures and diverse methodologies to predict the likelihood of default among the companies. Altman (1968), Ohlson (1980), and Zmijewski (1984) used accounting variables to estimate the probability of bankruptcy in a static model.

Altman (1968) introduced the Z-score model to predict corporate bankruptcy of manufacturing firms by using a variety of financial ratios assembled together in a multiple discriminant analysis model. He developed the model by using a matched sample of 33 bankrupt and 33 non-bankrupt manufacturing firms from 1946–1965. Results of the model established that bankruptcy could be accurately predicted (approximately 80 percent) up to two years prior to actual failure. However, the accuracy of the model was observed to diminish rapidly after the second year. Since the inception of Z-score by Altman (1968), it has been used in a number of studies. To name a few, Dichev (1998), Griffin and Lemmon (2002), and Ferguson and Shockley (2003) utilized Z-score to assess the likelihood of default and also analyze the relationship between risk and average return for distressed firms. Similarly, Ohlson (1980) introduced an alternative econometric technique based on the logistic transformations (Logit model). He identified four basic factors, viz., the size of the company, a measure(s) of the financial structure, performance measure(s), current liquidity measure(s). The findings reported that of the four variables, the size of the company appeared to be the most significant predictor of financial distress one year prior to actual default. Despite the widespread applicability of these accounting-based models, they do not give consistent results due to ex-post financial information and absence of asset volatility (Hillegeist *et al., 2004;* Vassalou and Xing, 2004).

Hillegeist *et al*. (2004) compared the performance of accounting-based models, *viz*., Altman's (1968) Z-score and Ohlson's (1980) O-score, to that of Black-Scholes (1973) and Merton (1974) option pricing model for assessing the probability of bankruptcy during the period 1980-2000. It was observed that market-based Black-Sholes-Merton, hereafter BSM, model outperformed both the accounting-based models. Vassalou and Xing (2004) used option pricing model developed by Black-Scholes (1973) and Merton (1974) to compute a measure of likelihood of default among the individual companies and used it further to explore the relationship between expected stock returns and default likelihood indicator (DLI). Similarly, Zhang (2012); Outecheva (2007); Garlappi *et al*. (2006); and Bharat and Shumway (2008) have utilized BSM probability as a proxy for probability of default, distress or bankruptcy.

Shumway (2001) proposed a simple hazard model for forecasting bankruptcy incorporating three market-based variables. He advocated that static models, e.g., Altman (1968) Z-score, were inappropriate owing to the nature of data required for estimating the probability of bankruptcy. The results revealed that accounting variables used to estimate hazard models were found to be unrelated to bankruptcy prediction. On the other hand, a hazard model using market-driven measures was found to be more accurate in terms of forecasting bankruptcy. Bharat and Shumway (2008) examined the accuracy of Merton's (1974) option pricing model by comparing it to the functional form of the model. The authors advocated that hazard models that utilized the Merton (1974) model as input variables performed better vis-à-vis those that exclude them for computing the probability of default. A detailed summary of the relevant studies related to the probability of financial distress has been presented in Table 1.

Table 1: Summary of the Major Studies Related to Prediction of Corporate Financial Distress

