European Journal of Economics, Finance and Administrative Sciences
ISSN 1450-2275 Issue 76 June, 2015

http://www.europeanjournalofeconomicsfinanceandadministrativesciences.com

An Insurance Model for the Protection of Corporations against the Bankruptcy of Suppliers

Raul Valverde
John Molson Business School, Concordia University, Montreal, Canada
1455 de Maisonneuve Blvd W., Montreal, Qc, Canada, H3G 1M8
E-mail: rvalverde@jmsb.concordia.ca

Abstract

Many banks provide supply-chain finance solutions that might include insurance services that further mitigate trade risk such as the default of suppliers. This study proposes the development of an insurance model that uses the Black-Scholes-Merton (BSM) Model for default prediction and risk pooling management techniques as a way to reduce the risk due to supplier bankruptcy and estimate an insurance premium that banks can use to charge this service to their customers. In order to demonstrate the use of the proposed insurance model, a sample of companies is selected from the New York Stock exchange and data for historical stock prices from the Center for Research in Security Prices database is collected in order to calculate the probability of bankruptcy of a sample of suppliers from different industries by using the BSM model. A Monte Carlo simulation to simulate the impact on risk and expected losses on the number of insurance policies sold is implemented with the use of simulation software. The results show that the simulation is useful to estimate the number of sold policies required in order to reduce the risk to a minimum level and predict with a high level of certainty the losses due to bankruptcy of suppliers.

Keywords: Black-Scholes-Merton, Supply Chain Finance, Supply Chain Insurance, Supply Chain Risk Management, Monte Carlo Simulation for Supply Chain.

1. Introduction

Companies are increasingly forming global supply chains and favouring global sourcing practices to lower the purchase prices. Although supply chain management has been used in practice during several decades, a new trend of developing financial services for the supply chain has emerged in the last ten years (Popa 2013); this has originated the concept of Supply Chain Finance (SCF). There are several definitions of SCF. According to Killen and Associates (2002), SCF represents all transaction activities that go from the flow of cash from the customer's initial order through reconciliation and payment to the seller. Lamoureux and Evans (2011) define SCF as the sequence of financial events and processes that take place as commercial transactions are executed. Popa (2013) also recognizes that SCF is different from the physical supply chain as it deals with the flow of cash instead of goods (Popa 2013). SCF has been recognized as an important issue in the supply chain mainly because its bad management can cause late delivery, negative cash positions and poor working capital management. SCF deals with many aspects of the supply chain including Supplier Risk Management, Supply Chain Financing, Tax Optimization, working capital optimization (including inventory) and the Impact of purchasing and supply chain management on key financial performance ratios. SCF, in general, will translate into cost reduction, service improvement, better risk management and richer management information from a buyer and supplier perspective. SCF also requires collaboration of partners that are committed to sharing resources, capabilities, information and risks on a medium to long term contractual basis while preserving their legal and economic independence (Popa 2013).

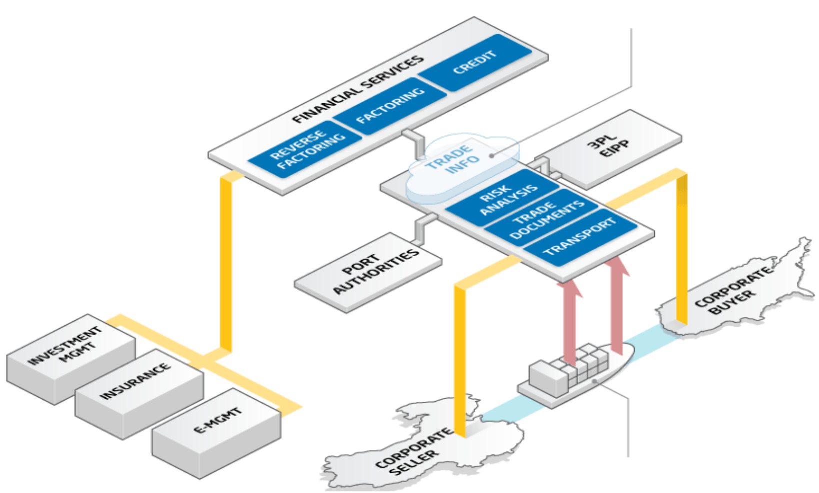
Although the concept of supply chain finance is still expanding in scope, banks have initially understood SCF as a marketing umbrella to repackage traditional products such as trade, insurance, payments and cash management (Popa 2013). However, SCF now has been expanded to include working capital management and the offering of risk management services. Since many banks provide supply-chain finance solutions (see figure 1), this might include insurance services that further mitigate trade risk. A supply chain insurance can be a possible way to hedge a company against the risk of bankruptcy of suppliers. This event can generate losses and extra costs that include (a) losses due to supply chain disruption, (b) delayed or stopped finished goods shipments, (c) difficulty in finding cost-effective alternate suppliers and sourcing contracts, (d) emergency procurements, (e) loss of reputation and market share loss, among others. In summary, If a supplier goes bankrupt, that firm may not be able to meet all of its customer requirements in the short-term, and will not meet any customer requirements if it eventually goes out of business (Valverde & Talla 2013).

This study proposes the development of an insurance model with the help of bankruptcy models and risk pooling management techniques. The proposed model uses pooling arrangements and the BSM bankruptcy model as a way to reduce the risk due to suppliers' bankruptcy and estimate an insurance premium that banks can charge to their customers for this service. First, a sample of companies are selected from the New York Stock exchange and data for historical stock prices from the CRSP database (Center for Research in Security Prices) are collected in order to calculate the probability of bankruptcy of a sample of suppliers from different industries by using the Black-Scholes-Merton (BSM) model. The data collected for this research is collected by using a judgment sampling method. A VBA program for Excel is developed in order to calculate the probability of bankruptcy with the help of the BSM model for the sample of selected companies. VBA programming and Excel has provided good results in the development of risk management applications (Valverde 2011, Valverde 2010).Risk pools are then created from the sample of companies and Monte Carlo simulations is conducted in order to estimate expected losses and risk.

The research questions are:

1) Can the propose supply chain risk management insurance model reduce the risk of bankruptcy of suppliers in a corporate setting?
2) Is the model appropriate to calculate an insurance premium that could be used to implement the insurance model by insurance and financial institutions?

Figure 1: Supply Chain Financial Services



1.1. Supply Chain Risk Management

Risk management is a critical part of supply chain management (SCM) as the risk of bottlenecks, disruptions and incurring unforeseen costs are greater in cross continent and global supply chains. Supply chains are surrounded by potential risks including natural disasters, fraud, economic issues, changes in tax laws, disruptions caused by suppliers' bankruptcy, interest rates and foreign exchange rates fluctuations among other things. Supply Chain Risk Management (SCRM) includes strategies to manage risks along the supply chain (Shi 2004). The growing incidence of natural disasters caused by climate change, terrorist acts, embargoes, fraud, money laundering and economic volatility adds to the risk profile of a global supply chain.

Issues associated with risk and continuity in the supply chain have received considerable attention from both the practitioner and academic communities (Zsidisin 2010). Supply chain risks can generate losses that can be at times quite large due to the disruption of the supply chain. Losses can include loss of reputation, emergency procurement, delays in the production among others.

Research has shown that current principles used in supply chains have resulted in very vulnerable chains (Stephens and Valverde 2013). For example, the drive towards efficient supply networks has amounted into those networks becoming more vulnerable to business disruptions. Some supply chains aim at reducing vulnerability, but there remain chances that can result into disruption escalation. Therefore, it is easy to deal with the internal sources more than the external ones. This is true because despite all the security measures that are put in place, chances of a terrorist attack to take place are still there. Human factors can also cause vulnerabilities in the supply chain. For example, cargo can be stolen despite all the security measures set aside.

There are different ways that have been adopted by companies in reducing vulnerabilities, for example reengineering or decreasing vulnerability by adjusting the structure and design within supply chains (Talla and Valverde 2012). Introduction of analysis tools can act as answers to the drastic supply chain disruption. The analysis application can help in handling incidents in an adequate manner in the future. Kraus & Valverde (2014) developed a tool for the detection of fraud in supply chain, this tool analyzes supply chain transactions in order to reduce the risk of fraud in the supply chains. Vulnerabilities in the supply chan can be mitigated with the help of supply chain tools.

