A SUPPLY CHAIN FINANCIAL MANAGEMENT INSURANCE MODEL FOR THE PROTECTION OF CORPORATIONS AGAINST THE BANKRUPTCY OF SUPPLIERS BY USING THE BLACK-SCHOLES-MERTON MODEL

By

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ABSTRACT

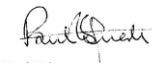
Many banks provide supply-chain finance solutions that might include insurance services that further mitigate trade risk such as the default of suppliers. This study proposes the development of an insurance model that uses the Black-Scholes-Merton Model (BSM) (1973) for default prediction and risk pooling 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 CRSP database (Center for Research in Security Prices) is collected in order to calculate the probability of bankruptcy of a sample of suppliers from different industries by using the BSM model. Twelve pools of companies of different sizes are created and a VBA program for Excel is developed in order to calculate probability of bankruptcy tables of companies belonging to the different pools. 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. The expected losses for a risk pool can be used by a financial institution in order to price an insurance contract that hedges a company against the risk of default of suppliers.

DECLARATION

I hereby certify that this dissertation constitutes my own product, that where the language of others is set forth, quotation marks so indicate, and that appropriate credit is given where I have used the language, ideas, expressions, or writings of another.

I declare that the dissertation describes original work that has not previously been presented for the award of any other degree of any institution.

Signed,



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Chapter 1. INTRODUCTION

Many banks provide supply-chain finance solutions that might include insurance services that further mitigate trade risk (see figure 1). A supply chain financial management insurance is a possible way to hedge a company against the risk of bankruptcy of suppliers. Although there is a need to offer suppliers default insurance as it is currently offered by institutions such as Zurich Insurance (Manmohan 2012), there is still little attention from academia for the development of an insurance model that can be used by institutions to offer this instrument that can protect against supplier's bankruptcy risk. This study proposes the development of an insurance model with the help of bankruptcy models and risk pooling management techniques. The model makes use of pooling arrangements and the Black-Scholes-Merton (1973), herewith referred to as 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.

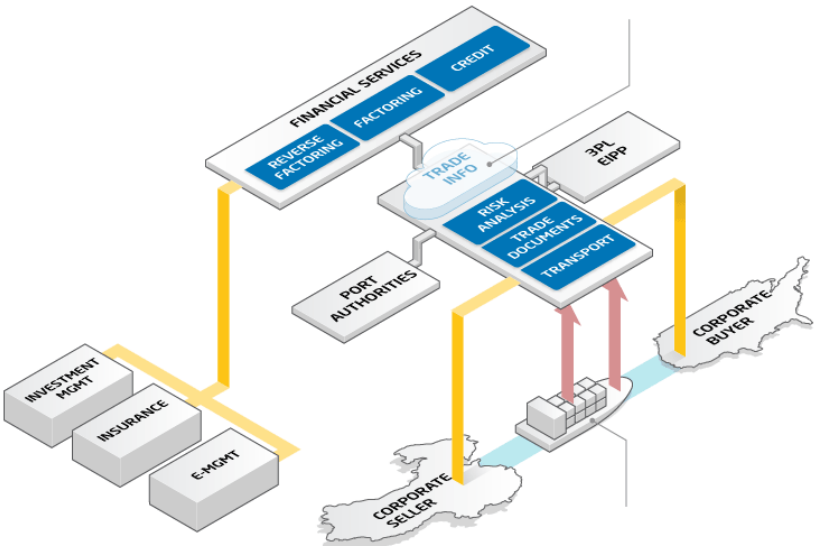

Figure 1 Supply Chain Financial Services

1.1 Approach

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 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. 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:

i) Can the propose supply chain risk management insurance model reduce the risk of bankruptcy of suppliers in a corporate setting?

ii) Is the model appropriate to calculate an insurance premium that could be used to implement the insurance model by insurance and financial institutions?

Chapter 2. BACKGROUND AND REVIEW OF LITERATURE

2.1 Background

In this chapter, a review of supply chain finance literature is conducted in order to understand better the application of finance and accounting concepts in the offering of financial services for supply chain such as insurance services. Risk management for Supply Chain will help to understand the critical risk management issues that affect supply chains. The discussion of the Credit Analysis literature will help to understand the different techniques used by banks to estimate default probabilities of institutions that can help us to feed risk management models that can be used to offer insurance services for the supply chain. Risk pooling literature will help to understand how this concept can be used to develop insurance services in the supply chain services industry. Finally, literature on Monte Carlo analysis will help us to understand how this technique can be used to validate the model and estimate losses that can be used to valuate insurance premiums, estimate maximum losses and risk estimates. The literature is divided in multiple themes including Supply Chain Finance, Risk Management in Supply Chain and Credit Risk Management.

2.2 Supply Chain Finance

Companies are increasingly forming global supply chains and favouring global sourcing practices to lower the purchase prices (Valverde & Saade 2015)(Valverde 2012). 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)(Khan & Valverde 2014); this has originated the concept of Supply Chain Finance (SCF). There are several definitions of SCF. According to Killen and Associates (2002), SCF repre-

sents 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, 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 (Zsidisin 2010).

In the next section, financial risk management in the SCM will be discussed.

2.3 Risk Management in Supply Chain

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 (Kraus & Valverde 2014). Supply Chain Risk Management (SCRM) includes strategies to manage risks along the supply chain (Shi 2004)(Stephens & Valverde 2013). 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.

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) (Valverde & Talla 2013). 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 (Milne, 2010; Wagner et al, 2004).

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 (Manmohan 2012). 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 (Manmohan 2012).

In the next section, Credit Risk Management techniques will be discussed to understand the different mechanisms that a bank can use in order to determine default probabilities that can be used in the development of insurance services.

2.4 Credit Risk Management

Credit risk arises from the possibility that borrowers, bond issuers, and counterparties in derivatives transactions may default (Hull 2012) (Valverde 2011). Typi-

cally it is measured by credit ratings, but most banks have their own internal ratings systems for borrowers. There are several techniques for Credit-risk analysis including credit ratings and mathematical models such as the Z-Score (Altman 2000) and Black-Scholes-Merton (BSM) model (Black & Scholes1973).

2.4.1 Credit Ratings

One of the rating agencies' objectives is ratings stability. Rating agencies want to avoid ratings reversals whereby a firm is downgraded and then upgraded a few weeks later. Ratings therefore change only when there is reason to believe that a long-term change in the firm's creditworthiness has taken place. The reason for this is that bond traders are the major users of ratings. Often they are subject to rules governing what the credit ratings of the bonds they hold must be. If these ratings changed frequently they might have to do a large amount of trading just to satisfy the rules. Rating agencies try to 'rate through the cycle'. Suppose that an economic downturn increases the probability of a firm defaulting in the next 6 months, but makes very little difference to the firm's cumulative probability of defaulting over the next three to five years. A rating agency would not change the firm's rating (Hull 2012).

Most banks have internal credit ratings that assess the creditworthiness of their corporate and retail clients. The internal ratings based (IRB) approach in Basel II allows bank to use their internal ratings in determining the probability of default, PD. Under the advanced IRB approach, they are also allowed to estimate the loss given default, LGD, the exposure at default, EAD, and the maturity, M (Hull 2012).

2.4.2 Altman's Z-score

The Altman's Z-score uses a discriminant analysis that attempts to predict defaults from five accounting ratios.

$$Z\text{-Score} = 1.2A + 1.4B + 3.3C + 0.6D + 1.0E \quad (1)$$

where:

A = Working Capital/Total Assets

B = Retained Earnings/Total Assets

C = Earnings Before Interest & Tax/Total Assets

D = Market Value of Equity/Total Liabilities

E = Sales/Total Assets

All variables are scaled by total assets, except for market value of equity, which is scaled by book value of total liabilities. If Z-score > 3, the firm is unlikely to default. If it is between 2.7 and 3.0, we should be 'on alert'. If it is between 1.8 and 2.7, there is a good chance of default. If it is less than 1.8, then the probability of a financial embarrassment is very high (Altman 2000).

A paper published by (Grice & Ingram, 2001), explored the generalizability of Altman's Z-score model in modern times. The authors claim that the model is designed for old style parameters and firm characteristics, so it is not so useful for bankruptcy prediction of contemporary firms, but it can be still useful for predicting financial stress conditions. The authors also argue that the model does not account for non-financial events, this is a limitation of the model as it does not capture all events that may cause bankruptcy (Grice & Ingram, 2001).