Name of the Author(s) and year of study	Objective(s)	Sample firms and period of study	Variables		Tools used	Major findings of the study
			Dependent variables	Independent variables		
Altman (1968)	To predict corporate bankruptcy of manufacturing firms.	33 bankrupt and 33 non-bankrupt manufacturing firms Period:1946- 1965	Z-score	Working capital to total assets (WC/TA), retained earnings to total assets (RE/TA), earnings before interest and taxes to total assets (EBIT/TA), market equity to total liabilities (ME/TL), and sales to total assets (S/TA).	Multiple discriminant analysis	Results of the model found that bankruptcy can be accurately predicted (approximately 80%) up to two years prior to actual failure with the accuracy diminishing rapidly after the second year.
Ohlson (1980)	To assess the probability of default.	105 bankrupt firms and 2,058 non-bankrupt firms Period:1970-1976	O-score	The size of the company, a measure(s) of the financial structure, performance measure(s), current liquidity measure	Logit regression	The findings reported that of the four variables, the size of the company appeared to be the most significant predictor of financial distress.
Opler and Titman (1994)	To examine the effect of financial distress on corporate performance.	46,799 firm-years Period:1972-1991	Firm performance	Log of sales, industry -adjusted profitability, industry –adjusted asset sale rate, industry –adjusted investments/ assets, distressed industry dummy and high leverage dummy.	OLS regression analysis	The results indicated that there is a positive relationship between financial condition and firm performance in industry downturns. particularly for the firms with significant R&D expenditures and for those in more concentrated industries.
Shumway (2001)	To propose a simple hazard model to forecast bankruptcy more accurately.	28,226 firm years and 300 . bankruptcies Period:1962- 1992	Firm age	Working capital to total assets (WC/TA), retained earnings to total assets (RE/TA), earnings before interest and taxes to total assets (EBIT/TA), market equity to total liabilities (ME/TL), and sales to total assets (S/TA).Market variables – size, default spread , sigma, expected returns.	Regression analysis, discriminant analysis and logit regression	He advocated that static models, e.g., Altman (1968) Z-score, were inappropriate owing to the nature of data required for estimating the probability of bankruptcy. The results revealed that accounting variables used to estimate hazard models were found to be unrelated to bankruptcy prediction. On the other hand, a hazard model using market-driven measures was found to be more accurate in terms of forecasting bankruptcy.
Hillegeist *et al.* (2004)	To compare the performance of (Black-Scholes-Merton probability) BSM-Prob model against the Altman and Ohlson models.	14,303 individual firms and 756 bankrupt firms Period: 1980-2000.	Bankruptcy in the 4 to 16 months following the fiscal year-end.	Accounting ratios (Altman and Ohlson), Annual rate, Market Variables	Correlation, Logit regression	The findings demonstrated that of all the models, BSM-Prob model outperformed the traditional accounting models.

RESEARCH METHODOLOGY

Population and Sample Selection

All the companies listed on NSE *Nifty*-500 index spanning a period of ten years, i.e., commencing from April 1, 2007 to March 31, 2017 formed the universe for the present study. The final sample comprised of 171 companies and 1,710 company year observations. The sample selection criterion used to form the final sample has been presented in Table 2.

Table 2: Sample Selection Criteria

Sample Selection Criteria	Number of Companies
Companies listed on NSE Nifty-500 as on March 31, 2017	500
Less:	
Financial companies (NIC code 64110 and 66309)*	81
Companies with missing data	248
Final Sample	171

* **Note:** NIC code 64110 and 66309 consist of the companies in the financial sector.

Data and Variable specification

The required data for computing BSM-probability of default has been accessed from corporate database *PROWESS* maintained by Centre for Monitoring Indian Economy (CMIE). The data pertaining to total liabilities, market capitalization, monthly stock returns, dividend rate, and dividend has also been retrieved from the same database. However, RBI Bulletin, an annual publication of Reserve Bank of India, has been used for yields on 91-day T-bills. In order to identify financially distressed companies, the variables used for the study have been specified below:

Current value of assets (cannot be directly obtained from any of the above mentioned source. Therefore, it has initially been calculated by the summation of market capitalization and total liabilities (Hillegeist *et al*., 2004).

Asset volatility (σ_A) is also inaccessible directly similar to current value of assets. Considering the methodology adopted by Hillegeist *et al*. (2004), the initial values of standard deviation of asset returns (σ_A) have been determined by dividing the product of standard deviation of monthly stock returns and market capitalization to that of current value of assets.

Face value of total liabilities (*X*) constitute both long-term as well as short-term debt likely to mature at time *T* as proposed by Hillegeist *et al*. (2004).

Size (V_E) also called as the market value of equity has been taken as market capitalization of the firm calculated as the product of closing price and outstanding market shares at the end of the financial year.

Dividend (*d*) has been computed by summing up the common and preferred dividends declared during the year.

Dividend rate (δ) has been calculated by using the estimated current value of assets. Following Hillegeist *et al*. (2004), it has been computed as the ratio of sum of previous year's common and preferred dividends to that of estimated current value of assets.

Risk-free rate (*r*) pertains to rate of return on risk-free or government securities, denoted as, T-bills. It has been retrieved from RBI Bulletin as the implicit yield of the 91-day treasury bills at the end of every month.

