Does risk management have an influence on market value in non-financial industries?
Evidence from the chemical industry

Tim Felix Glombitza

Dissertation submitted in partial fulfilment of requirements for the MSc. in Finance, at the Universidade Católica Portuguesa, June 2018.

Thesis is written under the supervision of Diana Bonfim

ABSTRACT

Title: Does risk management have an influence on market value in non-financial industries? Evidence from the chemical industry

Author: Tim Felix Glombitza

This thesis focuses on the structure of risk management in the chemical industry to evaluate the relationship between risk management and market value performance. The objective is to draw an integral picture of the companies' risk management procedures. Furthermore, the most popular tools and general trends for risk management in the chemical industry are examined. The analysis is based on two pillars, quantitative (ratios) and qualitative (risk score) data obtained from company annual reporting. Therefore, handpicked balance sheet data from 82 of the largest chemical producers worldwide over 10 years has been collected, processed and evaluated.

The data suggests an increased attention regarding risk management in the chemical sector, since companies worldwide increased their efforts significantly during the research period. Furthermore, almost all companies monitor and hedge their risk exposure in one way or another.

However, it is not possible to infer that risk management contributes significantly to the market value development of chemical companies in the researched sample. The quantitative data analysed, shows significant results and indicates an interest of investors regarding risk or in other words risk aversion. For the risk score, which measures institutional risk management efforts of companies, no statistical significance – hence contribution to company's performance – can be observed.

In conclusion, risk management plays an increasingly important role for company's strategic decision-making, while investors seem to care only about the outcome of the risk profile of companies and not how they are accomplished.

Keywords: Risk, risk management, chemical industry, empirical analysis, enterprise risk management (ERM), market value development, hedging, annual reporting.

Abstrato (Português)

Título: Será que a gestão de risco tem influência no valor de mercado em indústrias não-financeiras? Evidências retiradas da indústria química

Autor: Tim Felix Glombitza

Esta tese foca-se na gestão de risco na indústria química, de modo a analisar a relação entre gestão de risco e *performance* de mercado. O objetivo é recolher uma fotografia dos procedimentos de gestão de risco das empresas. Além disso, as ferramentas mais populares e tendências gerais para gestão de risco na indústria química são examinadas. A análise é baseada em dois pilares, dados quantitativos (rácios) e qualitativos (pontuação de risco) obtidos do reporte annual das empresas. Assim, dados de 82 dos maiores produtores químicos mundiais durante mais de 10 anos foram recolhidos, processados e avaliados.

Os dados sugerem uma atenção acrescida relativamente à gestão de risco no setor químico, já que mundialmente as empresas aumentaram significativamente os seus esforços durante o período de pesquisa. Além disso, quase todas as empresas monitorizam e fazem *hedging* da sua exposição de risco de uma forma ou outra.

Porém, não é possível inferir que a gestão de risco contribui significativamente para o desenvolvimento de valor de mercado das empresas químicas na amostra analisada. Os dados quantitativos analisados mostram resultados significativos e indicam um interesse dos investidores à aversão de risco. Para a pontuação de risco, que mede os esforços institucionais na gestão de risco, significância estatística – logo contribuição para a *performance* – não é observada.

Concluindo, a gestão de risco tem um papel cada vez mais importante na tomada de decisão de empresas, enquanto os investidores aparentam apenas preocupar-se com o resultado do perfil de risco das empresas e não como este é atingido.

Palavras-Chave: Risco, gestão de risco, indústria química, análise empírica, gestão de risco de empresas, desenvolvimento em valor de mercado, *hedging*, reporte anual

Acknowledgements

I would like to thank my thesis advisor, Diana Bonfim, for providing important insights, support and valuable advisory throughout the time.

In addition, I would like to thank Tim Ole Ibbeken for the support and various discussion concerning econometrics. Moreover, I would also like to thank Maria Inês Pereira for her support.

Finally, I would like to thank my family, who have always given me support and motivation throughout my academic life. A very special thanks to my mother for being my greatest inspiration and my biggest supporter in everything.

Table of Contents

Table of Figures

List of abbreviations

Enterprise Risk Management…………………………………………………...……ERM

Three Lines of Defense………………………………………………………………...TLoD

Capital Expenditures…………………………………………………………………CAPEX

Value at Risk…………………………………………………………………………..VaR

Earnings at Risk……………………………………………………………………..…EaR

Expected Shortfall………………………………………………………………………ES

1. Introduction

During the last years, risk management has played an increasingly important role in a company's strategic decision making. This is not only true for the financial industry which experienced one of the biggest crisis in the last century, but also industrial and manufacturing companies were affected. The aftermath has led to various efforts to monitor, manage and eliminate risk. Risk management departments were built, Chief Risk Officers positions created, and frameworks were developed and implemented. The academic focus, influenced by those events, increased.

Nevertheless, most of the research focussed on financial institutions. Today, risk management for financial institutions is a widely researched and almost mature field of academic literature and various academic papers found evidence that effective risk management can create value and even more importantly, is remunerated by shareholders in the financial industry. (Charles Smithson, 2005) But it is still an academic blind spot if those results also held outside the financial industry. Only small niche sectors like (oil refiners, gold miners, airliners) were researched regarding risk management strategies and practices. Additionally, those studies were done with small samples, often focussed on only one country or region and on certain aspects like hedging activities, enterprise risk management systems, etc… (cf. David A. Carter D. A., 2017).

An integrated, comprehensive, assessment of risk management in large multinational firms, their application of different techniques and potential gains from it, has yet to be explored. Maybe even more important is the question whether financial markets or shareholders are willing to remunerate increased risk management activities and pay price premiums for those companies. Alternatively, the risk-return trade-off theories would suggest that less risky firms (through more effective risk management) can actually yield lower returns.