2.4.3 Black-Sholes-Merton model

A model that is used to ensure that an instrument is priced consistently with the observed market prices of other similar instruments is the Black-Scholes-Merton model (BSM) (Hull 2012). The BSM option pricing model (Black & Scholes1973) can be used to estimate the probability of bankruptcy of suppliers by extracting and examining the riskiness in the stock market price of suppliers. The model assumes: maturity of liabilities equals one year; the dividend rate is based on the sum of common dividends, preferred dividends, and interest expense; call option equation has been modified to account for the fact that shareholders receive common dividends (Black & Scholes1973). Merton (1974) mathematically developed the options pricing model for the valuation of derivatives that lead to the generation of new types of financial instruments and facilitated more efficient risk management in society,

The basic idea for estimating the probability of a supplier company bankruptcy is to recognize the stock price movement pattern of the supplier company, and evaluate historic events information, which is available to the public via company press meets, market focus, and so on. The procedure for extracting such information was developed by Hillegeist et al (2004).

According to option-pricing theories (Black & Scholes1973), a market-based measure, that is called Black-Sholes-Model probability of bankruptcy (BSM-PB), should use all available information about the probability of bankruptcy. The BSM-PB contains relatively more information than just the Score variables used traditionally for bankruptcy prediction; however the accounting measures will not be incrementally informative to BSM-PB. Hillegeist et al (2004) tested the validity of these implications using a large sample consisting of 65,960 firm-year observations including 516 bankruptcies during the period 1979-1997. They found that

BSM-PB has relatively more explanatory power than either of the two scores, even when the scores are decomposed to reflect industry differences or annual changes.

The model assumes that volatility is a crucial variable in bankruptcy prediction since it captures the likelihood that the value of a firm's assets will decline to such an extent that the firm will be unable to repay its debts. Equity can be viewed as a call option on the value of the firm's assets. The strike price of the call option is equal to the face value of the firm's liabilities and the option expires at time T when the debt matures.

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2.4.4 Comparison between different credit analysis methods

Although the Z-Score model seems to be quite simple to calculate and interpret, Hillegeist et al (2004) recommends the use of the BSM for default probability calculations mainly because it provides relatively more information than just the score variables used traditionally for bankruptcy prediction with Z-Score model. However, the main weakness of the BSM is that it relies on stock market information that might not be available for all the companies (in the particular case of this research, this means the suppliers that are part of a supply chain). The other weakness is its complexity; the calculation of BSM requires a strong finance theory background that might not be part of the profile of a typical supply chain manager. Also, the accounting measures will not be incrementally informative to BSM model as it is with the Z-Score model.

On the other hand, Z-Score values can be calculated for any company that is willing to disclose financial statements even if these are not public. However, the Z-Score value is not a probability itself but just a score value that can determine

the likelihood that a company will go bankrupt but it does not generate a probability number and therefore cannot be used to prepare a probability distribution used for insurance purposes.

Credit ratings used by banks are mainly classification systems that can help a bank manager to easily determine the interest rates of a loan without complex calculations. However, they do not allow to determine probabilities that can be used to determine probability distributions required to implement insurance services.

From the three options reviewed, the BSM is the model that best serves the purpose to implement insurance services models. The next section examines the concept of risk pooling in insurance services.

2.4.5 Risk Pooling for Risk Management

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 (McDonald et al. 2006). A risk pool is one of the forms of risk management practiced in insurance.

Correlation analysis is very important in pooling arrangements. A positive correlation in losses is less desirable than null correlation (uncorrelated losses) in the context of risk management. While a positive correlation in losses reduces the extent to which risk pooling lowers the standard deviation of losses, null correlation in losses increase it.

The concept of pooling losses has been used in supply chain (Levi et al. 2003) for inventory management. Risk pooling suggests that demand variability is reduced

if demand is aggregated across locations because as demand is aggregated across different locations, it becomes more likely that low demand from one customer will be offset by high demand from another. This reduction in variability leads to a decrease in safety stock and therefore reduces average inventory. This suggests that the use of centralized warehouses would be able to reduce inventory costs as it reduces safety stock but this benefit will decrease as the correlation between demand of two different locations demanding inventory becomes positive (Levi et al. 2003).

In general, risk pooling has a number of advantages when it comes to risk management. Losses become more predictable, the maximum probable loss declines, and the distribution of costs becomes more symmetric. The predictability increases with the number of participants and decreases with correlation in losses.

In the case of insurance, this means that the more insurance policies are sold by a bank or insurance company the more predictable the expected losses will be and the lower the probability of extreme losses will be. However, insurance companies and banks should be aware that losses events should have low correlation for the pooling arrangements to work this way. Risk pooling can be used to generate the probability distributions that in combination with other mathematical methods such as Monte Carlo analysis can be used to simulate scenarios for different number of insurance contracts and estimate risk and average losses. Monte Carlo analysis is covered in more detail in the next section.

2.4.6 Losses estimation via Monte carlo analysis

Monte Carlo analysis is a technique that is used in Finance in order to simulate losses in financial risk management (Hull 2012). The idea of Monte Carlo simula-

tions is to generate random numbers in order to model the stochastic behavior of an input parameter. Each different sequence of random numbers causes another result.

Given a probability distribution of losses, Monte Carlo analysis can be used to estimate the average, total and variance of the losses after a determined number of events. The analysis can be quite useful to estimate premiums and risk for insurance services (Korn et al 2010). In the case of insurance, Monte Carlo analysis can be used to estimate the total, variance and average losses given a number of policies sold. Monte Carlo analysis only requires a probability or frequency distribution that can be sampled from historical data or calculated based on mathematical models such as the BSM Model.

Monte Carlo simulations have a successful history of providing reliable results for supply chain risk management and finance. Deleris et al (2004) uses Monte Carlo simulations to estimate the probability distribution of supply chain losses caused by disruptions. Cohen and Huchzermeier (1999) use Monte Carlo simulations to produce accurate estimates of the firm's downside risk exposure to price/foreign exchange rate risk in the supply chain. Grittner and Valverde (2012) use 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) use 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) simulate the operations of the supply chain, interactions with a bank and the bank behaviour for inventory financing model for supply chain risk management.

Given the amount of random variables in the supply chain financial risk management field, Monte Carlo analysis is a justifiable research tool as it is capable of handling situations with a certain degree of uncertainty as long as the behaviour can be modeled with a probability distribution.

2.5 Summary

From this literature review several lessons and concepts can be learned. First, the extant literature supports an increasing use of financial theory in supply chain management. Several companies around the world are offering financial services for supply chain management including insurance services. This serves as a justification of this research as the proposed research intends to use financial risk management theory to solve a supply chain problem that is the losses caused by bankruptcy of suppliers.

In this chapter, risk management issues in supply chain management were reviewed including the risk of bankruptcy of suppliers that is the main focus of this study. Different credit analysis mechanisms were reviewed and the Black-Scholes-Merton model was justified for this study mainly because it fits the best the development of an insurance model that could be easily created with available public stock market data. Risk pooling in insurance was reviewed as the main tool to reduce risk by selling a large number of insurance contracts and by helping in the estimation of insurance premiums. Monte Carlo analysis principles were reviewed and justified as a good option for this research given that the existent literature provides evidence of good results in finance and supply chain management research.

In general, this literature review helped to identify the need for an insurance model for supply chain management that, for this study, is concentrated mainly

on the risk of bankruptcy of suppliers but that can be extended in the future to other types of risks. The literature review also provided the necessary theoretical background to perform this study.

Chapter 3. RESEARCH METHODOLOGY AND RESEARCH DESIGN

This chapter 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.

3.1 Research questions

The research questions of this research are:

i) Can the proposed supply chain risk management insurance model reduce the risk of bankruptcy of suppliers in a corporate setting?

ii) Is the proposed model appropriate to calculate an insurance premium and risk that can be used by insurance and financial institutions to implement the insurance model?

3.2 Data collection

The research will use the Black-Scholes-Merton (BSM) 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.