Standard deviation of stock returns (σ_E) has been taken as the standard deviation of stock returns calculated from monthly adjusted closing prices of the respective companies.

TOOLS OF ANALYSIS

The statistical model, viz., Black-Scholes (1973) and Merton (1974) technique used for the purpose of the study has been discussed in this section. A sophisticated package i.e., *R Studio* (version 3.4.3.) has been used for data analysis. Black-Scholes-Merton probability of default, hereafter (BSM-Prob), has been calculated by following option-pricing methodology. Under this methodology, the equity of a firm is viewed as a call option on the underlying value of assets the firm wherein the strike price is equal to the face value of firms' total debt. The claimant exercises the option only when the firm's assets are greater than it's liabilities. BSM-Prob has been calculated following the methodology adopted by Hillegeist *et al.* (2004) as shown in Equation (1).

$$BSM\ Prob = N\left[-\frac{ln\left(V_A / X\right)+\left(\mu-\delta-\left(\frac{\sigma_A^2}{2}\right)\right)T}{\sigma_A\sqrt{T}}\right] \quad (1)$$

Where,

N (.) = cumulative density function of a standard normal distribution

V_A = current value of assets

X = face value of total liabilities

μ = continuously compounded expected return

δ = dividend rate

σ_A = asset volatility

T = time to maturity of debt (taken as 1)

As mentioned earlier that two variables, *viz*., current value of assets and asset volatility are not directly observable. Hence, these variables have been initially estimated by using the formula adopted by Hillegeist *et al*. (2004). Thus, current value of assets has been set equal to the sum of total liabilities and market value of equity. Likewise, asset volatility has been calculated by dividing the product of standard deviation of monthly stock returns and market capitalization to that of current value of assets. Thereafter, *R Studio* (version 3.4.3) program that follows an iterative procedure as mentioned in the Appendix has been used to simultaneously solve Equations (2). After determining the values of these unknown variables, expected returns (μ) have been computed using these values from Equation (3).

$$\left.\begin{aligned} V_E = V_A.e^{-\delta T}.N\left(\frac{ln[V_A/X]+\left(r-\delta+\left(\sigma_A^2/2\right)\right).T}{\sigma_A^2.\sqrt{T}}\right) \\ -X.e^{-rT}.N\left(\frac{ln[V_A/X]+\left(r-\delta+\left(\sigma_A^2/2\right)\right).T}{\sigma_A^2.\sqrt{T}}\right)+\left(1-e^{-\delta T}\right).V_A \\ \sigma_E\left(V_A.e^{-\delta T}.N\left(\frac{ln[V_A/X]+\left(r-\delta+\left(\sigma_A^2/2\right)\right).T}{\sigma_A^2.\sqrt{T}}\right).\sigma_A\right)/V_E \end{aligned}\right\} \quad (2)$$

Where,

r = risk free rate

σ_E = volatility of equity

V_E = market value of equity

d = dividends

$$\mu(t) = \bar{m}ax\left[\frac{V_A(t)+Dividends-V_A(t-1)}{V_A(t-1)}, r\right] \quad (3)$$

Where,

$\mu_{(t)}$ = expected returns at time (t)

V_A(t) = asset volatility at time (t)

V_A(t-1) = asset volatility at time (t-1)

Finally, after the unobservable variables have been determined, Equation (1) has been used to compute the values of BSM-Prob for each company-year. In order to divide the companies into distressed and solvent categories, a threshold of 0.05 has been considered (Hillegeist *et al*., 2004). Therefore, the companies with BSM-Prob less than 0.05 constituted sound companies whereas distressed companies comprised of those having BSM-Prob>=0.05.

ANALYSIS AND RESULTS

This section elaborates the results of the analysis as described in Section 3.3. Table 3 describes the classification criteria used to categorize the companies into financially sound and distressed. Table 4 shows the number of financially distressed and sound companies by year. The Table has been compiled from the results of BSM-Prob for all the companies from FY 2007-FY2016 as demonstrated in Table 5 in the Appendix. It is evident from Table 4 that approximately 4 percent of the total companies were found to be distressed and the remaining sample comprised of the sound companies.