SCF has been used for the risk management of supply chains. SCF includes risk mitigation instruments such as trade credit insurance that protect suppliers against the risk of non-payment by foreign buyers (Lamoureux 2011). Supplier risks can also be reduced by financial risk management strategies such as attenuating price volatility of supplier pricing for goods and services through negotiation of long term contracts and consolidation of requirements with other firms/organizations, minimization of currency risk on contracts denominated in foreign currencies through the various forms of hedging (e.g. forward contracts, futures contracts), minimizing the risk of potential supplier bankruptcy through financial analysis and surveillance and minimizing the cost of supplier financing in developing and emerging markets by providing advanced payments (Lamoureux 2011). A firm is obliged to evaluate the financial viability of suppliers in order to avoid the consequences of suppliers' default, insolvency, or bankruptcy (Valverde & Talla 2013).

Consulting firms such as Deloitte and PriceWaterhouseCoopers (PWC) and insurance companies such as Zurich Insurance provide consulting services on assessing and mitigating supply chain risks arising from product development to outsourcing and from finance to logistics. Zurich's supply chain risk management practice provides consulting services to reduce supply chain failures and insurance coverage including supplier defaults and supply delay so that the insurer can reduce financial risk exposure.

2. Materials and Methods

This section outlines the research methodology and design for this study. It starts with the research questions and also covers the data collection techniques, mathematical models used, simulation techniques and the limitations for this research.

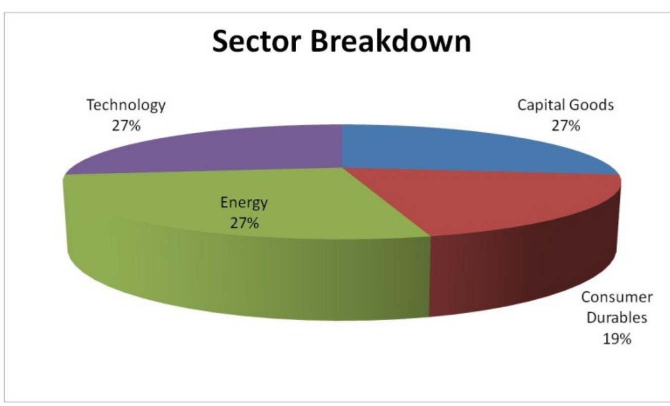
2.1 Data Collection

The research will use the Black-Scholes-Merton (BSM) (1973) option pricing model for estimating the probability of bankruptcy of suppliers based on the financial data collected for historical stock prices from the CRSP database (Center for Research in Security Prices).

The data collected for this research will be collected by using a judgment sampling method. Remenyi et al (1998) acknowledge that judgment samples are inherently subjective but justify the use of judgment samples on the grounds that “samples are taken where individuals are selected with a specific purpose in mind, such as their likelihood of representing best practice in a particular issue”. From the outset it became clear that statistical sampling techniques on this type of research would have not been possible given the large amount of companies that act as suppliers for companies, this would have resulted an extremely high sample size that could not be computed for this dissertation given time limitations. The proposed sample size is 100 companies from a variety of industries operating in four different sectors: Energy, Consumer Durables, Technology, and Capital goods. These industries were judged appropriate for the study given their large number of suppliers and potential of losses due to supplier bankruptcy. This sample, in the opinion of the author, should be large enough to test the proposed model.

Data collected for the purpose of this analysis was obtained from two resources. First, listings were collected from NASDAQ's website (http://www.nasdaq.com/screening/companies-by-industry.aspx?) for organizations operating in four different sectors: Energy, Consumer Durables, Technology, and Capital goods (See figure 2). These industries were considered appropriate as organizations operating in these heavy or industrial goods industries will likely incur excess costs should a supplier declare bankruptcy. Examples of industries excluded were public utilities, transportation, and finance, which represent service based organizations that are not the focus of this research. In all, 1,046 company names were extracted, from which a convenience sample of 100 organizations was extracted.

Figure 2: Sector breakdown



The daily stock price data from January 1st 1994 to 2014 (the last twenty years) was then collected via the CHASS Data Centre (University of Toronto) CRSP Database, with the common assumption that the average number of Trading days in one year is 252.

The risk free rates for the last 10 years were downloaded (Bank of Canada, http://www.bankofcanada.ca/rates/interest-rates/t-bill-yields/selected-treasury-bill-yields-10-yearlookup/) for T-bills with 1-month, 3-month, 6-month, and 1-year maturity. A 10-Year average yield of the different term Treasury Bills was calculated and documented in table 1.

Table 1: Treasury Bills Free Rate

1-Month	3-Month	6-Month	1-Year	Average
0.0178	0.0186	0.0197	0.0197	0.0193

2.2 Black-Scholes Model

The BSM model is used to calculate the probability of bankruptcy for the sample of firms selected for this study. The equation for valuing equity as a call option on the value of the firm's assets is given in equation 2 (Hull 2012). This equation is modified for dividends and reflects that the stream of dividends paid by the firm accrues to the equity holders.

The BSM equation is:

$$E_0 = V_0 N(d_1) - De^{-rT} N(d_2) \tag{1}$$

Where $N(d_1)$ and $N(d_2)$ are the standard cumulative normal of d_1 and d_2 which are:

$$d_1 = \frac{\ln(V_0/D) + (r + \sigma_V^2/2)T}{\sigma_V \sqrt{T}}; d_2 = d_1 - \sigma_V \sqrt{T} \tag{2}$$

E_0 is the current market value of equity; V_0 is the current market value of assets; D is the face value of debt maturing at time T; r is the continuously-compounded risk-free rate and σ_V is the standard deviation of asset returns.

Equation (3) (Hull 2012) together with the option pricing relationship described in equation 2 enables V_0 and s_V to be determined from E_0 and σ_E.

$$\sigma_E E_0 = \frac{\partial E}{\partial V} \sigma_V V_0 = N(d_1) \sigma_V V_0 \tag{3}$$

Under the BSM model, the probability of bankruptcy is simply the probability that the market value of assets , V_0 is less than the face value of the liabilities, D, at time T (i.e $V_0(T) < D$). The BSM model assumes that the natural log of future asset values is normally distributed. The probability of bankruptcy is a function of the distance between the current value of the firm's assets and the face value of its liabilities, adjusted for the expected growth in asset values relative to asset volatility.

As shown in Hull(2012), the probability that V_0 (T) $< D$ or probability of bankruptcy can be calculated as indicated in equation 5:

$$N(-d2) \tag{4}$$

An Excel spreadsheet is developed in order to calculate the probability of bankruptcy with the help of the BSM model for the sample of selected companies. The BSM model is fed by using daily return data from the Center for Research in Security Prices database (http://www.crsp.com).

The Excel spreadsheet with the help of the solver module is used to calculate the probability of bankruptcy. The calculation is performed in three steps. In this initial step, E_0 will is set equal to the total market value of equity based on the closing price at the end of the firm's fiscal year, σ_E is computed by using daily return data from the historical stock prices from the Center for Research in Security Prices database (http://www.crsp.com) over twenty years of trading data. D is set equal to the book value of total liabilities, T is equal to one year, and r is set at the one-year treasury bill rate. In the second step, the values of d_1, d_2, σ_V and V_0 are estimated by simultaneously solving equations 1, 2 and 3.

Finally, the value of d_2 is used to calculate the probability of bankruptcy for each firm-year via equation 4 by using the standard normal distribution of -d_2.

2.3 Risk Pooling

The research use pooling arrangements among suppliers as a way to reduce the risk due to supplier bankruptcy. The pooling arrangement can be used by an insurance company to reduce risk and estimate an average loss that can be used to estimate insurance premiums. A risk pool is one of the forms of risk management practiced in insurance. Pooling arrangements do not change a company's expected loss, but reduce the uncertainty (standard deviation) of a loss. Risk pooling arrangements make each participant's loss more predictable (Levi et al. 2003).

This study plans to use pooling arrangements among suppliers as a way to reduce the risk of suppliers' bankruptcy. Pooling arrangements of 5, 10, 25 and 50 companies with 3 different sets of companies are created in order to see the effect of the number of companies in terms of risk reduction and to estimate an average loss that can be used to estimate insurance premiums

The concept of pooling losses has been used in supply chain (Levi et al. 2003). Risk pooling suggests that demand variability is reduced if one aggregates demand across locations because as demand is aggregated across different locations, it becomes more likely that high demand from one customer will be offset by low demand from another. This reduction in variability allows a decrease in safety stock and therefore reduces average inventory, this suggests that the use of centralized warehouses reduces inventory costs as it reduces safety stock but this benefit decreases as the correlation between demands of the different locations becomes positive (Levi et al. 2003).