This blind spot of research for non-financial companies with high exposure to market risk in a mature industry with a worldwide scope is the starting point of this thesis. To assess the influence of (market) risk management an industry should have a high degree of fixed costs, be very competitive, show relatively low margins, offer limited opportunities for differentiation, have products that are highly substitutable, firms should compete internationally and face large market risk exposure. Companies operating in such industries have limited opportunities to differentiate and realise competitive advantages. Therefore, even marginal competitive advantages such as superior risk management, could lead to a significant increase in operating performance.

As a result, these market characteristics lead to a promising field which studies the marginal differences in companies' risk management and the impact on companies' performance. A perfectly suited market to conduct research on this relationship within a sector is the chemical industry.

The chemical industry is one of those sectors which has a high exposure to price risks, namely oil prices. On the one hand, oil is a crucial input factor for chemical sites which produce mainly derivatives of oil. On the other, oil prices have the function as a benchmark or marker for its derivative prices. Considering that approximately 50% of the product costs stem from raw materials -commodities, mostly oil- (Deloitte, 2014) chemical companies have a high capital demand for production sites, which implies high fixed costs. Products are highly substitutable and price risk on the input site has a huge impact on the performance of a chemical firm. Even on the output side, chemical companies have a large price risk exposure. This is a result of the limited pricing power for producers of commodity chemicals. Companies that produce speciality and fine chemicals, which are mixed and/or produced in smaller quantities and realise higher pricing power amongst customers, still rely heavily on volatile input prices. During the last ten years, the chemical industry experienced a volatile environment, as oil prices alternatively skyrocketed and crashed. The magnitude of volatility for chemical commodity derivatives even reached a historic high. (Federal Reserve Bank of St. Louis, 2018) At that time, especially (market) risk management was being challenged, and effective risk management should therefore have had an essential impact on the business performance in the chemical industry.

This thesis focuses on the structure of risk management in the chemical industry to evaluate the relationship between risk management and market value performance. It focuses on the way companies manage risk in times of unrest with the objective of drawing an integral picture of the companies' risk management procedures in the research period.
Hence, publicly available information from annual reports has been gathered, evaluated and analysed to answer the following questions.

1.1 Problem Statement

The primary objective of this study is to examine the role of risk management in non-financial industries with high market risk exposure. Contrary to available research that focuses only on certain elements of risk management, this thesis approaches risk management differently. The objective is to research the aggregated structure of risk management in chemical companies. Not only certain aspects like hedging strategies or organizational structure are considered. Risk management data is collected, aggregated and evaluated for all various aspects of risk management in a company.

In order to measure the overall impact of integrated risk management on a company's performance, answering following questions is central:

Q1: Does risk management have an influence on market value in the chemical industry?

Q2: Is there evidence of increased risk management efforts in the last decade?

Q3: What techniques/frameworks are most effective/prominent in the industry?

1.2 Scope of Analysis

To answer the questions above, this study focuses on risk management of the largest companies measured by sales in the global chemical market. A hand-picked database is developed to capture (qualitative) risk management data, supplemented with (quantitative) risk-related performance ratios which build the second pillar of the analysis.

1.3 Structure

For a better understanding of the recent research and the general ongoing academic discussions about risk management, the existing literature is reviewed in Chapter 2.
The following, third Chapter, focusses on the methodology. Firstly, the data collection procedures are described. Second, an explanation of each qualitative as well as quantitative factor that is included will be provided as well as its relation to risk management.
Afterwards, Chapter 4, summary statistics are provided to facilitate a better understanding of the data used for the subsequent regression analysis.

In Chapter 5, the empirical approach will be explained, including the research methods and statistical test that were used to develop the different regression models.

The empirical results are discussed in Chapter 6 and lastly, a conclusion is drawn in Chapter 7.

2. Literature Review

Most of the research in the area of risk management is focused on the financial and insurance industry, given that risk is their business. Risk management in financial institutions is, therefore, a widely analysed and almost mature field of academic research. For non-financial firms, there is scant literature available apart from studies on the implications of hedging. In addition, the studies that are available outside the financial industry, focus only on certain aspects of risk management, most of them -once again- hedging activities. Only a few studies go a step beyond and measure other risk management activities. All of them have in common that they are limited to either a certain geographic region (mostly North America) or niche sectors (oil refineries, gold mining, aviation), which limits their meaningfulness for general results validity.

2.1 Theoretical Implications of Risk Management

Starting our review in a perfect world, according to Modigliani and Miller, risk-management should be irrelevant. This implies no information asymmetries, taxes and transaction costs. In this theoretical framework, the cost of risk management equals the cost of bearing risk. (Franco Modigliani, 1959)

In either case, this theory cannot be transferred to the real world. Introducing market imperfections implies that risk management can alter firm value. In practice, imperfections in capital markets create a rationale for lowering the volatility of earnings through hedging. Conventional explanations relate to the cost of financial distress, tax incentives, and the underinvestment problem. As a result, risk management could add value if hedging positions in derivatives contracts carry forward or if active trading activities create a profit or decrease volatility in profits. Moreover, another central assumption in the risk management literature was disproved. that derivatives transactions have zero net present value. (Tim R. Adam C. S., Hedging, speculation, and shareholder value, 2006)

2.2 Human Biases

Furthermore, the impact of personal biases and overconfidence on corporate risk management must be included. Managers tend to increase speculative activities after speculative gains while they do not decrease their activity after losses. (Tim R. Adam C. S., 2015) Managerial risk aversion has been argued as a driver of corporate risk management behaviour. In addition, to considering financial distress and tax arguments for hedging, (Clifford W. Smith, 1985) also proposed an argument focused on managerial risk aversion and its interaction with firm-related wealth and compensation structure. These important implications are supported by evidence that remuneration schemes significantly impact cautiousness and treatment of risk. (Tufano, 1996)