Table 3: Criteria for the Classification of Sample Companies

BSM-PD Criterion to Divide the Sample Companies	Category	No. of Sample Companies
BSM≥0.05	Distressed	7
BSM<0.05	Sound	164
TOTAL SAMPLE		171

The R code used to compute BSM-Prob has been given in the Appendix. It can also be observed from the Table that 2009 was marked by the highest number of financially distressed companies followed by 2010. The percentage of companies becoming distressed was the maximum in 2009 (44%) while there was nil distress in 2008, 2014 and 2016.

Table 4: Number of Financially Distressed and Sound Companies by Year (N=171)

Year	No. of distressed companies by Year	No. of sound companies by Year	% of distressed companies
2007	8	163	4.68
2008	0	171	0
2009	44	127	25.73
2010	9	162	5.55
2011	4	167	2.39
2012	1	170	0.59
2013	1	170	0.59
2014	0	171	0
2015	1	170	0.59
2016	0	171	0
Total Average Annual Number of Firms	7	164	4.01

Source: Researchers' own Analysis

SUMMARY AND CONCLUSION

Propelled by the aim to determine financially distressed companies among the NSE *Nifty*-500 companies, the study applies Black-Scholes (1973) and Merton (1974) option pricing methodology to estimate the probability of default of the said companies (BSM-Prob). The results demonstrated that approximately 4 percent of the total companies were found to be financially distressed through the period 2007-2016. The proportion of companies varied considerably across the years, the highest distress being in 2009.

Table 5: BSM-Prob for the Sample Companies (FY2007-FY2016)

Sr. No	Company Name	2007	2008	2009	2010	2011	2012	2013	2014	2015	0
1	A B B India Ltd.	0	0	0	0	0	0	0	0	0	0
2	A C C Ltd.	0	0	0	0	0	0	0	0	0	0
3	A I A Engineering Ltd.	0	0	0	0	0	0	0	0	0	0
4	Aarti Industries Ltd.	0.0006	0	0.0148	0	0	0	0	0	0	0
5	Aban Offshore Ltd.	0	0	0	0	0	0	0	0	0	0
6	Adani Enterprises Ltd.	0	0	0	0	0	0	0	0	0	0
7	Aegis Logistics Ltd.	0	0	0	0	0	0	0	0	0	0
8	Ajanta Pharma Ltd.	0	0	0.9205	0	0	0	0	0	0	0
9	Akzo Nobel India Ltd.	0	0	0	0	0	0	0	0	0	0
10	Allcargo Logistics Ltd.	0	0	0.0011	0	0	0	0	0	0	0
11	Amara Raja Batteries Ltd.	0	0	0	0	0	0	0	0	0	0
12	Ambuja Cements Ltd.	0.1752	0	1	0	0	0	0	0	0	0
13	Apar Industries Ltd.	0	0	0	0	0	0	0	0	0	0
14	Apollo Hospitals Enterprise Ltd.	0	0	0	0	0	0	0	0	0	0
15	Apollo Tyres Ltd.	0	0	0	0	0	0	0	0	0	0
16	Ashok Leyland Ltd.	0	0	0	0	0	0	0	0	0	0
17	Asian Paints Ltd.	0	0	0	0	0	0	0	0	0	0
18	Astral Poly Technik Ltd.	0	0	0	0	0	0	0	0	0	0
19	Astrazeneca Pharma India Ltd.	0	0	0	0	0	0	0	0	0	0
20	Bajaj Hindusthan Sugar Ltd.	0	0.0009	0.1808	0	0	0	0	0	0	0
21	Balkrishna Industries Ltd.	0	0	0	0	0	0	0	0	0	0
22	A B B India Ltd.	0	0	0	0	0	0	0	0	0	0
23	Ballarpur Industries Ltd.	0	0	0	0	0	0	0	0	0	0
24	Balmer Lawrie & Co. Ltd.	0	0	0	0	0	0	0	0	0	0
25	Balrampur Chini Mills Ltd.	0	0	0	0	0	0	0	0	0	0
26	Bata India Ltd.	0	0	0	0	0	0	0	0	0	0
27	Berger Paints India Ltd.	0	0	0	0	0	0	0	0	0	0
28	Bharat Forge Ltd.	0.1671	0	1	0	0	0	1	0.0001	0	0
29	Bharat Heavy Electricals Ltd.	0	0	1	0	0	0	0	0	0.967	0
30	Bharat Petroleum Corpn. Ltd.	0	0	1	0	0	0	0	0	0	0
31	Bharti Airtel Ltd.	0	0	0	0	0	0	0	0	0	0
32	Biocon Ltd.	0	0	1	0	0	0	0	0	0	0
33	Birla Corporation Ltd.	0	0	0	0	0	0	0	0	0	0
34	Blue Dart Express Ltd.	0	0	0	0	0	0	0	0	0	0
35	Blue Star Ltd.	0	0.0002	0.0134	0	0	0	0	0	0	0
36	Bombay Dyeing & Mfg. Co. Ltd.	0	0	0	0	0	0	0	0	0	0
37	Bosch Ltd.	0	0	0	0	0	0	0	0	0	0
38	Britannia Industries Ltd.	0	0	0	0	0	0	0	0	0	0