Once the probability of bankruptcy for the sample of 100 companies has been compiled, a loss distribution is computed in order to determine the probability of having 1, 2, 3, … 100 companies going bankrupt on a given year. This helps us to determine the probability of number of insurance claims during a year.

For a given number of possible bankruptcy events, the probability of no events or no bankruptcies is defined in equation 5:

$$S = \{1,2,3......x\} \; for \;\; x >= 1$$

$$P(0) = \prod_{i=1}^{i=x} (1 - Pi) \tag{5}$$

The probability of a given number of bankruptcies to occur (n) for a given possible set of companies (x) is described in equation 6:

$$P(n) = P(0) \sum_{i1,i2......in \in S, ik \; distinct} \frac{Pi_1 Pi_2 Pi_3 ....P_n}{(1-P_1)(1-P_2)(1-P_3)..............(1-P_n)} \tag{6}$$

Where there are $\binom{x}{n}$ terms in the summation.

2.4 Monte Carlo Simulations

In order to tackle the issues of validity and reliability, the study plans to validate the proposed model by simulating a possible bankruptcy of multiple suppliers based on the calculated probabilities and show that the model can be successful as a way to reduce the risk of supplier bankruptcy. The simulation also has the objective of showing that the average losses would be more predictable and used to calculate an insurance premium.

Monte Carlo simulations have a good history of providing reliable results for supply chain risk management. Deleris et al (2004) used Monte Carlo simulation to estimate the probability distribution of supply chain losses caused by disruptions, Cohen and Huchzermeier (1999) used Monte Carlo simulations in order to produce accurate estimates of a firm's downside risk exposure to price/foreign exchange risk in the supply chain. Grittner and Valverde (2012) used Monte Carlo simulations for the estimation of reordering points in the embedded systems industry by using historical demand taken from an Enterprise Resource Planning system. Stafanovic et al. (2008) used Monte Carlo simulation to generate demand as an external event to a system modeling in a supply network; the authors are able to demonstrate that Monte Carlo can be used to simulate supply chain risk events and are also able to show that Monte Carlo can be used as part of a simulation framework that can be used by supply chain professionals. Qin and Ding (2011) simulated the operations of the supply chain, interactions with a bank and the bank behaviour for inventory financing model for supply chain risk management. Valverde and Felix (2014) used Monte Carlo for RFID simulations for the supply chain management of the UK dental industry.

A Monte Carlo simulation for the bankruptcy of companies for multiple periods with the probabilities calculated with the BSM model is performed in this research. The objective of the simulation is to calculate losses for the bankruptcy of suppliers and compare them with the premium calculations. The simulation helps to test whether the risk management model is able to reduce the variability of losses and whether the estimated insurance premium are able to cover for all the losses. Ten simulations are performed for each risk pool of 5, 10, 50 and 100 in order to verify the results. An estimated expected loss and variance for each risk pool are calculated.

2.5 Limitations

The proposed study is limited to suppliers that are traded in the New York stock exchange market. This limits the results to only those companies that are traded in the financial market.

Given the time limitations and the large number of companies available, the research proposes a non probabilistic sampling method for simplicity. This makes generalization and inference about the entire population difficult.

3. Results and Discussion

3.1 Probability of Bankruptcy

The probability of bankruptcy for the sample of 100 companies was calculated by using the BSM model and the Excel Solver. In the initial step, V_E was set equal to the total market value of equity based on the closing price at the end of the firm's fiscal year, σ_E was computed using daily return data from the Center for Research in Security Prices database (http://www.crsp.com) over the period of twenty years. T was equal to one year, and r was set as the one-year treasury bill rate calculated in Table 1. Moreover, E_0 was set to the current market value of equity and D at the face value of debt maturing at time T. Appendix A shows these values that were used to feed the BSM model.

The values of d_1, d_2, σ_V and V_0 were estimated by simultaneously solving equations 2, 3 and 4 with the use of an Excel spreadsheet and by using the solver module. The results of these calculations are documented in appendix A. The value for d_2 was used to calculate the probability of bankruptcy for each firm-year via equation 5 by using the standard normal distribution of $-d_2$. The probability of bankruptcy generated for each company is presented in Table 2.

Table 2: Probability of bankruptcy of the supplier sample

Company Name	P(Bankruptcy)	Company Name	P(Bankruptcy)	Company Name	P(Bankruptcy)
VERMILION ENERGY INC	8.0102E-29	INGERSOLL-RAND PLC	1.2881E-06	CHECKPOINT SYSTEMS INC	0.00077991
ESPEY MFG & ELECTRONICS CORP	1.5833E-23	BRADY CORP	1.6203E-06	EMC CORP/MA	0.00078163
PENTAIR LTD	1.1416E-20	HOLLYFRONTIER CORP	2.8061E-06	MOTOROLA SOLUTIONS INC	0.00092862
STEEL PARTNERS HOLDINGS LP	2.0546E-19	BOLT TECHNOLOGY CORP	7.9838E-06	EMULEX CORP	0.00095299

Company Name	P(Bankruptcy)	Company Name	P(Bankruptcy)	Company Name	P(Bankruptcy)
EQT CORP	2.6836E-17	MAXIM INTEGRATED PRODUCTS	8.1329E-06	HYSTER-YALE MATERIALS HNDLNG	0.00095506
HUBBELL INC -CL B	9.3644E-16	SCHAWK INC - CL A	1.191E-05	HEWLETT-PACKARD CO	0.00112107
CHEVRON CORP	9.9684E-16	CASEYS GENERAL STORES INC	1.2473E-05	NORTEK INC	0.00197644
PARK ELECTROCHEMICAL CORP	1.8645E-12	INTL BUSINESS MACHINES CORP	1.5284E-05	WEATHERFORD INTERNATIONAL	0.00205811
EXXON MOBIL CORP	2.5359E-12	NABORS INDUSTRIES LTD	1.7621E-05	SORL AUTO PARTS INC	0.00224785
OCEAN RIG UDW INC	3.0049E-12	ASM INTERNATIONAL NV	2.2594E-05	BRUNSWICK CORP	0.00243416
CURTISS-WRIGHT CORP	3.7446E-11	ATLANTIC POWER CORP	2.2615E-05	EDUCATIONAL DEVELOPMENT CORP	0.00254451
EATON CORP PLC	6.3277E-11	COHERENT INC	2.3815E-05	XPLORE TECHNOLOGIES CORP	0.00259588
CST BRANDS INC	2.9891E-10	CSR PLC	2.9173E-05	LINEAR TECHNOLOGY CORP	0.00307739
GRACO INC	4.3774E-10	ASTEC INDUSTRIES INC	5.9996E-05	FORBES ENERGY SERVICES LTD	0.0034713
HUNTINGTON INGALLS IND INC	6.0338E-09	HALLIBURTON CO	6.0244E-05	NAVISTAR INTERNATIONAL CORP	0.00476683
KIMBERLY-CLARK CORP	6.6857E-09	II-VI INC	0.00013934	FORD MOTOR CO	0.00550534
CONTINENTAL MATERIALS CORP	2.746E-08	BASSETT FURNITURE INDS	0.00014012	VIEWTRAN GROUP INC	0.00795512
MURPHY OIL CORP	2.9512E-08	AZZ INC	0.00015031	U S CONCRETE INC	0.00879269
GENERAL DYNAMICS CORP	3.4036E-08	APPLE INC	0.00015289	PLEXUS CORP	0.01118444
HESS CORP	3.762E-08	CYBEROPTICS CORP	0.00016412	SIGMA DESIGNS INC	0.01347152
SEMGROUP CORP	4.1448E-08	NATURAL ALTERNATIVES	0.00017733	DYNAMIC MATERIALS CORP	0.01520283
UNITED TECHNOLOGIES CORP	5.5154E-08	MARATHON PETROLEUM CORP	0.00018087	CALAMP CORP	0.01675435
EMERSON ELECTRIC CO	8.1206E-08	PIONEER POWER SOLUTIONS INC	0.00019768	COMTECH TELECOMMUN	0.02117269
BRIGGS & STRATTON	9.6283E-08	TEXTRON INC	0.00022919	CYANOTECH CORP	0.02128995
RAYTHEON CO	1.0235E-07	CTS CORP	0.00023342	DATA I/O CORP	0.03042145
FRANKLIN	1.0697E-07	ASTRO-MED	0.00026589	SMART	0.03192828