2.3 Drivers of Risk Management

The economic main drivers of hedging for companies in oil and gas industry which face similar challenges to chemical companies, are financial leverage managed price risks, economies of scale in hedging costs and basis risk associated with hedging instruments. (Haushalter, 2000) While, Graham et al. provided evidence suggesting that although tax convexity does not seem to be a factor in hedging decisions, firms appear to be hedging to increase their debt capacity and thereby increase tax shields. They also found that firms hedge to reduce expected distress costs. (John R. Graham, 2002) In contrast, Rampini et al. argue that risk management theories incorporating financial constraints ignore collateral trade-offs. As a result, firms facing greater financial constraints employ less risk management because collateral needs for debt obligations (which finance investment) are more valuable. (Adriano A. Rampini, 2014)

2.4 Hedging, a Controversial Discussion

Hedging as the most prominent practice in risk management is a subject of controvers amongst academics. Most of the literature focuses on the determinants of hedging and the impact on revenues or market values. Furthermore, a positive relation between (currency-) risk management and firm market value for non-financial firms has been identified. Empirical evidence assumes that foreign currency derivatives usage (hedging) contributes to the market development of companies by approximately 5%. (George Allayannis, 2001). In addition, it was shown that hedging is associated with enhancement of a firm’s credit quality, thereby lowering financing costs. (N.K Chidambaran, 2001) Support for the argumentation that hedging is providing value for shareholders has been provided by a research of gold mining firms. Gold miners consistently realise abnormal positive cash flows from their derivative transactions due to positive risk premia. As there has been no corresponding increase in systematic risk, evidence was found that these derivative transactions increased shareholder value. But there is also an important limitation of this effect. Only companies that regularly hedged realise significant cash flow gains, while selective hedging realised only small gains in the best cases (Tim R. Adam, 2006).

Surprisingly, Carter et al. demonstrated that the more active hedgers of fuel costs among airlines are the larger firms with the least debt and highest credit ratings. (David A. Carter D. A., 2006) These findings contradicted the theoretical literature on risk management, which proposes that firms that are more likely to experience financial distress should also be more aggressive in managing their risks (Clifford W. Smith, 1985) and (KA Froot, 1993). While, a study of 119 oil and gas companies found that hedging does not affect market value of these companies, it did lower their stock price sensitivity to oil and gas prices (Yanbo Jin, 2006). On the other hand, for a sample of 34 oil refiners. Peter Mackay et al. could show that hedging concave revenues and leaving concave costs exposed each represented between 2% and 3% of firm value. They validated the approach by regressing Tobin's Q on the estimated values and found results consistent with the model. This also holds for alternative risk management techniques such as real optionality, vertical integration, and diversification (Peter Mackay, 2007). Furthermore, a positive relation association (currency-) risk management and firm market value for non-financial firms was identified.

In contrast to various other studies that implied a positive effect of hedging on firms' market values, also negative effects can arise for output hedging. Stock market reactions showed strong negative reactions towards hedging announcements for gold producers, which implies that possible gains from hedging activities are offset by concerns about a change in the expected future financial condition (cost of financial distress) of the company. These findings also suggest that the market believed private information was revealed by gold miners with the hedging announcements (Vikas Raman, 2010).

Peter Mackay delivered support for this argumentation from a different direction. Markets reward firms when hedging creates value while penalising them when it does not. The market bids up firms that hedge more as the risk of financial distress rises, it outlines a trade-off between the real-side value of risk management and the usual financial motives. (Peter Mackay, 2010) The assumptions of the potential negative effect of output hedging was also researched and validated by a more recent study. They highlight the important differentiation between input and output hedging and the different market reactions towards it (David de Angelis, 2016).

2.5 Drivers of Hedging

Moreover, studies showed that many firms do not hedge because of risk-reducing they speculated, which is known in practice as "selective hedging". They varied the size and timing of their derivatives transactions based on their market views. Dolde reported that almost 90% of firms in his survey of 244 Fortune 500 firms at least sometimes base the size of their hedges on their views of future market movements (Dolde, 1993). Bodnar et al. surveyed derivatives policies by 399 U.S. non-financial firms. They also stated that about 50% of the researched firms admit to sometimes adjust their hedging (and 10% frequently) size and/or the timing of a hedge on speculative motivation (GM Bodnar, 1998). These findings suggest that the practice of hedging departs considerably from the underlying assumption in the theoretical literature that firms use derivatives to reduce risk, not to speculate. There was also considerable evidence found of selective hedging in their sample of gold mining firms. No economically significant cash flow gains on average from selective hedging was reported (Tim R. Adam C. S., 2006). Brown et al. also studied selective hedging in the gold mining industry and came to a similar conclusion (Gregory W. Brown, 2006).

It can be seen that hedging, its drivers and effects on firm performance are widely researched with the first studies dated back to the 1980's, with different conclusions and no generally valid, academically justified effect of hedging. Nonetheless, this study wants to provide a bigger picture and not limit itself to hedging although hedging and the associated risks that are managed or even eliminated by company hedging activity are a major driver of the risk score approach.

2.6 Organisational Implications for Risk Management

During the last decade, a comparable immature field of risk management research developed. Studies that focus on the organisational structure of risk management, its impacts and implications. The importance of these organisational structures on effective risk management was shown by various studies.

The first step to manage risk is the identification and measurement, Stein highlights the importance of the organizational structure of the risk management function to determine how effectively qualitative and quantitative information on risk is shared between top management and the individual business segments (Stein, 2002). Accordingly, information was collected about the organisational structure of the risk management function at each company. In addition, the importance of a prominent role of risk managers that facilitates the communication between the top management and the various business entities that deal with risk daily was shown by (Stulz, 2008). Not only was information gathered on whether there was a designated risk function tasked with managing enterprise-wide risk but also on how important such an official was within the organisation. Robert E. Hoyt et al. analysed the relationship between enterprise risk management (ERM) and the effect on firm value. They found a positive connection between firm value and the use of ERM. With an ERM premium of roughly 20% on Tobin's Q, their proxy for firm value were statistically and economically significant (Robert E. Hoyt, 2011). As this positive effect of ERM seems evident, it is also a part of the analysis provided in this study. For the financial industry, those implications were extended to the nature of the risk managing function.