Sr. No	Company Name	2007	2008	2009	2010	2011	2012	2013	2014	2015	0
39	C C L Products (India) Ltd.	0	0	0	0	0	0	0	0	0	0
40	C G Power & Indl. Solutions Ltd.	0	0	0	0	0	0	0	0	0	0
41	Cadila Healthcare Ltd.	0	0	0	0	0	0	0	0	0	0
42	Carborundum Universal Ltd.	0	0	0	0	0	0	0	0	0	0
43	Castrol India Ltd.	0	0	0	0	0	0	0	0	0	0
44	Century Plyboards (India) Ltd.	0	0	0	0	0	0	0	0	0	0
45	Chennai Petroleum Corpn. Ltd.	0	0	1	0	0	0	0	0	0	0
46	Cipla Ltd.	0	0	0	0	0	0	0	0	0	0
47	Coromandel International Ltd.	0	0	0	0	0	0	0	0	0	0
48	Crisil Ltd.	0	0	0	0	0	0	0	0	0	0
49	Cummins India Ltd.	0	0	0	0	0	0	0	0	0	0
50	D C M Shriram Ltd.	0	0	0.0001	0	0	0	0	0	0	0
51	Dabur India Ltd.	0	0	0.9997	0	0	0	0	0	0	0
52	Deepak Fertilisers & Petro-chemicals Corpn. Ltd.	0	0	0	0	0	0	0	0	0	0
53	Divi'S Laboratories Ltd.	0	0	1	0	0	0	0	0	0	0
54	Dr. Reddy'S Laboratories Ltd.	0	0	0	0	0	0	0	0	0	0
55	Dredging Corpn. Of India Ltd.	0	0	0	0	0	0	0	0	0	0
56	E I D-Parry (India) Ltd.	0	0	0	0	0	0	0	0	0	0
57	E I H Ltd.	0	0	0	0	0	0	0	0	0	0
58	Eicher Motors Ltd.	0	0	0	0	0	0	0	0	0	0
59	Emami Ltd.	0	0	0.0969	0	0	0	0	0	0	0
60	Engineers India Ltd.	0.0097	0	0.969	0	0	0	0	0	0	0
61	Essel Propack Ltd.	0	0	0	0	0	0	0	0	0	0
62	Eveready Industries (India) Ltd.	0	0	0	0	0	0	0	0	0	0
63	Exide Industries Ltd.	0	0	0	0	0	0	0	0	0	0
64	Finolex Cables Ltd.	0	0	0	0	0	0	0	0	0	0
65	Finolex Industries Ltd.	0	0	0	0	0	0	0	0	0	0
66	G A I L (India) Ltd.	0.0003	0	1	0	0	0	0	0	0	0
67	G E Power India Ltd.	0	0	0	0	0	0	0	0	0	0
68	G H C L Ltd.	0	0	0.0035	0	0	0	0	0	0	0
69	G V K Power & Infrastructure Ltd.	0	0	0	0	0	0	0	0	0	0
70	Gateway Distriparks Ltd.	0	0	0	0	0	0	0	0	0	0
71	Gillette India Ltd.	0	0	0	0	0	0	0	0	0	0
72	Glaxosmithkline Consumer Healthcare Ltd.	0.0706	0	1	0	0	0	0	0	0	0
73	Glaxosmithkline Pharmaceuti-cals Ltd.	0	0	0	0	0	0	0	0	0	0
74	Glenmark Pharmaceuticals Ltd.	0	0	0	0	0	0	0	0	0	0
75	Godfrey Phillips India Ltd.	0	0	0	1	0	0	0	0	0	0
76	Godrej Consumer Products Ltd.	0	0	2.00E-04	1	0	0	0	0	0	0
77	Godrej Industries Ltd.	0	0	0	0	0	0	0	0	0	0
78	Granules India Ltd.	0	0	0	0	0	0	0	0	0	0
79	Greaves Cotton Ltd.	0	0	0	0	0	0	0	0	0	0