Company Name	P(Bankruptcy)	Company Name	P(Bankruptcy)	Company Name	P(Bankruptcy)
ELECTRIC CO INC		INC		TECHNOLOGIES INC	
PHILLIPS 66	1.4021E-07	APPLIED MATERIALS INC	0.00026789	COBRA ELECTRONICS CORP	0.03868253
ASHLAND INC	1.8507E-07	GENERAL ELECTRIC CO	0.00035189	LILIS ENERGY INC	0.05813517
APPLIED INDUSTRIAL TECH INC	2.3362E-07	FLOWSERVE CORP	0.00044937	MITEK SYSTEMS INC	0.0819747
CRANE CO	5.8832E-07	BEL FUSE INC	0.00047658	TECH DATA CORP	0.16963718
SCHLUMBERGER LTD	7.083E-07	SPARTON CORP	0.00054959	WHIRLPOOL CORP	0.19310801
FLEXSTEEL INDUSTRIES INC	7.4639E-07	POWER SOLUTIONS INTL INC	0.0007378	NF ENERGY SAVING CORP	0.23296333
BABCOCK & WILCOX CO	9.1305E-07	NEWPARK RESOURCES	0.0007689	SAEXPLORATION HOLDINGS INC	0.36475281
				CROWN HOLDINGS INC	0.99612488

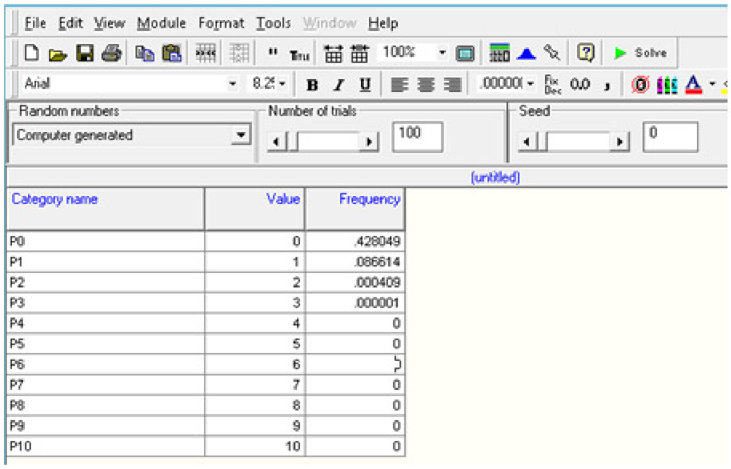
3.2 Risk Pools

Pooling arrangements of different sizes (5, 10, 25 and 50 companies) for 3 different set of companies were created. Appendix B contains the tables of the different pooling arrangements with the different set of companies that are used in this study. For each pooling arrangement, a probability table was calculated by using equations 6 and 7 and with the help of a VBA program for Excel. The VBA program reads the probabilities of bankruptcy for each company in each of the pooling arrangements and uses equations 6 and 7 to compute the probabilities that suppliers will go bankrupt in a year. For example, in Table 10, the probability that no company goes to bankrupt for sample 4 (10 companies) is 90%, the probability that only one company goes out of business is 9.6%. The same Table also shows that the probability that 5 or more companies go bankruptcy is close to zero. It is interesting to notice that the probability of no bankruptcy is the highest for all tables. These probability tables for all the different pooling arrangements used for the study are included in Appendix C.

3.3 Monte Carlo Simulation

A Monte Carlo simulation was performed in order to calculate the expected losses of bankruptcy and standard deviations of losses for the different risk pooling arrangements for this study. POM for Windows Software (http://wps.prenhall.com/bp_weiss_software_1/) was used for this simulation. POM is a management science software that supports Monte Carlo simulations. The tables with the risk pooling arrangements probabilities included in Appendix C were loaded into POM in order to perform the simulation. Figure 3 shows a table that contains the probabilities of losses for a risk pooling arrangement of 10 companies for sample 6 (Table 10, Appendix C). The number of trials in the simulation represents the number of policies that can be sold by an insurance company, for each simulation the number of trials was set to 5, 10, 50 and 100.

Figure 3: POM Simulation for 10 companies for Sample 6



For each risk pooling arrangement, 100 simulations were performed and average standard deviations computed and reported in Tables 3 and 4.

Table 3: Results for the simulation for samples 1, 2, 3, 4, 5 and 6 with Standard Deviation for various quantities of policies sold

		5 Company Pools			10 Company Pools		
		Sample 1	**Sample 2**	**Sample 3**	**Sample 4**	**Sample 5**	**Sample 6**
Standard Deviation for various quantities of policies sold	5 Policies Standard Deviation	0.1767	0.2207	0.2043	0.1717	0.0823	0.1943
	10 Policies Standard Deviation	0.1143	0.1303	0.1203	0.1065	0.0595	0.1155
	50 Policies Standard Deviation	0.0457	0.0565	0.0510	0.0424	0.0236	0.0453
	100 Policies Standard Deviation	0.0329	0.0382	0.0347	0.0274	0.0171	0.0320
	% Change Standard Deviation	**-81%**	**-83%**	**-83%**	**-84%**	**-79%**	**-84%**

Table 4: Results for the simulation for samples 7, 8, 9, 10, 11 and 12 with Standard Deviation for various quantities of policies sold

		25 Company Pools			50 Company Pools		
		Sample 7	**Sample 8**	**Sample 9**	**Sample 10**	**Sample 11**	**Sample 12**
Simulation Probability of Bankruptcy Average & Standard Deviation for various quantities of policies sold	5 Policies Standard Deviation	0.3007	0.1595	0.2407	1.1599	0.8486	0.2577
	10 Policies Standard Deviation	0.1840	0.1010	0.1490	0.8581	0.7255	0.1508
	50 Policies Standard Deviation	0.0808	0.0446	0.0712	0.4162	0.3409	0.0729
	100 Policies Standard Deviation	0.0534	0.0295	0.0459	0.3552	0.3619	0.0844
	% Change Standard Deviation	**-82%**	**-82%**	**-81%**	**-69%**	**-57%**	**-67%**

Tables 3 and 4 confirm that standard deviations (measurement of risk) are reduced by increasing the number of insurance policies being sold. The standard deviations are being reduced to a maximum of 84% by increasing the sale of insurance policies from 5 to 100 policies per risk pool arrangement. The simulation proves to be an excellent tool to measure risk with a given number of policies being sold.

Costs in the case of a partner organization declaring bankruptcy include administrative costs, related to the closure, shortages and stock outs, and loss of goodwill and reputation; all are possible side effects and are difficult to measure. In the case of industrial sectors like automotive and aerospace, substantial costs will be incurred in substantiating new suppliers and parts as decreed by the transportation regulatory body. The loss per bankruptcy for the simulation was simply set to a convenience value of $50,000 to demonstrate that with the knowledge of the insurance per bankruptcy claim value, one could compute expected losses for the risk pooling arrangement or insurance payout (Pindyck and Rubinfeld 2005). The loss per bankruptcy represents the payout in the insurance contract that the insurance company needs to pay per bankruptcy.

The average expected losses represent the minimum value that must be collected to ensure that the insuring organization breaks even on a policy in which the payout per bankruptcy is $50,000. Table 5 includes the average expected losses for the different samples included in this study for the 100 Monte Carlo simulations performed for this research.

Table 5: Average Expected losses for the simulation for the different samples

# Companies	Sample #	5 Policy Average Expected Loss	10 Policy Average Expected Loss	50 Policy Average Expected Loss	100 Policy Average Expected Loss
5	1	$ 3,700.00	$ 4,050.00	$ 4,060.00	$ 4,235.00
	2	$ 11,200.00	$ 11,650.00	$ 11,990.00	$ 11,870.00
	3	$ 8,700.00	$ 9,350.00	$ 9,740.00	$ 9,675.00
10	4	$ 5,100.00	$ 5,450.00	$ 4,960.00	$ 4,855.00
	5	$ 1,500.00	$ 1,800.00	$ 1,720.00	$ 1,765.00
	6	$ 8,100.00	$ 8,350.00	$ 8,540.00	$ 8,480.00
25	7	$ 23,900.00	$ 24,350.00	$ 23,750.00	$ 23,995.00
	8	$ 55,200.00	$ 55,500.00	$ 55,340.00	$ 55,180.00
	9	$ 19,200.00	$ 18,850.00	$ 18,700.00	$ 18,880.00
50	10	$ 77,300.00	$ 85,150.00	$ 80,620.00	$ 80,915.00
	11	$ 97,200.00	$ 94,200.00	$ 96,530.00	$ 95,890.00
	12	$ 15,800.00	$ 14,950.00	$ 15,440.00	$ 14,565.00

By examining Table 5, we can observe that expected losses become more predictable as we increase the number of policies sold. For example, for sample 5, there is a difference of only $45 between 100 and 50 policies sold. This means that the insurance company could expect to lose around $1,700 per insurance policy sold if the company is being able to sell at least 50 policies. The simulation can be used as a tool to estimate expected losses by an insurance company that can then use this value to price an insurance contract by adding a desired profit.