The study by Andrew Ellul et al. measured the effect of a strong and independent risk management function in cutting tail risk exposure in the financial industry. The study was based on a Risk Management Index, comparable to the approach used here. Banks with better risk management showed lower tail risk, had less nonperforming loans, and boasted better operating and stock return performance during financial crisis years (Andrew Ellul, 2013). According to their results, the independence and effectiveness of risk management in a company is also considered in this thesis and the approach of an adjusted Risk Score to measure the risk management efforts has been chosen. In a more recent study, Gordon Bondnar et al. provided a survey about the exposure to the six areas of risk. Interest rate, foreign exchange, commodity, energy, credit and geopolitical risk were the prevalent risks firms were concerned about. They also found out that vast majority of firms that face material risk in these areas were managing this risk, however only about two-thirds used derivative transactions and their risk management was more focussed on an operational approach. Most common were combined approaches. Companies that used financial derivatives tended to use basic instruments (forwards) over options and they preferred over-the-counter instruments to exchange-traded products. Also, credit risk was identified as one of the most important types of risk in their sample which was handled via operational methods, whereas, companies dealt with geopolitical risk in a variety of ways. They also documented substantial and predictable differences in behaviour between financial and nonfinancial firms, but found only small deviations regarding the geographical location. Their analysis pointed out that risk management is an important part of corporate activities (Gordon M. Bodnar, 2011).

2.7 Summary of Risk Management Literature

All in all, it is evident that (financial) hedging is the most researched area in risk management. During the last years, the academic literature shifted the focus towards a broader set of determinants of risk management. Not only (financial) hedging activities are a crucial part of risk management, also company culture, organizational structures and operational risk management effect the company's risk management efficiency. To ensure an integrated view of all aspects that influence companies risk management, this study will consider various aspects like frameworks, standards, organisational structure, hedging, risk monitoring, etc… with the objective to draw an integral picture of the companies' risk management procedures for the company sample.

3. Methodology

3.1 Sample Collection and Construction of Variables

The data for this thesis were gathered from various sources. The starting point for the data collection process was the largest 100 producers of chemical products by sales in 2016, identified by the Independent Chemical Information Service. (ICIS, 2017)
To conduct the analysis of risk management practices, data of the organizational structure of the risk management is hand collected by analysing and evaluating annual reports of the companies. When this data was not available, Securities and Exchange Commission (SEC) K-10 statements and proxy statements were gathered, approximately ten times. This data was then used to create a unique dataset of risk management practices of chemical producers worldwide for the period from 2006-2016. Due to the effort involved in manually collecting and validating the information for each company and the immense time exposure of handpicking balance sheet information, the sample focuses only on the largest companies by sales in US-$ (Appendix 8.2). Only public information is considered which implies that only companies that publish annual data were included in the analysis.
During the research other problems occurred, which led to a reduction of the sample size from 100 to 82 companies:

Firstly, some companies are privately owned (3 companies) and do not publish annual reports.
Secondly, some companies are under foreign law that does not require the release of annual reports by international accounting standards (4 companies);
Thirdly, some annual reports were only available in local languages (e.g. Mandarin or Spanish).
Fourthly, due to mergers and acquisitions, spin-offs and bankruptcy led to an insufficient time-frames (11 firms with less than five consecutive years of reporting and hence were excluded).
This led to a reduction in the size to 82 companies meeting the requirements for inclusion in the sample. As a result, a panel dataset over ten years was created and analysed.
For the second pillar of the analysis, financial data was sourced from *Thomson Reuters DataStream* and risk-related performance ratios were calculated.

3.2 Dependent Variables

Market value

To assess the impact of risk management on market value development annual data were used. Market values deliver the most integral picture about the condition of a company, as it includes not only the current condition derived from financial data but, also expectations regarding future performance, business model and industry in general. The market value data used in this study was obtained from *Thomson Reuters DataStream*. To avoid the impact of currency fluctuations, such as a higher valuation based on currency appreciations that have no significant statement about the business performance of a company, the researched market values were deducted in local currencies by the end of the year according to the cut-off day for the annual reporting. One exception was Japanese companies, which publish according to the government financial year 1 April – 31 March. Based on this data, the yearly change was calculated.

3.3 Explanatory Variables

3.3.1 Company (Dummy) & Year (Dummy)

The dataset consists of panel data for the 2005-2016 years for 82 different companies. Company dummies were introduced to convert the associated company data as panel variable and year dummies as time variable for fixed effects estimates (regressions).

3.3.2 Region (Dummy)

Another effect that could mislead the statistical analysis (for some models) is the region of origin. To control this potential impact, categorical region dummies were recorded. Country fixed effects were not considered because of the high degree of internationalization within the chemical sector. Problems that could arise with the introduction of country fixed effects are the categorisation of companies that realised more turnover in foreign markets than in domestic ones.

1 = North America
2 = South America
3 = Europe
4 = Asia
0 = other Countries (Africa, Australia)

Another problem with fixed country effects are the limited amount of observations in countries outside the top 3 (USA, Japan, Germany). For some countries there existed only one company in the sample.

3.4 Quantitative Data – Balance Sheet Ratios

The evaluation of the financial data was also performed with ratios for the same reasons that applied to the market value development (currency fluctuations). Analysed performance ratios were chosen, based on risk management relevant content and information, which will be explained in detail in the following chapter. Even though just a couple of ratios (with risk management relevant information) were included in the regression analysis, a broader set of ratios are shown in the summary statistics. The objective was to build a better understanding of the chemical industry, its challenges and operating characteristics.

3.4.1 Fixed Assets to Common Equity Ratio

The Fixed Assets to Common Equity measures the intensity of long-term tangible assets on the balance sheet of chemical companies financed by shareholder’s equity. A high fixed assets to common equity ratio indicates a high degree of funding of long-term tangible assets via one’s own capital. Therefore, a lower ratio indicates a strong financial position of the company and greater security and feasibility for creditors. Additionally, it can be interpreted as an indicator for creditworthiness as it shows how much of the fixed assets are financed by own capital and can be liquidated or collateralized in crisis situations if needed.