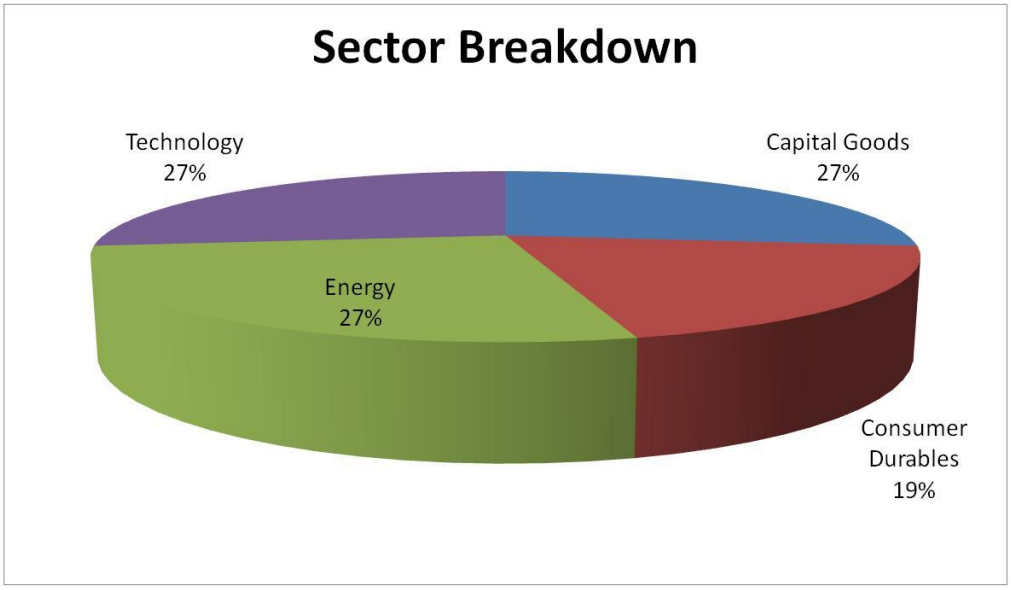


Figure 2 Sector Breakdown

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.

3.3 Treasury Bills Free rate

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-year-lookup/) 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

3.4 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:

$$E_0 = V_0 N(d_1) - De^{-rT} N(d_2) \quad (2)$$

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

$$d_1 = \frac{\ln(V_0/D) + (r + \sigma_V^2/2)T}{\sigma_V \sqrt{T}}; d_2 = d_1 - \sigma_V \sqrt{T} \quad (3)$$

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

$$\sigma_E E_0 = \frac{\partial E}{\partial V}\sigma_V V_0 = N(d_1)\sigma_V V_0 \tag{4}$$

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 (Black & Scholes1973), the probability that V_0 (T) < D or probability of bankruptcy can be calculated as indicated in equation 5(Hull 2012):

$$N(-d2) \tag{5}$$

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 2, 3 and 4.

Finally, the value of d_2 is used to calculate the probability of bankruptcy for each firm-year via equation 5 by using the standard normal distribution of $-d_2$.

3.5 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 (McDonald 2006).

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 (Simchi-Levi, 2009). 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 (Simchi-Levi, 2009).

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 6:

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

$$P(0) = \prod_{i=1}^{i=x} (1 - Pi) \tag{6}$$

The probability of a given number of bankruptcies to occur (n) for a given possible set of companies (x) is described in equation 7:

$$P(n) = P(0) \sum_{i1,i2.....in \in S, ik \;\; distinct} \frac{Pi_1 Pi_2 Pi_3 .....P_n}{(1-P_1)(1-P_2)(1-P_3).....(1-P_n)} \tag{7}$$

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

For example, let us assume that we have 3 companies with a probability of bankruptcy for company 1 of 0.01, company 2 of 0.02 and company 3 of 0.015. The probabilities of 0, 1, 2 and 3 bankruptcies are calculated as follows:

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

$$P(0) = (1-.01)(1-.02)(1-.015) = 0.955647$$

$$P(1) = 0.955647x\left(\frac{0.01}{1-0.01} + \frac{0.02}{1-0.02} + \frac{0.015}{1-0.015}\right) = 0.043709$$

$$P(2) = 0.955647x\left(\frac{(0.01)(0.02)}{(1-0.01)(1-.02)} + \frac{(0.02)(0.015)}{(1-0.02)(1-0.015)} + \frac{(0.01)(0.015)}{(1-0.01)x(1-0.015)}\right) = 0.000641$$

$$P(3) = 0.955647x\left(\frac{(0.01)(0.02)(0.015)}{(1-0.01)(1-0.02)(1-0.015)}\right) = 0.000003$$

3.6 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 pro-

duce accurate estimates of a firm's downside risk exposure to price/foreign exchange risk in the supply chain.

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.

3.7 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.

3.8 Summary

This chapter has outlined the research design and methodologies that will be used for this dissertation. First, a sample of 100 companies is used to collect data from the CRSP database that is used to calculate the probability of bankruptcy of suppliers. Risk pooling is then used to create an insurance instrument that can be

used to insure companies against supplier bankruptcy. A Monte Carlo simulation is used to calculate expected losses and risk for pools of companies of different sizes with the intention to show how this tool can be used to calculate expected losses and risk that can be useful to estimate insurance premiums.

Chapter 4. RESULTS AND DISCUSSION

4.1 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 1 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 1. 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
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 SORL	0.00205811
EXXON MOBIL CORP	2.5359E-12	NABORS INDUSTRIES LTD	1.7621E-05	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 TECHNOLOGIE	5.5154E-08	MARATHON PETROLEUM	0.00018087	CALAMP CORP	0.01675435

S CORP		CORP			
		PIONEER			
		POWER		COMTECH	
EMERSON		SOLUTIONS		TELECOMM	
ELECTRIC CO	8.1206E-08	INC	0.00019768	UN	0.02117269
BRIGGS &				CYANOTEC	
STRATTON	9.6283E-08	TEXTRON INC	0.00022919	H CORP	0.02128995
RAYTHEON				DATA I/O	
CO	1.0235E-07	CTS CORP	0.00023342	CORP	0.03042145
FRANKLIN				SMART	
ELECTRIC CO		ASTRO-MED		TECHNOLO	
INC	1.0697E-07	INC	0.00026589	GIES INC	0.03192828
		APPLIED		COBRA	
		MATERIALS		ELECTRONI	
PHILLIPS 66	1.4021E-07	INC	0.00026789	CS CORP	0.03868253
				LILIS	
		GENERAL		ENERGY	
ASHLAND INC	1.8507E-07	ELECTRIC CO	0.00035189	INC	0.05813517
APPLIED				MITEK	
INDUSTRIAL		FLOWSERVE		SYSTEMS	
TECH INC	2.3362E-07	CORP	0.00044937	INC	0.0819747
				TECH DATA	
CRANE CO	5.8832E-07	BEL FUSE INC	0.00047658	CORP	0.16963718
SCHLUMBERG		SPARTON		WHIRLPOO	
ER LTD	7.083E-07	CORP	0.00054959	L CORP	0.19310801
				NF	
FLEXSTEEL		POWER		ENERGY	
INDUSTRIES		SOLUTIONS		SAVING	
INC	7.4639E-07	INTL INC	0.0007378	CORP	0.23296333
				SAEXPLOR	
BABCOCK &				ATION	
WILCOX CO	9.1305E-07	NEWPARK		HOLDINGS	
		RESOURCES	0.0007689	INC	0.36475281
				CROWN	
				HOLDINGS	
				INC	
					0.99612488

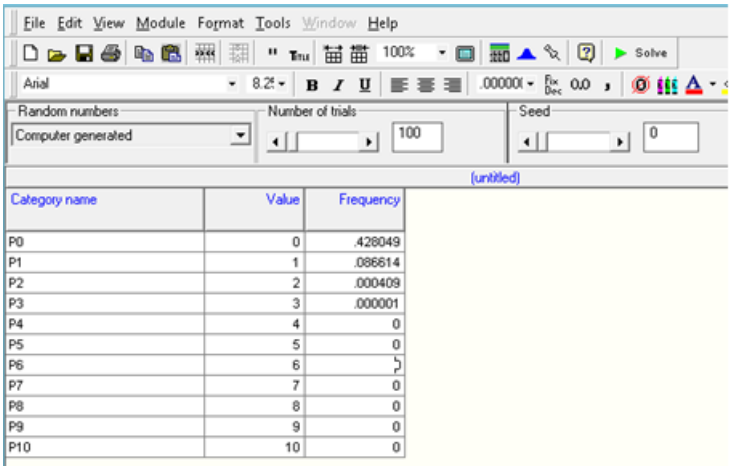
4.2 Risk Pools

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 (Appendix D), 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 19, 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 bank-

ruptcy 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.