4. Conclusions

4.1 Research Questions and Answers

The answer to the first research question for the study "can the proposed supply chain risk management insurance model reduce the risk of bankruptcy of suppliers in a corporate setting?" is positive. Tables 3 and 4 show that model can be effective at reducing the targeted risk. Tables 3 and 4 also show that the insurance company would be able to benefit from a lower risk as the number of insurance policies sold increases. The answer to the second research question "Is the proposed model appropriate to calculate an insurance premium and risk that can used to implement the insurance model by insurance and financial institutions?" is also positive. Table 5 shows that average expected losses can be calculated from Monte Carlo simulations and these values can be used to price insurance premiums. Expected losses become more predictable by selling higher levels of insurance contracts (more than 50), these values can be used to price insurance contracts by adding a desired level of profit on top of the expected losses. As the risk of variability of losses decreases with the number of sold policies, insurance companies can have a high level of certainty that they will be able to profit from these contracts while the insured companies would be able to benefit by hedging the risk of bankruptcy of suppliers.

4.2 Limitations of the Results

The BSM used for the proposed model presents some limitations that can make challenging its implementation. The BSM model relies on financial public information that can be used to feed the model, this could be an important limitation given the fact that not all the suppliers are public companies that are traded in the stock market.

The suggested model assumes that companies in risk pool arrangements have uncorrelated losses; this is an important assumption that is required in order to reduce risk. However, in practice companies might have correlated losses; in particular, if they belong to the same industry that might be affected by similar events such as an economic crisis in a particular industry sector. The model can be affected by correlation of losses among companies that can be hard to measure.

Another important limitation of the proposed model in the complexity of the computations for the implementation of the model; this study was conducted with pooling arrangements of up to 50 companies but insurance companies might require larger sizes and this would require a large computer power that might make the model difficult to implement with average computer power.

4.3 Limitations of the Results

One of the main challenges of this research was the intensive computation required to produce the probability tables for a given risk pooling arrangement. Some of the calculations required several days to be produced and as the number of companies included in the risk pool increases, the time required to compute these tables increase exponentially and the time required to compute large pools can be in the order of months. Future research should concentrate in the generation of equations that can make risk pooling calculations more efficient; these equations could use exponential regression analysis in order to fit the table in a simple equation that can be used to produce the probabilities with less intensive calculations. Insurance industry might not be able to use the proposed model unless simplified equations are produced that could make its implementation more efficient.

Future research should also explore the use of different bankruptcy models and measure the performance of these models against the BSM model. Although the BSM model proved to be robust for the proposed application, the literature in the field has several bankruptcy models that might be more suitable for the intended application in this research. For example, the model proposed by Flores-Lopez and Ramon-Jeronimo (2013), requires less data that might be hard to get for this type of analysis and explores the use of cooperative models and bootstrapping strategies for default prediction. The use of this model in combination with risk pooling and Monte Carlo simulations can be explored as a possible solution to the lack of availability of data for non public suppliers.

Future research should also focus on the development of losses models that can estimate the losses of bankruptcy per supplier. This research assumes that these losses are given but in practice these losses would need to be estimated by insurance companies. A losses model would be required for this task in the future.

4.3 Summary

The study clearly shows the usefulness of estimating the probability of bankruptcy of suppliers from available financial public information in order to create an insurance contract that can hedge the risk of the supply chain. These insurance contracts can be managed by insurance carriers and sold to companies as supplier bankruptcy insurance. The research study applies financial and accounting theory to the supply chain risk management field and shows how this can be useful to create financial instruments for financial risk management hedging. As supply chains become more global and international economic events affect these chains, financial risk such as price, interest, default risks would need to be hedged and financial and accounting theory would become more relevant for this field. This research shows the potential benefit of financial and accounting theory to supply chains in the global context.

Acknowledgment
Special thanks to David Pacheco for his support in the preparation of this paper.

References
[1] Black F. and M. Scholes, (1973) 'The Pricing of Options and Corporate Liabilities', *The Journal of Political Economy* Vol 81(3) pp 637-654

[2] Deleris, L. A., Elkins, D., and Paté-Cornell, M. E. (2004) 'Analyzing losses from hazard exposure: a conservative probabilistic estimate using supply chain risk simulation' *In Simulation Conference, 2004. Proceedings of the 2004 Winter* (Vol. 2, pp. 1384-1391). IEEE.

[3] Felix, F., and Valverde, R. (2014). An RFID Simulation for the Supply Chain Management of the UK Dental Industry. Journal of Theoretical and Applied Information Technology, 60(2), 390-400.

[4] Florez-Lopez, R. and Jeronimo J.M.R. (2013) 'Modelling credit risk with scarce default data: on the suitability of cooperative bootstrapped strategies for small low-default portfolios' *Journal of the Operational Research Society* Vol 65 (3) pp. 416-434.

[5] Grittner, D. H., and Valverde, R. (2012) 'An object–oriented supply chain simulation for products with high service level requirements in the embedded devices industry' *International Journal of Business Performance and Supply Chain Modelling* Vol 4(3) pp 246-270.

[6] Hull, J. (2012) Risk Management and Financial Institutions, John Wiley & Sons.

[7] Killen & Associates (2002) 'Optimizing the Financial Supply Chain : How CFO of Global Enterprises are Succeeding by Substituting Information for Working Capital', *Killen and Associates*, Report, Palo Alto, CA.

[8] Lamoureux, J. F., and Evans, T. (2011) 'Supply Chain Finance: A New Means to Support the Competitiveness and Resilience of Global Value Chains' Export Development, Canada [ONLINE] Available at: http://www.international.gc.ca/economist-economiste/assets/pdfs/research/TPR_2011_GVC/12_Lamoureux_and_Evans_e_FINAL.pdf. [Accessed 29 April 2014]

[9] Levi, D.S. P.Kaminsky and E. Simchi-Levi (2003). 'Chapter 3: Inventory Management and Risk Pooling'; Designing & Managing the Supply Chain, Second Edition (p-66).

[10] Merton, R. C., 1974, 'On the pricing of corporate debt: The risk structure of interest rates', *Journal of Finance* 29, pp. 449-470.

[11] Pindyck, R. S., and Rubinfeld D. L (2005). Microeconomics. Upper Saddle River, NJ: Pearson Prentice Hall.

[12] Popa, V. (2013). 'The Financial Supply Chain Management: a New Solution for Supply Chain Resilience'. *The AMFITEATRU ECONOMIC journal*, Vol 15(33), pp. 140-153.

[13] Qin, Z., and Ding, X. (2011) 'Risk Migration in Supply Chain Inventory Financing Service' *Journal of Service Science & Management*, Vol 4(2), pp. 221-226.

[14] Remenyi, D. Williams, B. Money, A. and Swartz, E. 1(998), Doing research in business and management: An introduction to process and method. Sage Publications, London.

[15] Stefanovic, D., and Stefanovic, N. (2008) 'Methodology for modeling and analysis of supply networks' *Journal of Intelligent Manufacturing* Vol*19*(4), pp. 485-503.

[16] Stephens, J., and Valverde, R. (2013), Security of E-Procurement Transactions in Supply Chain Reengineering. Computer and Information Science, Volume 6 No. 3, p1.

[17] Talla M. and Valverde R. (2012), Data oriented and Process oriented Strategies for Legacy Information Systems Reengineering, ACEEE International Journal on Information Technology, Volume 2 No. 1.

[18] Valverde, R. (2010). An Adaptive Decision Support Station for Real Estate Portfolio Management. *Journal of Theoretical and Applied Information Technology*, *12*(2), 84-86.