Sr. No	Company Name	2007	2008	2009	2010	2011	2012	2013	2014	2015	0
80	Greenply Industries Ltd.	0	0	0.8486	1	0	0	0	0	0	0
81	Gujarat State Fertilizers & Chemicals Ltd.	0	0	1.00E-04	0	0	0	0	0	0	0
82	Gujarat State Petronet Ltd.	0.231	0	1	0	1	1	0	0	0	0
83	H C L Infosystems Ltd.	0	0	0	0	0	0	0	0	0	0
84	H C L Technologies Ltd.	0	0	0	0	0	0	0	0	0	0
85	H S I L Ltd.	0	0	0	0	0	0	0	0	0	0
86	H T Media Ltd.	0	0	0.059	0	0	0	0	0	0	0
87	Havells India Ltd.	0	0	0	0	0	0	0	0	0	0
88	Heidelberg Cement India Ltd.	0	0	1.00E-04	0	0	0	0	0	0	0
89	Hero Motocorp Ltd.	0	0	0	0	0	0	0	0	0	0
90	Hexaware Technologies Ltd.	0	0	0	0	0	0	0	0	0	0
91	Himachal Futuristic Communi-cations Ltd.	0	0	0	0	0	0	0	0	0	0
92	Himatsingka Seide Ltd.	0	0	1	0	0	0	0	0	0	0
93	Hindustan Petroleum Corpn. Ltd.	1	0	1	0	0.9049	0	0	0	0	0
94	Hindustan Unilever Ltd.	0	0	1	0	0	0	0	0	0	0
95	Hindustan Zinc Ltd.	0	0	0	0	0	0	0	0	0	0
96	I F B Industries Ltd.	1	0	1	0	1	0	0	0	0	0
97	I T C Ltd.	0	0	0	0	0	0	0	0	0	0
98	I T D Cementation India Ltd.	0	0	1	0	0	0	0	0	0	0
99	Idea Cellular Ltd.	0	0	0	0	0	0	0	0	0	0
100	Igarashi Motors India Ltd.	0	0	1	0	0	0	0	0	0	0
101	India Cements Ltd.	0	0	1	0	0	0	0	0	0	0
102	Indian Hotels Co. Ltd.	0	0	0.0162	0	0	0	0	0	0	0
103	Indo Count Inds. Ltd.	0	0	0	0	0	0	0	0	0	0
104	Indoco Remedies Ltd.	0	0	0	0	0	0	0	0	0	0
105	Indraprastha Gas Ltd.	0	0	0	0	0	0	0	0	0	0
106	J B Chemicals & Pharmaceuti-cals Ltd.	0	0	0	0	0	0	0	0	0	0
107	J B F Industries Ltd.	0	0	0	0	0	0	0	0	0	0
108	J K Tyre & Inds. Ltd.	0	0	0	0	0	0	0	0	0	0
109	Jai Corp Ltd.	0	0	0.9998	0	0	0	0	0	0	0
110	Jaiprakash Associates Ltd.	0	0	0	0	0	0	0	0	0	0
111	Jaiprakash Power Ventures Ltd.	0	0	0.1859	0	0	0	0	0	0	0
112	Jindal Poly Films Ltd.	0	0	1	0	0	0	0	0	0	0
113	Jindal Saw Ltd.	0	0	1	0	0	0	0	0	0	0
114	Jindal Stainless Ltd.	0.0014	0	1	0	0	0	0	0	0	0
115	Jindal Steel & Power Ltd.	0	0	0	0	0	0	0	0	0	0
Sr. No	Company Name	2007	2008	2009	2010	2011	2012	2013	2014	0	2016
116	Johnson Controls-Hitachi Air Conditioning India Ltd.	0	0	0	0	0	0	0	0	0	0
117	Jubilant Life Sciences Ltd.	0	0	0	0	0	0	0	0	0	0
118	K P I T Technologies Ltd.	0	0	0	0	0	0	0	0	0	0
119	Kajaria Ceramics Ltd.	0	0	0.011	0	0	0	0	0	0	0