4.3 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 Table 24 in Appendix C, this table contains the probabilities of losses for a risk pooling arrangement of 10 companies for sample 6. 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.



Category name	Value	Frequency
P0	0	.428049
P1	1	.086614
P2	2	.000409
P3	3	.000001
P4	4	0
P5	5	0
P6	6	0
P7	7	0
P8	8	0
P9	9	0
P10	10	0

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
	1	**$ 3,700.00**	**$ 4,050.00**	**$ 4,060.00**	**$ 4,235.00**
5	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**
	4	**$ 5,100.00**	**$ 5,450.00**	**$ 4,960.00**	**$ 4,855.00**
10	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**
	7	**$ 23,900.00**	**$ 24,350.00**	**$ 23,750.00**	**$ 23,995.00**
25	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**
	10	**$ 77,300.00**	**$ 85,150.00**	**$ 80,620.00**	**$ 80,915.00**
50	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.

4.4 Summary

For this study, first the BSM probability of bankruptcy was calculated for 100 companies randomly selected for different industries. 12 different risk pools of 5, 10, 25 and 50 companies were formed and tables with the probabilities that suppliers will go bankrupt in a year were calculated and used for the Monte Carlo insurance simulation. The simulation was able to show the expected risk reduc-

tion given a number of insurance policies sold and the expected losses for an insurance contract.

Chapter 5. CONCLUSIONS

5.1 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.

5.2 Limitation 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.

5.3 Future research

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 com-

pute 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.

5.4 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 insur-

ance 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.

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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 ELECTROCHEMICAL 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
CONTINENTAL 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 TECHNOLOGIES CORP	22800	0.0191	31866	0.27995	0.164487524	5.4734	5.3089	54234.7	5.5154E-08
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
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 PARTS INC	46.203	0.0191	179.857	0.64717	0.517128432	3.3582	2.8411	225.172	0.00224785
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	53.104	0.0191	135.578	0.60711	0.438998061	3.1386	2.6996	187.656	0.0034713

SERVICES LTD									
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
SAEXPLORATION HOLDINGS INC	40.986	0.0191	10.893	1.16451	0.348139006	0.6939	0.3458	48.1881	0.36475281
CROWN HOLDINGS INC	2920	0.0191	4	0.51260	0.17865427	2.4841	-2.6628	1767.35	0.99612488

Appendix B. SAMPLES

Table 7 Sample 1 (5 companies)

Sample	Name		Industry	BSM Prob
HAL	HALLIBURTON CO		Oilfield Services/Equipment	6.024E-05
CUO	CONTINENTAL MATERIALS CORP	Capital Goods	Building Products	2.746E-08
PLXS	PLEXUS CORP	Technology	Electrical Products	0.0111844
AAPL	APPLE INC	Technology	Computer Manufacturing	0.0001529
CYAN	CYANOTECH CORP	Consumer Durables	Specialty Chemicals	0.02129

Table 8 Sample 2 (5 companies)

Sample	Name	Sector	Industry	BSM Prob
GE	GENERAL ELECTRIC CO	Energy	consumer electronics/appliances	0.000351893
NFEC	NF ENERGY SAVING CORP	Capital Goods	Metal Fabrications	0.232963334
CSRE	CSR PLC	Technology	Semiconductors	2.91733E-05
EMC	EMC CORP/MA	Technology	Electronic Components	0.000781629
CKP	CHECKPOINT SYSTEMS INC	Consumer Durables	Telecommunications Equipment	0.000779913

Table 9 Sample 3 (5 Companies)

Sample	Name	Sector	Industry	BSM Prob
MPC	MARATHON PETROLEUM CORP	Energy	Integrated Oil Companies	0.000180867
BELFA	BEL FUSE INC	Capital Goods	Electric Products	0.000476585
ASMI	ASM INTERNATIONAL NV	Technology	Industrial Machinery/Components	2.25936E-05
CW	CURTISS-WRIGHT CORP	Technology	Industrial Machinery/Components	3.7446E-11
WHR	WHIRLPOOL CORP	Consumer Durables	consumer electronics/appliances	0.193108013

Table 10 Sample 4 (10 companies)

Sample	Name	Sector	Industry	BSM Prob
SEMG	SEMGROUP CORP	Energy	Oilfield Services/Equipment	4.1448E-08
LLEX	LILIS ENERGY INC	Energy	Oil & Gas Production	0.058135171
BWC	BABCOCK & WILCOX CO	Energy	Industrial Machinery/Components	9.13046E-07
GGG	GRACO INC	Capital Goods	Fluid Controls	4.37737E-10
DAIO	DATA I/O CORP	Capital Goods	Electric Products	0.030421446
GD	GENERAL DYNAMICS CORP	Capital Goods	Marine Transportation	3.40363E-08
SIGM	SIGMA DESIGNS INC	Technology	Semiconductors	0.013471524
MXIM	MAXIM INTEGRATED PRODUCTS	Technology	Semiconductors	8.13295E-06
EMC	EMC CORP/MA	Technology	Electronic Components	0.000781629
AIT	APPLIED INDUSTRIAL TECH INC	Consumer Durables	Industrial Specialties	2.33623E-07

Table 11 Sample 5 (10 companies)

Sample	Name	Sector	Industry	BSM Prob
WFT	WEATHERFORD INTERNATIONAL	Energy	Oil & Gas Production	0.002058
BC	BRUNSWICK CORP	Energy	Industrial Machinery/Components	0.002434
PSIX	POWER SOLUTIONS INTL INC	Energy	Industrial Machinery/Components	0.000738
HII	HUNTINGTON INGALLS IND INC	Capital Goods	Marine Transportation	6.03E-09
BELFA	BEL FUSE INC	Capital Goods	Electric Products	0.000477
COHR	COHERENT INC	Capital Goods	Biotechnology: Laboratory Analytical Instruments	2.38E-05

SMT	SMART TECHNOLOGIES INC	Technology	Computer Peripheral Equipment	0.031928
CTS	CTS CORP	Technology	Electrical Products	0.000233
LLTC	LINEAR TECHNOLOGY CORP	Technology	Semiconductors	0.003077
SGK	SCHAWK INC -CL A	Consumer Durables	Containers/Packaging	1.19E-05

Table 12 Sample 6 (10 companies)

Sample	Name	Sector	Industry	BSM Prob
BGG	BRIGGS & STRATTON	Energy	Industrial Machinery/Components	9.62832E-08
SAEX	SAEXPLORATION HOLDINGS INC	Energy	Oil & Gas Production	0.364752811
HFC	HOLLYFRONTIER CORP	Energy	Integrated Oil Companies	2.80613E-06
NFEC	NF ENERGY SAVING CORP	Capital Goods	Metal Fabrications	0.232963334
IIVI	II-VI INC	Capital goods	Electronic Components	0.000139337
GGG	GRACO INC	Capital Goods	Fluid Controls	4.37737E-10
XPLR	XPLORE TECHNOLOGIES CORP	Technology	Computer Manufacturing	0.002595881
EMC	EMC CORP/MA	Technology	Electronic Components	0.000781629
HPQ	HEWLETT-PACKARD CO	Technology	Computer Manufacturing	0.001121073
AZZ	AZZ INC	Consumer Durables	Building Products	0.000150312

Table 13 Sample 7 (25 companies)

Sample	Name	Sector	Industry	BSM Prob
SEMG	SEMGROUP CORP	Energy	Oilfield Services/Equipment	4.1448E-08
VET	VERMILION ENERGY INC	Energy	Oil & Gas Production	8.01015E-29
SAEX	SAEXPLORATION HOLDINGS INC	Energy	Oil & Gas Production	0.364752811
XOM	EXXON MOBIL CORP	Energy	Integrated Oil Companies	2.53595E-12
PSX	PHILLIPS 66	Energy	Integrated Oil Companies	1.40214E-07