3.4.2 Total Liabilities to Total Capital Ratio

This is a ”classic” way to measure a company’s leverage. In financial theory, the perfect leverage is a trade-off decision between interest tax shield benefits and bankruptcy costs. Modigliani and Miller's Capital-Structure Irrelevance Proposition has shown this holds in a perfect market, however, this market exists only in theory. As a result, companies have to carefully consider this trade-off between risk and reward. There is no academic consensus which exact leverage meets the best risk-reward scheme for a certain company or industry. Leverage ratios are pro-cyclical, follow trends and depend on the industry as well as the observed business. In practice, leverage ratios around 0.5 are considered as desirable by investors and up to 0.7 are tolerated in capital-intensive industries. All in all, it can be extrapolated, that markets reward companies with an increased leverage if they believe the gains of the tax shield outweigh the bankruptcy costs and vice versa.

3.4.3 Capital Expenditures (CAPEX) to Total Assets

CAPEX to total assets ratio reflect the investment activity of a company. Investments in long-term assets (PP&E) do not generate immediate returns, contrary to the interests of investors. However, a certain investment is needed to maintain the company's operations to avoid an undermining of the ability to operate properly. Another possible positive interpretation by investors could be an investment in increasing the scale of the company's business operations (economies of scale). All in all, an observation of this ratio should contribute to disclose of the long-term strategic orientation of a company by answering the question if a company is building a capital stock or living from it to realize short-term profits at the cost of a sustainable long-term business development.

3.4.4 Tobin's Q

Tobin's Q ratio is used as a formal, theoretical, proxy to measure the "fair" intrinsic firm value of a company. Especially, due to the high M&A activity in the chemical sector and the associated impacts on short-term market valuation and price, a theoretical measure is introduced. A Tobin's Q above one indicates an overvaluation, while a ratio below 1 indicates an undervaluation. A consistent undervaluation of a company could also imply structural problems that are not reflected in the balance sheet data, like an eroding business model, litigation, etc.

Due to the low-interest environment during the last years' higher values for this ratio can be expected. Anyway, the fundamental message remains untouched. Additionally, there is evidence that Tobin's Q can be used as an indicator for superior long-term operating performance. (Liang Fu, Tobin's q Ratio and Firm Performance, 2016) The calculation is based on balance sheet data from *Thomson Reuters DataStream*.

$$Tobin's\ Q = \frac{Equity\ Market\ Value + Liabilities\ Market\ Value}{Equity\ Book\ Value + Liabilites\ Book\ Vlaue}$$

3.4.5 Altman's Z'-Score

As a substitute for credit ratings that indicates the bankruptcy probability of firms, the Altman Z'-Score is used. It is assumed that market participants prefer companies with a low probability of default and therefore are willing to pay a price premium on their stocks. Due to a lack of availability of credit ratings for the entire company sample, the "classic" Altman's Z

- Score model for manufacturing, non-financial firms, is applied as a default probability measure:

$$\text{Altman Z} - \text{Score} =$$

$$1.2 * \frac{Working\ Capital}{Total\ Assets} + 1.4 * \frac{\text{Retained Earings}}{Total\ Assets} + 3.3 * \frac{EBIT}{Total\ Assets} + 0.6 * \frac{Market\ value\ of\ Equity}{Bookvalue\ of\ Liabilites} + 1.0 * \frac{Sales}{Total\ Assets}$$

An Atman Z'-Score above 2.99 is equivalent to the "safe" zone, while values between 1.81 and 2.99 mark the boundaries of the "grey" zone. Companies with a Z-Score below 1.81 enter the "distress" zone.

X1 - Contains information about the capital intensity of the industry/company
X2 - Measures the earning power
X3 - Gives intelligence about the operating efficiency apart from tax and leveraging factors
X4 - Shows up security price fluctuation
X5 - Measure the total asset turnover
(Altman, 2000)

Altman's Z-Score already includes many standard performance ratios. Therefore, it contributes greatly to understand the financial condition of a company

3.5 Qualitative Data - Risk Score

Additionally, to the ratio analysis, a risk score based on qualitative data was developed. The required, qualitative, risk management information is collected manually from annual reports risk sections. The intention behind the score is to explore the intensity of effort and techniques that companies apply to monitor and manage risk. As most investors do not have access to private information only public information which is clearly announced in annual reports is considered. To quantify the information, variables are used in two ways. Binary variables are used to measure the existence of risk management tools, while categorical variables measure the levels of quality of risk management tools. A detailed explanation of the scores are provided with the discussion of each variable.

Firms are not required to report their risk management activities in a standardized way and the quality and quantity of risk management disclosure vary widely across the sample. This made a detailed keyword search necessary. Annual reports, financial reports and proxy statements were searched regarding acronyms or/and individual words like "risk committee", "chief risk officer", "enterprise risk management", "risk matrix", "strategic risk management", "COSO", "integrated risk management", "TLoD" in order to identify the associated information. An example of a "hit and "no hit" is provided below:

Example for a "hit":

"The BASF Group's risk management process is based on the international risk management standard COSO II Enterprise Risk Management – Integrated Framework (2004) …"
Source: BASF Report 2014 - Economic, environmental and social performance

Example for "no hit":

"…maintain and operate its risk management system in accordance with established risk management regulations."
Source: Mitsui Chemicals Annual Report 2013

Every search hit was manually reviewed within its context in order to determine useful information. Each successful hit was then dated and recorded for each of the years. To identify the earliest evidence of risk management activities of each firm.