Sr. No	Company Name	2007	2008	2009	2010	2011	2012	2013	2014	2015	0
120	Kansai Nerolac Paints Ltd.	0	0	0	0	0	0	0	0	0	0
121	Lupin Ltd.	0	0	0.579	0	0	0	0	0	0	0
122	Mahanagar Telephone Nigam Ltd.	0	0	0.941	0	0	0	0	0	0	0
123	Mahindra & Mahindra Ltd.	0	0	0	1	0	0	0	0	0	0
124	Mangalore Refinery & Petrochemicals Ltd.	0	0	0	0	0	0	0	0	0	0
125	Marico Ltd.	0	0	0	0	0	0	0	0	0	0
126	Marksans Pharma Ltd.	0	0	0.0021	0	0	0	0	0	0	0
127	Mcleod Russel India Ltd.	0	0	0	0	0	0	0	0	0	0
128	Merck Ltd.	0	0	0	0	0	0	0	0	0	0
129	Minda Industries Ltd.	0	0	0.0002	0.9009	0	0	0	0	0	0
130	Mindtree Ltd.	0	0	0	0	0	0	0	0	0	0
131	Motherson Sumi Systems Ltd.	1	0	1	0	0	0	0	0	0	0
132	Mphasis Ltd.	0	0	0	0	0	0	0	0	0	0
133	N C C Ltd.	0	0	0	0	0	0	0	0	0	0
134	Natco Pharma Ltd.	0	0	1	0	0	0	0	0	0	0
135	National Aluminium Co. Ltd.	0	0	0	1	0	0	0	0	0	0
136	National Fertilizers Ltd.	0	0	0	0	0	0	0	0	0	0
137	Nava Bharat Ventures Ltd.	0	0	0	0	0	0	0	0	0	0
138	Oracle Financial Services Software Ltd.	0	0	1	0	0.860	0	0	0	0	0
139	P I Industries Ltd.	0	0	0	0	0	0	0	0	0	0
140	P T C India Ltd.	0	0	0.015	0	0	0	0	0	0	0
141	P V R Ltd.	0	0	1	0	0	0	0	0	0	0
142	Petronet L N G Ltd.	0	0	1	0	0	0	0	0	0	0
143	Pfizer Ltd.	0	0	0.9601	0	0	0	0	0	0	0
144	Pidilite Industries Ltd.	0	0	1	1	0	0	0	0	0	0
145	Piramal Enterprises Ltd.	0	0	0	0	0	0	0	0	0	0
146	Polaris Consulting & Services Ltd.	0	0	0	0	0	0	0	0	0	0
147	Prism Cement Ltd.	0.934	0	1	0	0	0	0	0	0	0
148	Procter & Gamble Hygiene & Health Care Ltd.	0	0	0	0	0	0	0	0	0	0
149	Radico Khaitan Ltd.	0	0	0	0	0	0	0	0	0	0
150	Rajesh Exports Ltd.	0	0	0	0	0	0	0	0	0	0
151	Rallis India Ltd.	0	0	1	0	0	0	0	0	0	0
152	Ramco Cements Ltd.	0	0	0	0	0	0	0	0	0	0
153	Ramkrishna Forgings Ltd.	0	0	0	0	0	0	0	0	0	0
154	Rashtriya Chemicals & Fertilizers Ltd.	0	0	0	0	0	0	0	0	0	0
155	Raymond Ltd.	0	0	0	0	0	0	0	0	0	0
156	Redington (India) Ltd.	0	0	1	0	0	0	0	0	0	0
157	Reliance Industries Ltd.	0	0	1	1	0	0	0	0	0	0
158	Reliance Infrastructure Ltd.	0	0	0	0	0	0	0	0	0	0
159	S K F India Ltd.	0	0	0	0	0	0	0	0	0	0
160	S M L Isuzu Ltd.	0	0	0	0	0	0	0	0	0	0