BC	BRUNSWICK CORP	Energy	Industrial Machinery/Components	0.002434162
GE	GENERAL ELECTRIC CO	Energy	consumer electronics/appliances	0.000351893
EQT	EQT CORP	Energy	Oil & Gas Production	2.68357E-17
LLEX	LILIS ENERGY INC	Energy	Oil & Gas Production	0.058135171
SLB	SCHLUMBERGER LTD	Energy	Oilfield Services/Equipment	7.08297E-07
MUR	MURPHY OIL CORP	Energy	Integrated Oil Companies	2.95119E-08
PSIX	POWER SOLUTIONS INTL INC	Energy	Industrial Machinery/Components	0.000737796
WFT	WEATHERFORD INTERNATIONAL	Energy	Oil & Gas Production	0.002058105
HUBA	HUBBELL INC -CL B	Capital Goods	Electric Products	9.36439E-16
BOOM	DYNAMIC MATERIALS CORP	Capital Goods	Industrial Specialties	0.015202826
IIVI	II-VI INC	Capital goods	Electronic Components	0.000139337
VIEW	VIEWTRAN GROUP INC	Capital Goods	Electric Products	0.007955119
COHR	COHERENT INC	Capital Goods	Biotechnology: Laboratory Analytical Instruments	2.38146E-05
HII	HUNTINGTON INGALLS IND INC	Capital Goods	Marine Transportation	6.03382E-09
SORL	SORL AUTO PARTS INC	Capital Goods	Auto Parts	0.002247852
ASTE	ASTEC INDUSTRIES INC	Capital Goods	Construction Equipment; Trucks	5.99962E-05
GD	GENERAL DYNAMICS CORP	Capital Goods	Marine Transportation	3.40363E-08
IR	INGERSOLL-RAND PLC	Capital Goods	Auto Parts	1.2881E-06
USCR	U S CONCRETE INC	Capital Goods	Building Products	0.008792689
ESP	ESPEY MFG & ELECTRONICS CORP	Capital Goods	Industrial Machinery/Components	1.58327E-23

Table 14 Sample 8 (25 companies)

Sam-ple	**Name**	**Sector**	**Industry**	**BSM Prob**
EQT	EQT CORP	Energy	Oil & Gas Production	2.68357E-17
PSIX	POWER SOLUTIONS INTL INC	Energy	Industrial Machin-ery/Components	0.000737796
XOM	EXXON MOBIL CORP	Energy	Integrated Oil Companies	2.53595E-12
LLEX	LILIS ENERGY INC	Energy	Oil & Gas Production	0.058135171
BWC	BABCOCK & WILCOX CO	Energy	Industrial Machin-ery/Components	9.13046E-07
HFC	HOLLYFRONTIER CORP	Energy	Integrated Oil Companies	2.80613E-06
HY	HYSTER-YALE MATERIALS HNDLNG	Capital Goods	Construction Equipment; Trucks	0.000955062
SPLP	STEEL PARTNERS HOLDINGS LP	Capital Goods	Industrial Specialties	2.05462E-19
GD	GENERAL DYNAMICS CORP	Capital Goods	Marine Transportation	3.40363E-08
HUBA	HUBBELL INC -CL B	Capital Goods	Electric Products	9.36439E-16
CYBE	CYBEROPTICS CORP	Capital Goods	Electronic Components	0.000164121
BELFA	BEL FUSE INC	Capital Goods	Electric Products	0.000476585
FLS	FLOWSERVE CORP	Capital Goods	Fluid Controls	0.000449365
CTS	CTS CORP	Technology	Electrical Products	0.000233418
SPA	SPARTON CORP	Technology	Electrical Products	0.000549594

AAPL	APPLE INC	Technology	Computer Manufacturing	0.000152887
ELX	EMULEX CORP	Technology	Computer Communications Equipment	0.000952995
IBM	INTL BUSINESS MACHINES CORP	Technology	Computer Manufacturing	1.52835E-05
ASMI	ASM INTERNATIONAL NV	Technology	Industrial Machinery/Components	2.25936E-05
FELE	FRANKLIN ELECTRIC CO INC	Consumer Durables	Metal Fabrications	1.0697E-07
SGK	SCHAWK INC -CL A	Consumer Durables	Containers/Packaging	1.19104E-05
KMB	KIMBERLY-CLARK CORP	Consumer Durables	Containers/Packaging	6.68569E-09
CCK	CROWN HOLDINGS INC	Consumer Durables	Containers/Packaging	0.996124883
AIT	APPLIED INDUSTRIAL TECH INC	Consumer Durables	Industrial Specialties	2.33623E-07
EDUC	EDUCATIONAL DEVELOPMENT CORP	Consumer Durables	Consumer Specialties	0.002544513

Table 15 Sample 9 (25 companies)

Sample	**Name**	**Sector**	**Industry**	**BSM Prob**
MUR	MURPHY OIL CORP	Energy	Integrated Oil Companies	2.95119E-08
BOLT	BOLT TECHNOLOGY CORP	Energy	Metal Fabrications	7.98379E-06
BC	BRUNSWICK CORP	Energy	Industrial Machinery/Components	0.002434162
AT	ATLANTIC POWER CORP	Energy	Electrical Utilities: Central	2.26145E-05
PSX	PHILLIPS 66	Energy	Integrated Oil Companies	1.40214E-07
EQT	EQT CORP	Energy	Oil & Gas Production	2.68357E-17
HAL	HALLIBURTON CO	Energy	Oilfield Services/Equipment	6.02436E-05
SORL	SORL AUTO PARTS INC	Capital Goods	Auto Parts	0.002247852
CR	CRANE CO	Capital Goods	Metal Fabrications	5.88319E-07
USCR	U S CONCRETE INC	Capital Goods	Building Products	0.008792689
CYBE	CYBEROPTICS CORP	Capital Goods	Electronic Components	0.000164121
IR	INGERSOLL-RAND PLC	Capital Goods	Auto Parts	1.2881E-06
FLS	FLOWSERVE CORP	Capital Goods	Fluid Controls	0.000449365
ESP	ESPEY MFG & ELECTRONICS CORP	Capital Goods	Industrial Machinery/Components	1.58327E-23
COBR	COBRA ELECTRONICS CORP	Technology	Radio and Television Broadcasting; Communications Equipment	0.038682527
CSRE	CSR PLC	Technology	Semiconductors	2.91733E-05
AAPL	APPLE INC	Technology	Computer Manufacturing	0.000152887
TECD	TECH DATA CORP	Technology	Retail: Computer Software & Peripheral Equipment	0.169637181
MITK	MITEK SYSTEMS INC	Technology	Computer Peripheral Equipment	0.081974698

XPLR	XPLORE TECHNOLOGIES CORP	Technolo-gy	Computer Manufacturing	0.002595881
NTK	NORTEK INC	Consumer Durables	Home Furnishing	0.001976443
ASH	ASHLAND INC	Consumer Durables	Specialty Chemicals	1.85066E-07
WHR	WHIRLPOOL CORP	Consumer Durables	consumer electronics/appliances	0.193108013
SGK	SCHAWK INC -CL A	Consumer Durables	Containers/Packaging	1.19104E-05
PPSI	PIONEER POWER SOLUTIONS INC	Consumer Durables	Electrical Products	0.00019768

Table 16 Sample 10 (50 companies)