[19] Valverde, R. (2011). A Business Intelligence System for Risk Management in the Real Estate Industry. *International Journal of Computer Applications*, *27*(2), 14-22.

[20] Valverde R and Talla M (2013) 'Risk Reduction of the Supply Chain Through Pooling Losses in Case of Bankruptcy of Suppliers Using the Black–Scholes–Merton Pricing Model' in Chaubey P. Yogendra (ed) *Some Recent Advances in Mathematics and Statistics*, World Scientific, USA, pp. 248-256

Appendixes

Appendix A Probability of bankruptcy

Table 6: Probability of bankruptcy for the sample of 100 companies used for the study

Company Name	D (X)	R	E0	SE (SigE)	Sv(Sig A)	d1	d2	V0	P (Bankruptcy)
VERMILION ENERGY INC	347.444	0.0191	1716.38	0.19310	0.16110245	11.239	11.078	2057.25	8.0102E-29
ESPEY MFG & ELECTRONICS CORP	3.503	0.0191	31.843	0.25690	0.23187586	10.159	9.9273	35.2797	1.5833E-23
PENTAIR LTD	1610.2	0.0191	6095.3	0.21329	0.169392029	9.4176	9.2482	7675.04	1.1416E-20
STEEL PARTNERS HOLDINGS LP	235.055	0.0191	616.582	0.19852	0.144481745	9.0785	8.934	847.19	2.0546E-19
EQT CORP	523.41	0.0191	4034.79	0.28901	0.256379664	8.6347	8.3784	4548.3	2.6836E-17
HUBBELL INC -CL B	467	0.0191	1906.4	0.25284	0.203845137	8.1533	7.9495	2364.57	9.3644E-16
CHEVRON CORP	33018	0.0191	149113	0.25869	0.212519233	8.1543	7.9417	181506	9.9684E-16
PARK ELECTROCHE MICAL CORP	16.678	0.0191	299.922	0.43656	0.413976662	7.3611	6.9471	316.285	1.8645E-12
EXXON MOBIL CORP	71724	0.0191	174003	0.24893	0.177249761	7.0808	6.9035	244370	2.5359E-12
OCEAN RIG UDW INC	543.654	0.0191	2979.84	0.31692	0.268803403	7.1482	6.8794	3513.21	3.0049E-12
CURTISS-WRIGHT CORP	534.593	0.0191	1552.71	0.27839	0.208096163	6.7186	6.5105	2077.18	3.7446E-11
EATON CORP PLC	4914	0.0191	16791	0.29500	0.229192458	6.6604	6.4313	21612	6.3277E-11
CST BRANDS INC	463	0.0191	627	0.23889	0.138531129	6.3295	6.191	1081.24	2.9891E-10
GRACO INC	168.853	0.0191	634.365	0.31742	0.251693956	6.3823	6.1306	800.024	4.3774E-10
HUNTINGTON INGALLS IND INC	1392	0.0191	1521	0.24647	0.129865786	5.8286	5.6988	2886.67	6.0338E-09
KIMBERLY-CLARK CORP	5848	0.0191	4856	0.23332	0.10695	5.7882	5.6813	10593.4	6.6857E-09
CONTINENTA L MATERIALS CORP	13.035	0.0191	52.064	0.36243	0.290959478	5.7256	5.4346	64.8524	2.746E-08
MURPHY OIL CORP	3224.031	0.0191	8595.73	0.32424	0.237022173	5.6588	5.4217	11758.8	2.9512E-08
GENERAL DYNAMICS CORP	12194	0.0191	14501	0.26465	0.145014488	5.5412	5.3962	26464.3	3.4036E-08
HESS CORP	6558	0.0191	24720	0.36049	0.286038978	5.6642	5.3782	31153.9	3.762E-08
SEMGROUP CORP	499.214	0.0191	1053.9	0.30762	0.210019989	5.5707	5.3607	1543.67	4.1448E-08
UNITED	22800	0.0191	31866	0.27995	0.164487524	5.4734	5.3089	54234.7	5.5154E-08

Company Name	D (X)	R	E0	SE (SigE)	Sv(Sig A)	d1	d2	V0	P (Bankruptcy)
TECHNOLOGIES CORP									
EMERSON ELECTRIC CO	7625	0.0191	10585	0.28305	0.165845016	5.4037	5.2379	18065.7	8.1206E-08
BRIGGS & STRATTON	274.755	0.0191	667.938	0.32863	0.234140923	5.4405	5.2064	937.495	9.6283E-08
RAYTHEON CO	5810	0.0191	11035	0.30836	0.203332727	5.3983	5.195	16735.1	1.0235E-07
FRANKLIN ELECTRIC CO INC	138.474	0.0191	595.707	0.38687	0.315025205	5.5018	5.1868	731.561	1.0697E-07
PHILLIPS 66	12931	0.0191	21950	0.30286	0.191933218	5.3281	5.1361	34636.4	1.4021E-07
ASHLAND INC	1727	0.0191	4553	0.34367	0.250465242	5.3342	5.0837	6247.33	1.8507E-07
APPLIED INDUSTRIAL TECH INC	245.9	0.0191	759.615	0.36214	0.274851504	5.3141	5.0393	1000.86	2.3362E-07
CRANE CO	668.902	0.0191	1204.32	0.32428	0.209899809	5.0694	4.8595	1860.57	5.8832E-07
SCHLUMBERGER LTD	13525	0.0191	39469	0.37151	0.278038727	5.1007	4.8227	52738.1	7.083E-07
FLEXSTEEL INDUSTRIES INC	35.502	0.0191	151.237	0.41393	0.33644204	5.1486	4.8122	186.067	7.4639E-07
BABCOCK & WILCOX CO	927.228	0.0191	1164.69	0.30232	0.16974273	4.9415	4.7718	2074.37	9.1305E-07
INGERSOLL-RAND PLC	3408.6	0.0191	7068.9	0.35840	0.243300853	4.9453	4.702	10413	1.2881E-06
BRADY CORP	323.497	0.0191	830.797	0.37104	0.268481191	4.9234	4.6549	1148.17	1.6203E-06
HOLLYFRONTIER CORP	1674.49	0.0191	5999.62	0.41626	0.326781615	4.8673	4.5405	7642.43	2.8061E-06
BOLT TECHNOLOGY CORP	8.398	0.0191	70.709	0.55303	0.49531403	4.8102	4.3149	78.9481	7.9838E-06
MAXIM INTEGRATED PRODUCTS	404.893	0.0191	2508	0.50872	0.439163144	4.75	4.3108	2905.23	8.1329E-06
SCHAWK INC -CL A	73.652	0.0191	250.847	0.43883	0.340694924	4.5664	4.2257	323.106	1.191E-05
CASEYS GENERAL STORES INC	397.748	0.0191	602.295	0.35583	0.215928587	4.4312	4.2153	992.518	1.2473E-05
INTL BUSINESS MACHINES CORP	40154	0.0191	22792	0.29497	0.10811	4.2773	4.1692	62186.3	1.5284E-05
NABORS INDUSTRIES LTD	1311.424	0.0191	6038.27	0.48642	0.400984808	4.5376	4.1367	7324.89	1.7621E-05
ASM INTERNATIONAL NV	139.926	0.0191	1994.16	0.66752	0.624524691	4.7037	4.0792	2131.44	2.2594E-05
ATLANTIC POWER CORP	389.4	0.0191	608.3	0.36987	0.2271927	4.3062	4.079	990.333	2.2615E-05
COHERENT INC	145.828	0.0191	758.518	0.51100	0.429917169	4.4969	4.067	901.587	2.3815E-05
CSR PLC	218.214	0.0191	629.562	0.43930	0.327825553	4.3472	4.0194	843.647	2.9173E-05
ASTEC INDUSTRIES INC	133.531	0.0191	576.876	0.51061	0.416121021	4.2623	3.8461	707.88	5.9996E-05