Sr. No	Company Name	2007	2008	2009	2010	2011	2012	2013	2014	2015	0
161	S R F Ltd.	0	0	0	0	0	0	0	0	0	0
162	Sadbhav Engineering Ltd.	0	0	0	0	0	0	0	0	0	0
163	Sanofi India Ltd.	0	0	0	0.9973	0	0	0	0	0	0
164	Shoppers Stop Ltd.	0	0	0.9991	0	0	0	0	0	0	0
165	Shree Cement Ltd.	0	0	0.0002	0	0	0	0	0	0	0
166	Siemens Ltd.	0	0	0	0	0	0	0	0	0	0
167	Sobha Ltd.	0	0	0	0	0	0	0	0	0	0
168	Somany Ceramics Ltd.	0	0	0	0	0	0	0	0	0	0
169	Sonata Software Ltd.	0	0	1	0	0	0	0	0	0	0
170	Steel Authority Of India Ltd.	0	0	0	0	0	0	0	0	0	0
171	Sterlite Technologies Ltd.	0	0	0	0	0	0	0	0	**0**	**0**

APPENDIX: R CODE TO CALCULATE BSM-PROB

```
rm(list=ls())
## import data
 jap <- function(x,param)c(F1 = x[1]*exp(-param[6]*param[4])*pnorm((log(x[1]/param[3])+
        (param[5]-param[6]+ (x[2]^2/2))*param[4])/((x[2]^2)*sqrt(param[4])))-
                    param[3]*exp(-param[5]*param[4])*pnorm((log(x[1]/param[3])+
                                                (param[5]-param[6]- (x[2]^2/2))*param[4])/((x[2]^2)*sqrt(param[4])))
+(1-exp(-param[6]*param[4]))*x[1]-param[2],
                    F2 =  (x[1]*exp(-param[6]*param[4])*pnorm((log(x[1]/param[3])+
                                                (param[5]-param[6]+ (x[2]^2/2))*param[4])/((x[2]^2)*sqrt(param[4])))*x[2])/
param[2]-param[1])
 ##---------- 2007----------
 data_sta_2007 <- `2007.data.set.sta`
 data_param_2007 <- `2007.data.set.param`
 param_1 <- data.frame(data_param_2007)
 data_1 <- data.frame(data_sta_2007)
 ss2007 <- list()
 for(i in 1:342)
 {
  Ss2007 [i]<- multiroot(f = jap,start= t(data_1[i,][2:3]),maxiter = 10, parms=t(param_1[i,][2:7]))
 }
 com1 <- unlist(ss2007)
 seq1 <- seq(1,342,2)
 seq2 <- seq(2,342,2)
 Va1999 <- com1[seq1]
 Sig1999 <- com1[seq2]
```

##----------2008----------

The same code follows for the remaining years of the study for computing initial values, i.e., current value of assets (Va) and volatility of assets (sig).

```
Va <- list(Va2007,Va2008,Va2009,Va2010,Va2011,Va2012,Va2013,Va2014,Va2015,Va2016)

Sig<-list(Sig2007,Sig2008,Sig2009,Sig2010,Sig2011,Sig2012,Sig2013,Sig2014,Sig2015,Sig2016)
```

For calculating expected market return on assets (mu), the following steps have been followed:

```
m <-10

mu <- c()

for (i in 1:m)

{

 mu[i]<- max((Va[i]+Div-Va[i-1])/Va[i-1], param[5])}
```

Notes: Following the methodology of Hillegeist *et al*. (2004), the variables used for the estimation of BSM-PD have been calculated as under:

(1) sta denotes the starting (initial) values for market value of assets (Va) and asset volatility (Sig a), where:

Va = total liabilities + market capitalization

Siga = (standard deviation of equity returns of monthly returns * market capitalization) / total liabilities + market capitalization

(2) param denotes the parameters where param 1 symbolizes standard deviation of equity returns, param 2 equals market capitalization, param 3 denotes total liabilities, param 4 represents time (1 year) , param 5 refers to risk-free rate, and param 6 denotes dividend rate*.

*dividend rate has been calculated as: (previous year dividend + current year dividend) / total liabilities + market capitalization.

(3) *R Studio* (version 3.4.3.) has been used for computing the variables as described above.

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