Sample	Name	Sector	Industry	BSM Prob
PSX	PHILLIPS 66	Energy	Integrated Oil Companies	1.40214E-07
NBR	NABORS INDUSTRIES LTD	Energy	Oil & Gas Production	1.76206E-05
BGG	BRIGGS & STRATTON	Energy	Industrial Machinery/Components	9.62832E-08
HAL	HALLIBURTON CO	Energy	Oilfield Services/Equipment	6.02436E-05
GE	GENERAL ELECTRIC CO	Energy	consumer electronics/appliances	0.000351893
MPC	MARATHON PETROLEUM CORP	Energy	Integrated Oil Companies	0.000180867
EQT	EQT CORP	Energy	Oil & Gas Production	2.68357E-17
BWC	BABCOCK & WILCOX CO	Energy	Industrial Machinery/Components	9.13046E-07
HFC	HOLLYFRONTIER CORP	Energy	Integrated Oil Companies	2.80613E-06
SLB	SCHLUMBERGER LTD	Energy	Oilfield Services/Equipment	7.08297E-07
MUR	MURPHY OIL CORP	Energy	Integrated Oil Companies	2.95119E-08
EMR	EMERSON ELECTRIC CO	Energy	consumer electronics/appliances	8.12061E-08
XOM	EXXON MOBIL CORP	Energy	Integrated Oil Companies	2.53595E-12
SPLP	STEEL PARTNERS HOLDINGS LP	Capital Goods	Industrial Specialties	2.05462E-19
COHR	COHERENT INC	Capital Goods	Biotechnology: Laboratory Analytical Instruments	2.38146E-05
FLS	FLOWSERVE CORP	Capital Goods	Fluid Controls	0.000449365
ESP	ESPEY MFG & ELECTRONICS CORP	Capital Goods	Industrial Machinery/Components	1.58327E-23
F	FORD MOTOR CO	Capital Goods	Auto Manufacturing	0.005505335
GGG	GRACO INC	Capital Goods	Fluid Controls	4.37737E-10
SORL	SORL AUTO PARTS INC	Capital Goods	Auto Parts	0.002247852
CR	CRANE CO	Capital Goods	Metal Fabrications	5.88319E-07
USCR	U S CONCRETE INC	Capital Goods	Building Products	0.008792689
VIEW	VIEWTRAN GROUP INC	Capital Goods	Electric Products	0.007955119
CUO	CONTINENTAL MATERIALS CORP	Capital Goods	Building Products	2.74595E-08
HII	HUNTINGTON INGALLS IND INC	Capital Goods	Marine Transportation	6.03382E-09
HY	HYSTER-YALE MATERIALS HNDLNG	Capital Goods	Construction Equipment; Trucks	0.000955062
ETN	EATON CORP PLC	Technology	Industrial Machinery/Components	6.32767E-11
SIGM	SIGMA DESIGNS INC	Technology	Semiconductors	0.013471524
TECD	TECH DATA CORP	Technology	Retail: Computer Software & Periph-eral Equipment	0.169637181
MSI	MOTOROLA SOLUTIONS INC	Technology	Radio and Television Broadcasting; Communications Equipment	0.000928619

HPQ	HEWLETT-PACKARD CO	Technology	Computer Manufacturing	0.001121073
LLTC	LINEAR TECHNOLOGY CORP	Technology	Semiconductors	0.003077385
CSRE	CSR PLC	Technology	Semiconductors	2.91733E-05
CW	CURTISS-WRIGHT CORP	Technology	Industrial Machinery/Components	3.7446E-11
PLXS	PLEXUS CORP	Technology	Electrical Products	0.011184438
EMC	EMC CORP/MA	Technology	Electronic Components	0.000781629
SMT	SMART TECHNOLOGIES INC	Technology	Computer Peripheral Equipment	0.031928282
MXIM	MAXIM INTEGRATED PRODUCTS	Technology	Semiconductors	8.13295E-06
ALOT	ASTRO-MED INC	Technology	Computer Peripheral Equipment	0.000265889
EDUC	EDUCATIONAL DEVELOPMENT CORP	Consumer Durables	Consumer Specialties	0.002544513
NTK	NORTEK INC	Consumer Durables	Home Furnishing	0.001976443
BRC	BRADY CORP	Consumer Durables	Miscellaneous manufacturing industries	1.6203E-06
ASH	ASHLAND INC	Consumer Durables	Specialty Chemicals	1.85066E-07
KMB	KIMBERLY-CLARK CORP	Consumer Durables	Containers/Packaging	6.68569E-09
NAII	NATURAL ALTERNATIVES	Consumer Durables	Specialty Chemicals	0.000177333
CASY	CASEYS GENERAL STORES INC	Consumer Durables	Automotive Aftermarket	1.24727E-05
FELE	FRANKLIN ELECTRIC CO INC	Consumer Durables	Metal Fabrications	1.0697E-07
PPSI	PIONEER POWER SOLUTIONS INC	Consumer Durables	Electrical Products	0.00019768
CCK	CROWN HOLDINGS INC	Consumer Durables	Containers/Packaging	0.996124883
CKP	CHECKPOINT SYSTEMS INC	Consumer Durables	Telecommunications Equipment	0.000779913

Table 17 Sample 11 (50 companies)

Sample	Name	Sector	Industry	BSM Prob
BGG	BRIGGS & STRATTON	Energy	Industrial Machinery/Components	9.63E-08
AT	ATLANTIC POWER CORP	Energy	Electrical Utilities: Central	2.26E-05
LLEX	LILIS ENERGY INC	Energy	Oil & Gas Production	0.058135
EMR	EMERSON ELECTRIC CO	Energy	consumer electronics/appliances	8.12E-08
SLB	SCHLUMBERGER LTD	Energy	Oilfield Services/Equipment	7.08E-07
EQT	EQT CORP	Energy	Oil & Gas Production	2.68E-17
XOM	EXXON MOBIL CORP	Energy	Integrated Oil Companies	2.54E-12
SAEX	SAEXPLORATION HOLDINGS INC	Energy	Oil & Gas Production	0.364753
HES	HESS CORP	Energy	Integrated Oil Companies	3.76E-08
PSX	PHILLIPS 66	Energy	Integrated Oil Companies	1.4E-07
HAL	HALLIBURTON CO	Energy	Oilfield Services/Equipment	6.02E-05
MPC	MARATHON PETROLEUM CORP	Energy	Integrated Oil Companies	0.000181
HFC	HOLLYFRONTIER CORP	Energy	Integrated Oil Companies	2.81E-06
SPLP	STEEL PARTNERS HOLDINGS LP	Capital Goods	Industrial Specialties	2.05E-19
VIEW	VIEWTRAN GROUP INC	Capital Goods	Electric Products	0.007955

IIVI	II-VI INC	Capital goods	Electronic Components	0.000139
HY	HYSTER-YALE MATERIALS HNDLNG	Capital Goods	Construction Equipment; Trucks	0.000955
COHR	COHERENT INC	Capital Goods	Biotechnology: Laboratory Analytical Instruments	2.38E-05
CUO	CONTINENTAL MATERIALS CORP	Capital Goods	Building Products	2.75E-08
UTX	UNITED TECHNOLOGIES CORP	Capital Goods	Aerospace	5.52E-08
FLS	FLOWSERVE CORP	Capital Goods	Fluid Controls	0.000449
BELFA	BEL FUSE INC	Capital Goods	Electric Products	0.000477
HII	HUNTINGTON INGALLS IND INC	Capital Goods	Marine Transportation	6.03E-09
USCR	U S CONCRETE INC	Capital Goods	Building Products	0.008793
NAV	NAVISTAR INTERNATIONAL CORP	Capital Goods	Auto Manufacturing	0.004767
HUBA	HUBBELL INC -CL B	Capital Goods	Electric Products	9.36E-16
EMC	EMC CORP/MA	Technology	Electronic Components	0.000782
CMTL	COMTECH TELECOMMUN	Technology	Radio and Television Broadcasting; Communications Equipment	0.021173
TECD	TECH DATA CORP	Technology	Retail: Computer Software & Peripheral Equipment	0.169637
XPLR	XPLORE TECHNOLOGIES CORP	Technology	Computer Manufacturing	0.002596
COBR	COBRA ELECTRONICS CORP	Technology	Radio and Television Broadcasting; Communications Equipment	0.038683
ELX	EMULEX CORP	Technology	Computer Communications Equipment	0.000953
MSI	MOTOROLA SOLUTIONS INC	Technology	Radio and Television Broadcasting; Communications Equipment	0.000929
HPQ	HEWLETT-PACKARD CO	Technology	Computer Manufacturing	0.001121
PKE	PARK ELECTROCHEMICAL CORP	Technology	Electrical Products	1.86E-12
AMAT	APPLIED MATERIALS INC	Technology	Semiconductors	0.000268
SPA	SPARTON CORP	Technology	Electrical Products	0.00055
MITK	MITEK SYSTEMS INC	Technology	Computer Peripheral Equipment	0.081975
AAPL	APPLE INC	Technology	Computer Manufacturing	0.000153
CCK	CROWN HOLDINGS INC	Consumer Durables	Containers/Packaging	0.996125
FLXS	FLEXSTEEL INDUSTRIES INC	Consumer Durables	Home Furnishing	7.46E-07
CST	CST BRANDS INC	Consumer Durables	Automotive Aftermarket	2.99E-10
NAII	NATURAL ALTERNATIVES	Consumer Durables	Specialty Chemicals	0.000177
EDUC	EDUCATIONAL DEVELOPMENT CORP	Consumer Durables	Consumer Specialties	0.002545
PPSI	PIONEER POWER SOLUTIONS INC	Consumer Durables	Electrical Products	0.000198
CYAN	CYANOTECH CORP	Consumer Durables	Specialty Chemicals	0.02129
KMB	KIMBERLY-CLARK CORP	Consumer Durables	Containers/Packaging	6.69E-09
BSET	BASSETT FURNITURE INDS	Consumer Durables	Home Furnishing	0.00014
NTK	NORTEK INC	Consumer Durables	Home Furnishing	0.001976
WHR	WHIRLPOOL CORP	Consumer Durables	consumer electronics/appliances	0.193108