It is assumed that risk management has only a marginal impact on company valuation and to avoid collinearity problems, the data was consolidated into a risk management Score variable which captures concisely the information which was deducted from the balance sheets. The score consists of 13 different variables which track different risk management tools used by the researched companies, to answer the question how companies manage risk. This methodology is analogue to a risk management index approach that was adapted to a manufacturing industry and the public information used (Andrew Ellul, 2013). The extracted risk scores were calculated by the sum of the variables according to the applied risk management tools and/or frameworks. Some of them were coded binary, which meant companies received, for instance, one point for using an enterprise risk management System, while other variables were categorical, such as geographic diversification. This implies that a company with a worldwide presence receives more points and therefore overweight geographical diversification over the implementation of an ERM system.[1] It has to be said that these weights were set somewhat arbitrarily as there is no academically or practically consensus regarding the effectiveness of different risk management practices. Additionally, the small sample size and the (assumed) marginal impact of risk management on market value development had to be critically reviewed regarding continuing assumptions and manipulations. The maximum score a company could have reached was 30. The best score

[1] The risk score was also tested for an equal weighting of all composed factors with no improvement in statistical significance. As a result, the adjusted weighting is used to achieve a better fit of its components.

reached by a company in the sample was 24, from BASF SE. A detailed description of each possessed tool/technique follows.

3.5.1 Institutional Enterprise Risk Management (ERM)

Institutional ERM support companies towards capturing, evaluating and managing risks. It enables firms to manage a wide array of risks in an integrated, enterprise-wide way, compared to the classic separate "silo" management of risk. Investments in ERM lead to a superior operating performance by a closer supervision of risk and reduction of inefficiencies. ((Brian W. Nocco, 2006); (Robert E. Hoyt, 2011))

A definition of the abstract framework ERM is provided by the Committee of Sponsoring Organizations (COSO): "Enterprise risk management is a process, effected by an entity's board of directors, management and other personnel, applied in strategy setting and across the enterprise, designed to identify potential events that may affect the entity, and manage risk to be within its risk appetite, to provide reasonable assurance regarding the achievement of entity objectives." (Committee of Sponsoring Organizations of the Treadway Commission, 2004)

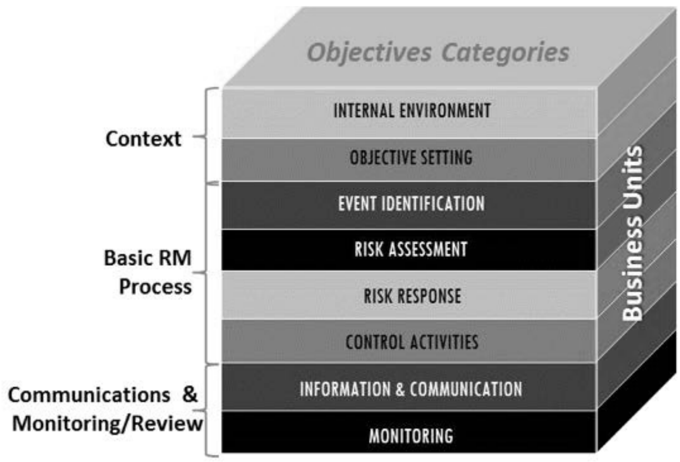

Figure 1:Enterprise Risk Management Theoretical Model
Source: (Committee of Sponsoring Organizations of the Treadway Commission, 2004)

3.5.2 Formalised risk evaluation process

The annual reports were also evaluated regarding a formalised risk management process. This meant, in other words, whether the company had established a risk management committee, a formalized and standardized reporting of risks, and a concrete timeframe for meetings and supervision of those risks. The variable captures a rational approach regarding risk to restrict the impact of personal biases. Managerial overconfidence, for example, can influence a number of corporate decisions and it can affect corporate risk management decisions. There is empirical evidence that corporate risk management practices are affected by behavioural managerial biases. (Tim R. Adam C. S., 2015) Risk committees can contribute to overcome or at least limit those (personal) behavioural biases through a combination of different people, perspectives and departments. For companies that implemented a risk management committee or a comparable panel, this variable turned to one, for companies that did not implement it, the variable remained at zero.

3.5.3 Risk Management framework/standard

A risk management framework or standard guarantees a certain quality of risk management within companies. Especially during the last years after the financial crisis, this became a more prominent topic. Various frameworks were developed, and it is more and more common for companies to base their risk management implementation on them. To name a couple of examples: The Enterprise Risk Management – Integrated Framework from the Committee of Sponsoring Organizations (COSO I/II), the Enterprise Risk Management Framework from the Risk Management Association (RMA) and the ERM "ISO 31000" certification from the International Organization for Standardization (ISO). It is assumed that these standards guarantee a certain level of risk management and lead to a more stringent and structured implementation of risk management in companies. As a result, companies which based their risk management framework on one of these standards or even received a certificate, are recorded with a variable value of one, others with zero.

3.5.4 Designated Chief Risk Officer

The Chief Risk Officer position gives an indication how prominent risk is in a company. Companies with a risk responsible position at the executive level are expected to be more aware of risks they take and improve firm performance. (Martin F. Grace, 2014) Not only CRO positions were recorded in the database, also comparable positions which are mainly responsible for risk management on an executive level were included. Nevertheless, the companies that received a score of one in this variable had to present a position on highest-level executive stage that is mainly responsible for risk, positions below the C-level were not recorded. (André P. Liebenberg, 2003)

3.5.5 Risk matrix

A risk matrix is an integral part of a risk assessment. It supports companies to define the level of risk, categorises and assesses the probability or likelihood against the category of consequence severity of a negative impact. While it is also a part of ERM frameworks, the risk matrix was recorded exclusively as it contributes greatly to the proper identification, evaluation and overview of business risks. These advantages persist even for companies that do not use an ERM framework. In this sample, there were two different versions of risk matrices, quantified versions which roughly estimated the potential impact of risk factors and the qualitative version that only described the potential impact without quantifying it. Both versions contribute to the understanding and mapping of the company's risk environment and appetite and were therefore recorded with a variable value of one.