Company Name	D (X)	R	E0	SE (SigE)	Sv(Sig A)	d1	d2	V0	P (Bankruptcy)
HALLIBURTON CO	5026	0.0191	13581	0.44990	0.330065521	4.1752	3.8451	18511.9	6.0244E-05
II-VI INC	94.434	0.0191	636.108	0.60605	0.529008761	4.1634	3.6344	728.754	0.00013934
BASSETT FURNITURE INDS	51.441	0.0191	157.409	0.48960	0.370744882	4.0037	3.6329	207.876	0.00014012
AZZ INC	118.899	0.0191	333.934	0.48072	0.356284594	3.971	3.6148	450.582	0.00015031
APPLE INC	43658	0.0191	123549	0.48343	0.358994637	3.9694	3.6104	166380	0.00015289
CYBEROPTICS CORP	5.423	0.0191	38.479	0.62088	0.54547309	4.1374	3.5919	43.7993	0.00016412
NATURAL ALTERNATIVES	5.942	0.0191	40.339	0.61659	0.538742708	4.1104	3.5717	46.1685	0.00017733
MARATHON PETROLEUM CORP	9824	0.0191	10920	0.38868	0.206474428	3.773	3.5665	20558.1	0.00018087
PIONEER POWER SOLUTIONS INC	12.345	0.0191	30.792	0.47454	0.340596888	3.8838	3.5432	42.9033	0.00019768
TEXTRON INC	3319	0.0191	4384	0.41036	0.235492039	3.7395	3.504	7640.17	0.00022919
CTS CORP	95.12	0.0191	296.729	0.50909	0.387312215	3.8864	3.4991	390.048	0.00023342
ASTRO-MED INC	9.892	0.0191	66.614	0.63174	0.551424838	4.0156	3.4642	76.3185	0.00026589
APPLIED MATERIALS INC	2443	0.0191	7088	0.50413	0.376762011	3.839	3.4622	9484.73	0.00026789
GENERAL ELECTRIC CO	519777	0.0191	130566	0.30474	0.06213	3.4502	3.3881	640620	0.00035189
FLOWSERVE CORP	1558.099	0.0191	1870.38	0.42253	0.232552745	3.553	3.3204	3398.96	0.00044937
BEL FUSE INC	66.89	0.0191	228.702	0.54904	0.426670761	3.7307	3.304	294.323	0.00047658
SPARTON CORP	56.091	0.0191	95.748	0.46515	0.295442471	3.5593	3.2638	150.776	0.00054959
POWER SOLUTIONS INTL INC	32.385	0.0191	50.421	0.46620	0.286070648	3.4655	3.1794	82.1916	0.0007378
NEWPARK RESOURCES	153.751	0.0191	581.054	0.58504	0.464536485	3.632	3.1675	731.884	0.0007689
CHECKPOINT SYSTEMS INC	177.733	0.0191	346.325	0.49413	0.328739782	3.4921	3.1633	520.685	0.00077991
EMC CORP/MA	11799	0.0191	22301	0.49087	0.32322714	3.4859	3.1627	33876	0.00078163
MOTOROLA SOLUTIONS INC	3220	0.0191	3659	0.44351	0.238118747	3.3503	3.1122	6817.89	0.00092862
EMULEX CORP	71.586	0.0191	587.625	0.72999	0.652124695	3.7566	3.1045	657.846	0.00095299
HYSTER-YALE MATERIALS HNDLNG	609.8	0.0191	449.8	0.40906	0.175652852	3.2795	3.1039	1048.04	0.00095506
HEWLETT-PACKARD CO	45521	0.0191	27269	0.40054	0.151952882	3.2081	3.0561	71927.5	0.00112107
NORTEK INC	449.7	0.0191	99.9	0.37833	0.06996191	2.9519	2.8819	541.075	0.00197644
WEATHERFORD INTERNATIONAL	5699	0.0191	8162	0.50239	0.298400642	3.1675	2.8691	13752.2	0.00205811
SORL AUTO	46.203	0.0191	179.857	0.64717	0.517128432	3.3582	2.8411	225.172	0.00224785

Company Name	D (X)	R	E0	SE (SigE)	Sv(Sig A)	d1	d2	V0	P (Bankruptcy)
PARTS INC									
BRUNSWICK CORP	883.1	0.0191	1038.4	0.48933	0.267056324	3.0827	2.8156	1904.64	0.00243416
EDUCATIONAL DEVELOPMENT CORP	4.449	0.0191	13.452	0.61377	0.463699198	3.265	2.8013	17.8155	0.00254451
XPLORE TECHNOLOGIES CORP	4.689	0.0191	15.522	0.62935	0.485762147	3.2807	2.7949	20.1208	0.00259588
LINEAR TECHNOLOGY CORP	1025.88	0.0191	981.908	0.48153	0.238163204	2.9776	2.7394	1988.17	0.00307739
FORBES ENERGY SERVICES LTD	53.104	0.0191	135.578	0.60711	0.438998061	3.1386	2.6996	187.656	0.0034713
NAVISTAR INTERNATIONAL CORP	4261	0.0191	3645	0.49565	0.23146	28.238	2.5923	7824.03	0.00476683
FORD MOTOR CO	175279	0.0191	26383	0.42521	0.05691	2.5993	2.5424	198057	0.00550534
VIEWTRAN GROUP INC	121.957	0.0191	247.9	0.63214	0.427466009	2.8384	2.411	367.431	0.00795512
U S CONCRETE INC	107.148	0.0191	83.727	0.52737	0.234964461	2.6092	2.3742	188.78	0.00879269
PLEXUS CORP	471.376	0.0191	699.301	0.61640	0.372688931	2.6567	2.284	1161.17	0.01118444
SIGMA DESIGNS INC	42.285	0.0191	158.391	0.78375	0.622820777	2.8352	2.2123	199.775	0.01347152
DYNAMIC MATERIALS CORP	31.192	0.0191	172.792	0.87629	0.746153316	2.9109	2.1648	203.295	0.01520283
CALAMP CORP	28.949	0.0191	117.549	0.82357	0.665479351	2.7914	2.1259	145.857	0.01675435
COMTECH TELECOMMUN	269.091	0.0191	404.062	0.67954	0.414469375	2.4446	2.0301	667.311	0.02117269
CYANOTECH CORP	2.885	0.0191	20.227	0.97116	0.854178075	2.882	2.0278	23.0427	0.02128995
DATA I/O CORP	4.327	0.0191	12.862	0.83831	0.635077964	2.5097	1.8746	17.0812	0.03042145
SMART TECHNOLOGIES INC	151.216	0.0191	61.016	0.59255	0.17668	2.0299	1.8532	209.064	0.03192828
COBRA ELECTRONICS CORP	33.62	0.0191	39.909	0.72114	0.401857162	2.168	1.7662	72.7135	0.03868253
LILIS ENERGY INC	3.631	0.0191	12.082	0.96771	0.757382318	2.328	1.5706	15.5925	0.05813517
MITEK SYSTEMS INC	5.818	0.0191	25.729	1.10625	0.919068511	2.311	1.3919	31.295	0.0819747
TECH DATA CORP	4617.588	0.0191	2098.61	0.46411	0.25225	1.2078	0.9556	4355.89	0.16963718
WHIRLPOOL CORP	6794	0.0191	4924	0.37358	0.22443	1.0909	0.8665	9504.72	0.19310801
NF ENERGY SAVING CORP	10.811	0.0191	31.865	1.35084	1.076097724	1.8052	0.7291	41.4737	0.23296333
SAEXPLORATI	40.986	0.0191	10.893	1.16451	0.348139006	0.6939	0.3458	48.1881	0.36475281

Company Name	D (X)	R	E0	SE (SigE)	Sv(Sig A)	d1	d2	V0	P (Bankruptcy)
ON HOLDINGS INC									
CROWN HOLDINGS INC	2920	0.0191	4	0.51260	0.17865427	-2.4841	-2.6628	1767.35	0.99612488

Appendix B Samples

Table 7: Samples 1, 2,3,4,5 and 6

Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6
HAL	GE	MPC	SEMG	WFT	BGG
CUO	NFEC	BELFA	LLEX	BC	SAEX
PLXS	CSRE	ASMI	BWC	PSIX	HFC
AAPL	EMC	CW	GGG	HII	NFEC
CYAN	CKP	WHR	DAIO	BELFA	IIVI
			GD	COHR	GGG
			SIGM	SMT	XPLR
			MXIM	CTS	EMC
			EMC	LLTC	HPQ
			AIT	SGK	AZZ