Table 18 Sample 12 (50 companies)

Sample	Name	Sector	Industry	BSM Prob
HAL	HALLIBURTON CO	Energy	Oilfield Services/Equipment	6.02436E-05
BGG	BRIGGS & STRATTON	Energy	Industrial Machinery/Components	9.62832E-08
EQT	EQT CORP	Energy	Oil & Gas Production	2.68357E-17
SLB	SCHLUMBERGER LTD	Energy	Oilfield Services/Equipment	7.08297E-07
GE	GENERAL ELECTRIC CO	Energy	consumer electronics/appliances	0.000351893
BC	BRUNSWICK CORP	Energy	Industrial Machinery/Components	0.002434162
CVX	CHEVRON CORP	Energy	Integrated Oil Companies	9.96843E-16
BWC	BABCOCK & WILCOX CO	Energy	Industrial Machinery/Components	9.13046E-07
WFT	WEATHERFORD INTERNATIONAL	Energy	Oil & Gas Production	0.002058105
MUR	MURPHY OIL CORP	Energy	Integrated Oil Companies	2.95119E-08
NBR	NABORS INDUSTRIES LTD	Energy	Oil & Gas Production	1.76206E-05
AT	ATLANTIC POWER CORP	Energy	Electrical Utilities: Central	2.26145E-05
HES	HESS CORP	Energy	Integrated Oil Companies	3.76202E-08
NFEC	NF ENERGY SAVING CORP	Capital Goods	Metal Fabrications	0.232963334
HII	HUNTINGTON INGALLS IND INC	Capital Goods	Marine Transportation	6.03382E-09
ESP	ESPEY MFG & ELECTRONICS CORP	Capital Goods	Industrial Machinery/Components	1.58327E-23
IIVI	II-VI INC	Capital goods	Electronic Components	0.000139337
USCR	U S CONCRETE INC	Capital Goods	Building Products	0.008792689
RTN	RAYTHEON CO	Capital Goods	Industrial Machinery/Components	1.02354E-07
BOOM	DYNAMIC MATERIALS CORP	Capital Goods	Industrial Specialties	0.015202826
CR	CRANE CO	Capital Goods	Metal Fabrications	5.88319E-07
SORL	SORL AUTO PARTS INC	Capital Goods	Auto Parts	0.002247852
ASTE	ASTEC INDUSTRIES INC	Capital Goods	Construction Equipment; Trucks	5.99962E-05
COHR	COHERENT INC	Capital Goods	Biotechnology: Laboratory Analytical Instruments	2.38146E-05
VIEW	VIEWTRAN GROUP INC	Capital Goods	Electric Products	0.007955119
F	FORD MOTOR CO	Capital Goods	Auto Manufacturing	0.005505335
CTS	CTS CORP	Technology	Electrical Products	0.000233418
CSRE	CSR PLC	Technology	Semiconductors	2.91733E-05
LLTC	LINEAR TECHNOLOGY CORP	Technology	Semiconductors	0.003077385
HPQ	HEWLETT-PACKARD CO	Technology	Computer Manufacturing	0.001121073
IBM	INTL BUSINESS MACHINES CORP	Technology	Computer Manufacturing	1.52835E-05
EMC	EMC CORP/MA	Technology	Electronic Components	0.000781629
SMT	SMART TECHNOLOGIES INC	Technology	Computer Peripheral Equipment	0.031928282
MXIM	MAXIM INTEGRATED	Technology	Semiconductors	8.13295E-06

	PRODUCTS			
PLXS	PLEXUS CORP	Technology	Electrical Products	0.011184438
SIGM	SIGMA DESIGNS INC	Technology	Semiconductors	0.013471524
CMTL	COMTECH TELECOMMUN	Technology	Radio and Television Broadcasting; Communications Equipment	0.021172693
PKE	PARK ELECTROCHEMICAL CORP	Technology	Electrical Products	1.86454E-12
SPA	SPARTON CORP	Technology	Electrical Products	0.000549594
SGK	SCHAWK INC -CL A	Consumer Durables	Containers/Packaging	1.19104E-05
NTK	NORTEK INC	Consumer Durables	Home Furnishing	0.001976443
BRC	BRADY CORP	Consumer Durables	Miscellaneous manufacturing industries	1.6203E-06
FLXS	FLEXSTEEL INDUSTRIES INC	Consumer Durables	Home Furnishing	7.46393E-07
AZZ	AZZ INC	Consumer Durables	Building Products	0.000150312
PPSI	PIONEER POWER SOLUTIONS INC	Consumer Durables	Electrical Products	0.00019768
KMB	KIMBERLY-CLARK CORP	Consumer Durables	Containers/Packaging	6.68569E-09
BSET	BASSETT FURNITURE INDS	Consumer Durables	Home Furnishing	0.000140123
CST	CST BRANDS INC	Consumer Durables	Automotive Aftermarket	2.9891E-10
EDUC	EDUCATIONAL DEVELOPMENT CORP	Consumer Durables	Consumer Specialties	0.002544513
AIT	APPLIED INDUSTRIAL TECH INC	Consumer Durables	Industrial Specialties	2.33623E-07

Appendix C. PROBABILITY TABLES

Table 19 Probability of number of companies going to bankruptcy for sample 1

Number of companies going to bankruptcy	Probability
0	0.967557445262308000
1	0.032197609250540900
2	0.000244894437942529
3	0.000000051047013725
4	0.000000000002194570
5	0.000000000000000000

Table 20 Probability of number of companies going to bankruptcy for sample 2

Number of companies going to bankruptcy	Probability
0	0.765547545547067000
1	0.233999249336514000
2	0.000452922009861140
3	0.000000283048706575
4	0.000000000057850688
5	0.000000000000001458

Table 21 Probability of number of companies going to bankruptcy for sample 3

Number of companies going to bankruptcy	Probability
P0	0.806343345116201000
P1	0.193525270633468000
P2	0.000131364735406749
P3	0.000000019514548183
P4	0.000000000000376086
P5	0.000000000000000000

Table 22 Probability of number of companies going to bankruptcy for sample 4

Number of companies going to bankruptcy	Probability
0	0.9001969833
1	0.0968130384
2	0.0029638665
3	0.0000260930
4	0.0000000189
5	0.0000000000
6	0.0000000000
7	0.0000000000
8	0.0000000000
9	0.0000000000
10	0.0000000000

Table 23 Probability of number of companies going to bankruptcy for sample 5

Number of companies going to bankruptcy	Probability
0	0.9593373113
1	0.0403449413
2	0.0003167217
3	0.0000010241
4	0.0000000016
5	0.0000000000
6	0.0000000000
7	0.0000000000
8	0.0000000000
9	0.0000000000
10	0.0000000000

Table 24 Probability of number of companies going to bankruptcy for sample 6

Number of companies going to bankruptcy	Probability
0	0.4849268510043
1	0.4280491998751
2	0.0866143760594
3	0.0004089641658
4	0.0000006085490
5	0.0000000003463
6	0.0000000000001
7	0.0000000000000
8	0.0000000000000
9	0.0000000000000
10	0.0000000000000

Table 25 Probability of number of companies going to bankruptcy for sample 7

Number of companies going to bankruptcy	Probability
0	0.57474096
1	0.38870427
2	0.05003456
3	0.00086165
4	0.00001311
5	0.00000010
6	0.00000000
7	0.00000000
8	0.00000000
9	0.00000000
10	0.00000000