3.5.6 Three Lines of Defence Model

The Three Lines of Defence (TLoD) model provides a framework which guarantees an effective and independent view on risk. Compared to other approaches that were recorded, it also includes an independent supervision of risk management from company bodies that are not involved in the operational, daily, management of business risk. Hence, it can be described as supervision of risk management supervisors. It contributes to an independent point of view for assessing, measuring, treating and migrating risk in a company and supports the disclosure of potential weak spots. The Chartered Institute of Internal Auditors describes the three lines of defence as following:

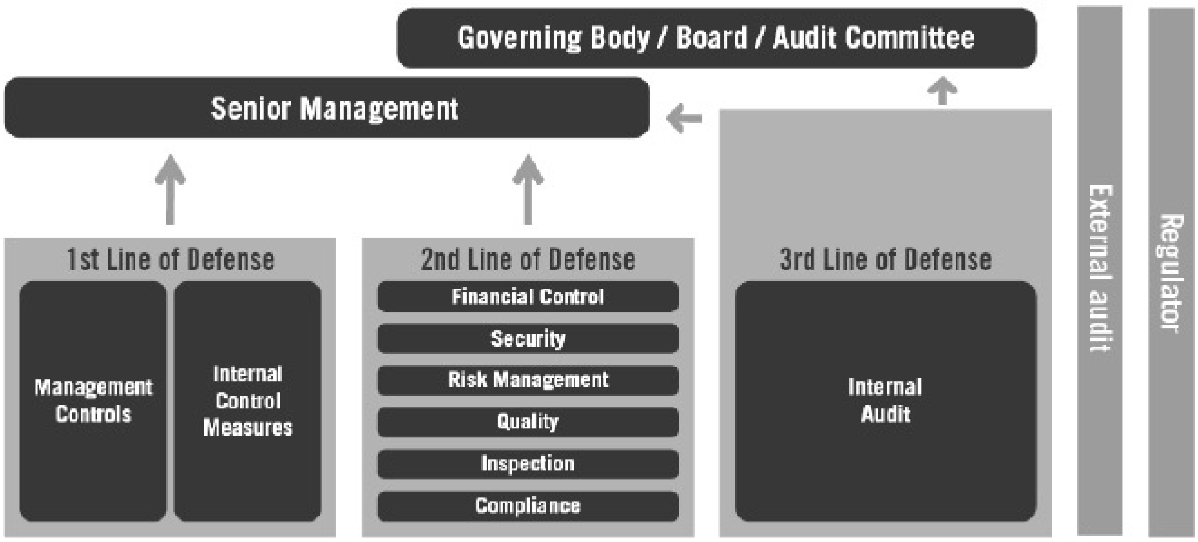

Figure 2: Three Lines of Defence
Source: (Chartered Institute of Internal Auditors, 2015)

The application of the TLoD model is recorded analogue to the other dichotomous variables. The variable takes a value of one for companies which apply the TLoD model and zero if they do not.

3.5.7 Risk measurement

A crucial part of risk management is the measurement of risk and its quantification. Companies face a diverse portfolio of risks in their daily operations. To identify key risks and the companies has an exposure to and to treat them, they have to be quantified first. This measurement and the optional quantification of risks is the first categorical variable introduced in the risk score. A qualitative description of risk (factors) is required by the SEC 10-K form while the quantification of risk is optional for companies listed in the U.S. As this quantification of risk can be very difficult or even impossible, for some kinds of risk in practice, this variable capture only market risk (systematic risk) that can be diversified according to the companies' risk management guidelines.

The risks considered here are interest rate, equity, currency and commodity risk based on the balance sheet items at the end of the year (annual report data). The score for this variable is assigned as follows:

0 - Qualitative description
1 - Sensitivity analysis
2 - Scenario analysis
3 - Value at Risk (VaR)

3.5.8 Forecast model

While the risk measurement already contains a kind of "forecast" or "what-if analysis" a detailed forecast of the business environment as well as the company performance, adds value to a comprehensive risk management. Risks and their potential impacts need to be assessed before a company can deal with them. Therefore, a detailed analysis of future events and impacts on a company level needs to be done. This includes not only economic and financial risks but, also geopolitical, environmental, law and security risks are incorporated here. One of the requirements from the SEC is a qualitative description of risk. (SEC Form 10-K, 'Risk factors') A quantification is not required by law but can add value and help categorise potential impact on companies' balance sheet items and business environment. Consequently, this leads to a more efficient behaviour when such circumstances arise (Pirrong, 2015)

0 - Qualitative description
1 - Sensitivity analysis
2 - Scenario analysis
3 - Value at Risk (VaR)

3.5.9 Exposure estimation

While the first two variables, risk measurement and forecast modelling, capture techniques that already measure risk in a "silo" approach (each risk for itself), an exposure estimation incorporates all different kinds of risk, quantifies and finally aggregates them to measure downturn scenarios and their impact on the company performance. While most of the described methods have their origin in the financial industry an adaptation for industrial companies can contribute to a better understanding and quantification of risks. In the sample data, four different methods of exposure estimation were found and recorded. The most common were basic sensitivity and scenario analysis. Some companies also apply more robust and detailed "worst case" scenario outcomes. They calculate value at risk (VaR) and earnings at risk (EaR) /expected shortfall (ES) models.

For the EaR or expected shortfall model, the worst case (tail loss) with a certain probability (commonly with the worst 1-5% probability) is calculated. For the VaR confidence intervals of 95-99% are applied to calculate the maximum loss in a certain time frame. A more detailed differentiation between the calculation methods (variance-covariance approach, Monte-Carlo approach) was not applied due to the limited amount of observations and rareness of application from companies in the chemical sector. The more sophisticated (quantitative) techniques are valued with a higher score, up to four points.