Table 8: Samples 7, 8,9,10,11 and 12

Sample 7	Sample 8	Sample 9	Sample 10	Sample 11	Sample 12
SEMG	EQT	MUR	PSX	BGG	HAL
VET	PSIX	BOLT	NBR	AT	BGG
SAEX	XOM	BC	BGG	LLEX	EQT
XOM	LLEX	AT	HAL	EMR	SLB
PSX	BWC	PSX	GE	SLB	GE
BC	HFC	EQT	MPC	EQT	BC
GE	HY	HAL	EQT	XOM	CVX
EQT	SPLP	SORL	BWC	SAEX	BWC
LLEX	GD	CR	HFC	HES	WFT
SLB	HUBA	USCR	SLB	PSX	MUR
MUR	CYBE	CYBE	MUR	HAL	NBR
PSIX	BELFA	IR	EMR	MPC	AT
WFT	FLS	FLS	XOM	HFC	HES
HUBA	CTS	ESP	SPLP	SPLP	NFEC
BOOM	SPA	COBR	COHR	VIEW	HII
IIVI	AAPL	CSRE	FLS	IIVI	ESP
VIEW	ELX	AAPL	ESP	HY	IIVI
COHR	IBM	TECD	F	COHR	USCR
HII	ASMI	MITK	GGG	CUO	RTN
SORL	FELE	XPLR	SORL	UTX	BOOM
ASTE	SGK	NTK	CR	FLS	CR
GD	KMB	ASH	USCR	BELFA	SORL
IR	CCK	WHR	VIEW	HII	ASTE
USCR	AIT	SGK	CUO	USCR	COHR
ESP	EDUC	PPSI	HII	NAV	VIEW
			HY	HUBA	F
			ETN	EMC	CTS
			SIGM	CMTL	CSRE
			TECD	TECD	LLTC
			MSI	XPLR	HPQ
			HPQ	COBR	IBM

Sample 7	Sample 8	Sample 9	Sample 10	Sample 11	Sample 12
			LLTC	ELX	EMC
			CSRE	MSI	SMT
			CW	HPQ	MXIM
			PLXS	PKE	PLXS
			EMC	AMAT	SIGM
			SMT	SPA	CMTL
			MXIM	MITK	PKE
			ALOT	AAPL	SPA
			EDUC	CCK	SGK
			NTK	FLXS	NTK
			BRC	CST	BRC
			ASH	NAII	FLXS
			KMB	EDUC	AZZ
			NAII	PPSI	PPSI
			CASY	CYAN	KMB
			FELE	KMB	BSET
			PPSI	BSET	CST
			CCK	NTK	EDUC
			CKP	WHR	AIT

Appendix C Probability Tables

Table 9: Probability of number of companies going to bankruptcy for samples 1,2 and 3

Number of companies going to bankruptcy	Probability of Bankruptcy for Sample 1	Number of companies going to bankruptcy	Probability of Bankruptcy for Sample 2	Number of companies going to bankruptcy for Sample 3	Probability
0	0.967557445	0	0.76554755	P0	0.80634335
1	0.032197609	1	0.23399925	P1	0.19352527
2	0.000244894	2	0.00045292	P2	0.00013136
3	5.1047E-08	3	2.8305E-07	P3	1.9515E-08
4	2.19457E-12	4	5.7851E-11	P4	3.7609E-13
5	0	5	1.458E-15	P5	0

Table 10: Probability of number of companies going to bankruptcy for samples 4,5 and 6

Number of companies going to bankruptcy	Probability of Bankruptcy for Sample 4	Number of companies going to bankruptcy	Probability of Bankruptcy for Sample 5	Number of companies going to bankruptcy	Probability of Bankruptcy for Sample 6
0	0.900196983	0	0.95933731	0	0.48492685
1	0.096813038	1	0.04034494	1	0.4280492
2	0.002963867	2	0.00031672	2	0.08661438
3	0.000026093	3	1.0241E-06	3	0.00040896
4	1.89E-08	4	1.6E-09	4	6.0855E-07
5	0	5	0	5	3.463E-10
6	0	6	0	6	1E-13
7	0	7	0	7	0
8	0	8	0	8	0
9	0	9	0	9	0
10	0	10	0	10	0

Table 11: Probability of number of companies going to bankruptcy for samples 7,8 and 9

Number of companies going to bankruptcy	Probability of Bankruptcy for Sample 7	Number of companies going to bankruptcy	Probability of Bankruptcy for Sample 8	Number of companies going to bankruptcy	Probability of Bankruptcy for Sample 9
0	0.57474096	0	0.00345084	0	0.62371402
1	0.38870427	1	0.88729925	1	0.36948505
2	0.05003456	2	0.11317559	2	0.00313854
3	0.00086165	3	0.00010112	3	0.00030856
4	0.00001311	4	5.619E-07	4	2.4613E-05
5	0.0000001	5	0	5	7.3118E-07
6	0	6	0	6	1.0753E-08
7	0	7	0	7	0
8	0	8	0	8	0
9	0	9	0	9	0
10	0	10	0	10	0
11	0	11	0	11	0
12	0	12	0	12	0
13	0	13	0	13	0
14	0	14	0	14	0
15	0	15	0	15	0
16	0	16	0	16	0
17	0	17	0	17	0
18	0	18	0	18	0
19	0	19	0	19	0
20	0	20	0	20	0
21	0	21	0	21	0
22	0	22	0	22	0
23	0	23	0	23	0
24	0	24	0	24	0
25	0	25	0	25	0

Table 12: Probability of number of companies going to bankruptcy for samples 10,11 and 12

Number of companies going to bankruptcy	Probability of Bankruptcy for sample 10	Number of companies going to bankruptcy	Probability of Bankruptcy for sample 11	Number of companies going to bankruptcy	Probability of Bankruptcy for sample 12
0	0.003522614	0	0.0010307	0	0.6928937
1	0.906573096	1	0.26627648	1	0.30445385
2	0.002782723	2	0.67558832	2	0.00230786
3	0.009071072	3	0.0202587	3	0.00030501
4	0.000667807	4	0.0085134	4	7.6375E-06
5	2.17831E-05	5	0.0016408	5	1.6536E-07
6	3.9759E-07	6	0.00017795	6	0
7	0	7	1.0807E-05	7	0
8	0.021314518	8	3.8249E-07	8	0
9	0.015173386	9	0.00994912	9	4.2652E-05
10	0.010801639	10	0.00622069	10	1.45E-05
11	0.007689482	11	0.00388949	11	4.9297E-06
12	0.005473988	12	0.00243191	12	1.6742E-06
13	0.003896831	13	0.00152056	13	5.6842E-07
14	0.002774072	14	0.00095073	14	1.9636E-07
15	0.001974807	15	0.00059444	15	6.2009E-08
16	0.001405831	16	0.00037168	16	2.067E-08
17	0.001000783	17	0.00023239	17	1.0335E-08
18	0.000712434	18	0.0001453	18	0
19	0.000507169	19	9.0853E-05	19	0
20	0.000361048	20	5.6803E-05	20	0
21	0.000257024	21	3.5514E-05	21	0
22	0.000182964	22	2.2209E-05	22	0

Number of companies going to bankruptcy	Probability of Bankruptcy for sample 10	Number of companies going to bankruptcy	Probability of Bankruptcy for sample 11	Number of companies going to bankruptcy	Probability of Bankruptcy for sample 12
23	0.000130253	23	1.3883E-05	23	0
24	9.27229E-05	24	8.6833E-06	24	0
25	6.6012E-05	25	5.4281E-06	25	0
26	4.6988E-05	26	3.3936E-06	26	0
27	3.34458E-05	27	2.124E-06	27	0
28	2.38193E-05	28	1.3265E-06	28	0
29	1.69518E-05	29	8.3008E-07	29	0
30	1.20723E-05	30	5.2083E-07	30	0
31	8.59036E-06	31	3.2552E-07	31	0
32	6.12048E-06	32	2.0345E-07	32	0
33	4.3494E-06	33	1.3021E-07	33	0
34	3.09639E-06	34	8.138E-08	34	0
35	2.20482E-06	35	4.8828E-08	35	0
36	1.56627E-06	36	3.2552E-08	36	0
37	1.12048E-06	37	1.6276E-08	37	0
38	7.95181E-07	38	8.138E-09	38	0
39	5.66265E-07	39	8.138E-09	39	0
40	3.9759E-07	40	8.138E-09	40	0
41	2.89157E-07	41	0	41	0
42	2.04819E-07	42	0	42	0
43	1.44578E-07	43	0	43	0
44	1.08434E-07	44	0	44	0
45	7.22892E-08	45	0	45	0
46	4.81928E-08	46	0	46	0
47	3.61446E-08	47	0	47	0
48	2.40964E-08	48	0	48	0
49	2.40964E-08	49	0	49	0
50	1.20482E-08	50	0	50	0