11	0.00000000
12	0.00000000
13	0.00000000
14	0.00000000
15	0.00000000
16	0.00000000
17	0.00000000
18	0.00000000
19	0.00000000
20	0.00000000
21	0.00000000
22	0.00000000
23	0.00000000
24	0.00000000
25	0.00000000

Table 26 Probability of number of companies going to bankruptcy for sample 8

Number of companies going to bankruptcy	Probability
0	0.00362338
1	0.93166421
2	0.11883437
3	0.00010618
4	0.00000059

5	0.00000000
6	0.00000000
7	0.00000000
8	0.00000000
9	0.00000000
10	0.00000000
11	0.00000000
12	0.00000000
13	0.00000000
14	0.00000000
15	0.00000000
16	0.00000000
17	0.00000000
18	0.00000000
19	0.00000000
20	0.00000000
21	0.00000000
22	0.00000000
23	0.00000000
24	0.00000000
25	0.00000000

Table 27 Probability of number of companies going to bankruptcy for sample 9

Number of companies going to bankruptcy	Probability
0	0.58005404
1	0.34362110
2	0.00291884
3	0.00028696
4	0.00002289
5	0.00000068
6	0.00000001
7	0.00000000
8	0.00000000
9	0.00000000
10	0.00000000
11	0.00000000
12	0.00000000
13	0.00000000
14	0.00000000
15	0.00000000
16	0.00000000
17	0.00000000
18	0.00000000
19	0.00000000
20	0.00000000

21	0.00000000
22	0.00000000
23	0.00000000
24	0.00000000
25	0.00000000

Table 28 Probability of number of companies going to bankruptcy for sample 10

Number of companies going to bankruptcy	Probability
0	0.00292377
1	0.75245567
2	0.00230966
3	0.00752899
4	0.00055428
5	0.00001808
6	0.00000033
7	0.00000000
8	0.01769105
9	0.01259391
10	0.00896536
11	0.00638227
12	0.00454341
13	0.00323437

14	0.00230248
15	0.00163909
16	0.00116684
17	0.00083065
18	0.00059132
19	0.00042095
20	0.00029967
21	0.00021333
22	0.00015186
23	0.00010811
24	0.00007696
25	0.00005479
26	0.00003900
27	0.00002776
28	0.00001977
29	0.00001407
30	0.00001002
31	0.00000713
32	0.00000508
33	0.00000361
34	0.00000257
35	0.00000183

36	0.00000130
37	0.00000093
38	0.00000066
39	0.00000047
40	0.00000033
41	0.00000024
42	0.00000017
43	0.00000012
44	0.00000009
45	0.00000006
46	0.00000004
47	0.00000003
48	0.00000002
49	0.00000002
50	0.00000001

Table 29 Probability of number of companies going to bankruptcy for sample 11

Number of companies going to bankruptcy	Probability
0	0.00126652
1	0.32720054
2	0.83016293
3	0.02489389

4	0.01046126
5	0.00201622
6	0.00021866
7	0.00001328
8	0.00000047
9	0.01222548
10	0.00764399
11	0.00477941
12	0.00298833
13	0.00186846
14	0.00116826
15	0.00073045
16	0.00045672
17	0.00028556
18	0.00017855
19	0.00011164
20	0.00006980
21	0.00004364
22	0.00002729
23	0.00001706
24	0.00001067
25	0.00000667

26	0.00000417
27	0.00000261
28	0.00000163
29	0.00000102
30	0.00000064
31	0.00000040
32	0.00000025
33	0.00000016
34	0.00000010
35	0.00000006
36	0.00000004
37	0.00000002
38	0.00000001
39	0.00000001
40	0.00000001
41	0.00000000
42	0.00000000
43	0.00000000
44	0.00000000
45	0.00000000
46	0.00000000
47	0.00000000

48	0.00000000
49	0.00000000
50	0.00000000

Table 30 Probability of number of companies going to bankruptcy for sample 12

Number of companies going to bankruptcy	Probability
0	0.67044394
1	0.29458955
2	0.00223309
3	0.00029513
4	0.00000739
5	0.00000016
6	0.00000000
7	0.00000000
8	0.00000000
9	0.00004127
10	0.00001403
11	0.00000477
12	0.00000162
13	0.00000055
14	0.00000019
15	0.00000006
16	0.00000002

17	0.00000001
18	0.00000000
19	0.00000000
20	0.00000000
21	0.00000000
22	0.00000000
23	0.00000000
24	0.00000000
25	0.00000000
26	0.00000000
27	0.00000000
28	0.00000000
29	0.00000000
30	0.00000000
31	0.00000000
32	0.00000000
33	0.00000000
34	0.00000000
35	0.00000000
36	0.00000000
37	0.00000000
38	0.00000000

39	0.00000000
40	0.00000000
41	0.00000000
42	0.00000000
43	0.00000000
44	0.00000000
45	0.00000000
46	0.00000000
47	0.00000000
48	0.00000000
49	0.00000000
50	0.00000000

Appendix D. RISK POOLING VBA CODE

```
Function Pn(n As Integer, x As Integer, Prob() As Double) As Double
Dim r As Long, i As Long, counter As Long
Dim vResult, vResults, vResultsX, bLoop As Boolean, bFlag As Boolean, lRow As Long, lTotalComb As Long


ReDim vResult(1 To x)
lTotalComb = Application.WorksheetFunction.Combin(n, x)
ReDim vResults(1 To lTotalComb, 1 To 1)
For r = 1 To x
   vResult(r) = r
   ActiveWorkbook.Save
Next r
vResults(1, 1) = Join(vResult, ",")

lRow = 1
bLoop = True
Do While bLoop
   For r = x To 1 Step -1
      If vResult(r) < n - x + r Then
         vResult(r) = vResult(r) + 1
         For i = r + 1 To x
            vResult(i) = vResult(i - 1) + 1
         Next i
         lRow = lRow + 1
```

```
            vResults(lRow, 1) = Join(vResult, ",")


            Exit For
        End If
    Next r
    If r = 0 Then bLoop = False
Loop

bFlag = True
Dim pos As Integer
Dim Indexes As String
Dim Summation As Double
Dim Npos As Integer
Dim Multipliers(100000) As Double

Summation = 0

For r = 1 To lTotalComb
    Indexes = vResults(r, 1)
    'count how many commas
    pos = InStr(1, Indexes, ",")
    counter = 1
    If pos = 0 Then
    Multipliers(counter) = CInt(Indexes)

    Else
       If InStr(pos + 1, Indexes, ",") = 0 Then
        Multipliers(counter) = CInt(Mid(Indexes, pos - 1, (Len(Indexes) - pos)))

     Else
        Multipliers(counter) = CInt(Mid(Indexes, pos - 1, (InStr(pos + 1, Indexes, ",") - pos)))
     End If


    End If
   Do While pos <> 0
    Dim start As Integer
    Dim Index As String

    start = pos


    pos = InStr(pos + 1, Indexes, ",")


    counter = counter + 1

    If pos = 0 Then
        Index = Mid(Indexes, start + 1, (Len(Indexes) - start) + 1)

    Else
        Index = Mid(Indexes, start + 1, (pos - start) - 1)
    End If

    Multipliers(counter) = CInt(Index)



    Loop

    Dim Multiply As Double
    Multiply = 1

    Npos = 1

    For Npos = 1 To counter



    Multiply = Multiply * (Prob(Multipliers(Npos)) / (1 - Prob(Multipliers(Npos))))

    Next Npos
```

```
    Summation = Multiply + Summation
   Next r
Pn = Summation

' write the results in column A for test
End Function

Sub CalculateProb()
Dim r As Integer

Dim P0 As Double

Dim n As Integer
Dim Prob(100) As Double
Dim a As Integer
n = InputBox("Sample Size")

For r = 0 To n - 1
    Prob(r + 1) = ActiveCell.Offset(r, 0).Value

    Next r

P0 = 1

For r = 1 To n
    P0 = (1 - Prob(r)) * P0

Next r
ActiveCell.Offset(n + 1, 0).Value = P0

For r = 1 To n
    ActiveCell.Offset(n + 1 + r, 0).Value = P0 * Pn(n, r, Prob())

  Next r


End Sub
```