0 - Qualitative description
1 - Sensitivity analysis
2 - Scenario analysis
3 - Value at Risk (VaR)
4 - Earnings at Risk (EaR) / Expected Shortfall (ES)

3.5.10 Diversification, geographical

A geographical diversification of business divisions reduces dependencies of regional economic cycles. This also contributes to decrease the volatility in the business areas where companies operate and diversify a broad set of external risk factors. (e.g. supplier risks, legislation risk, terrorism, seizure, natural disasters, war etc.) The geographical diversification was measured by the presence of subsidiaries in different countries and/or continents. Given that there is no academic consensus on how to differentiate multinational/international firms, joint-ventures and other legal constructs were only considered if the company holds a stake of 50% or more (controlling interest). While most (economic) crises/events occur with limited geographic extension and impacts (Asian crisis, Arab Spring, etc.), from a risk perspective a geographically diversified company should benefit from decreased geographic dependency.

0 - National Presence
1 - Multinational Presence (<=1 continent)
2 - International Presence (> 1continet)
3 - Global Presence (World-wide, on all Continents)

3.5.11 Business lines

As well as geographical diversity, a broad product portfolio can contribute to reducing the dependency on a certain chemical market sector and customers. Furthermore, it reduces the impact of price crashes of raw material or sales in certain segments. This gives well diversified companies a certain degree of flexibility to deal with unexpected events and makes them more robust to external (downward risks) impacts. In the chemical industry, where a high degree of substitution exists, this is an especially valuable advantage. The diversification of a company was measured by the amount of (product) divisions if the organisational structure is specified according to the product (end user orientation) or by product families in the portfolio for companies that follow a function structure. (e.g. business divisions according to geographical regions)

3.5.12 Hedging intensity

The variable hedging intensity records if a company regularly hedges input or output factors, focussing on commodity hedging. Companies which hedge raw material prices or other input factors like such as energy prices are recorded with a value of one, whereas companies that do not hedge input/output factors or only rarely do that are recorded with a zero. The effect of hedging on the company's performance is one of the most researched and controversy discussed field in academic literature regarding risk management. The consensus tends to be that hedging contributes to smooth earnings (decrease volatility) and limits risk exposure but also creates opportunity costs that could outweigh the positive effects.

3.5.13 Financial hedging intensity

Analogous to the variable hedging intensity, financial hedging intensity measures if a company regularly hedges (systematic) financial market risks, which can be diversified according to the companies' risk management guidelines. The market risks that are considered here are interest rate, equity, currency and exchange risk. Commodity risk is separately captured by the hedging intensity variable, given the controversial consequences of its implication. The methodology is similar to the variable hedging intensity. Financial hedging intensity is recorded with a value of one for companies which hedge regularly and a zero for companies that do not or only rarely hedge.

4. Summary Statistics

4.1 Sample Overview

The sample of 82 chemical companies was dispersed worldwide. However, 23 out of the 82 companies have their headquarters in the USA, followed by Japan with 19 companies and 10 German chemical companies. This means that 63% of the researched companies have their origin in these three countries. The average company in the sample has a sales volume of approximately $15 billion, employs close to 27.500 and is active in more than one continent (cf. Appendix 8.1).

When it was possible, subsidiaries only active in the chemical segment were observed as a substitute (e.g. Monsanto India). If this was not possible, a dummy for the chemical Industry was implemented (Chemical sales >= 50%) in order to deal with a potential upward bias in the number of employees and sales. This implication is only relevant for the industry characteristics and scope to facilitate a better understanding of the companies in the sample. For the empirical regression analysis, this should not have had any influences as it is not controlled by employees or sales.

What might be problematic it that some subsidiaries are entirely funded by their parental companies (e.g. Bayer CropScience) which could slightly bias the results for some ratios (e.g. Leverage). Additionally, it was assumed that companies roll-out their risk-management frameworks on a company level, including all subsidiaries, if there was no separated annual (risk) reporting found that indicated contrary. For a complete overview of the researched companies (Appendix 8.1).

4.2 Balance Sheet Ratios and Risk Score

	Obs.	*Mean*	*Median*	*Std. Dev.*	*Skewness*	*Kurtosis*	*Min*	*Max*
Market Value Change	836	0,1355	0,0658	0,4591	2,2121	12,4658	-0,8386	3,4274
Risk Score	852	10,4331	10,0000	3,6887	0,7908	4,4292	2,0000	24,0000
Fixed Assets/ Common Equity	891	0,9637	0,8211	0,6943	2,8988	27,4528	-2,6954	8,9256
Total Liabilities/ Total Capital	890	0,5599	0,5769	0,1513	-0,2350	4,0579	0,1000	1,3175
Capital Expenditures/ Total Assets	888	0,0600	0,0504	0,0438	5,1646	69,1108	0,0000	0,7394
Tobin's Q	884	2,3896	2,0400	1,5827	1,2820	5,1277	-1,8900	9,9600
Altman Z-Score	891	1,8833	1,8254	0,6777	0,8789	4,4137	-0,1482	4,9305

Table 1: Summary Statistics - Regression Variables

The sample is based on annual data (year-end prices) which implying a higher standard deviation when compared to monthly or daily data (Table 1). This also explains the larges spread between minimum and maximum prices. In addition, it serves as testament to the very volatile economic environment during the research period with the biggest economic crisis during the last 50 years. Therefore, a closer look at the kurtosis and skewness is necessary.

All variables included in the regression analysis show kurtosis values above three which implies the observations deviate closely around the mean values. The variable distribution is light-tailed and leptokurtic compared to a normal distribution. So, outliers are rare and should not seriously affect the evaluation and it is passed on a normalisation of the data (logs).

The skewness of the sample is positive for almost all variables which indicates a higher likelihood of positive deviations. As outliners in the data are rare, the sample is most likely not biased by it. The outliners or extreme values remaining in the sample were reviewed and validated for their economic plausibility. Outliners that were impossible to validate, were deleted. Extreme high positive values and a market value/price boost of more than 300% increase were a result of the sharp increase in the world crude oil market in 2009/2010. The companies which experienced such a sharp price increase had all a large focus on the petrochemical segment. The dependency of chemical companies on the crude price benchmark was already discussed at the beginning of this paper. These sharp price increases all happened in the years 2009-2010 and hence could be validated and thereby remaining in the sample.

The debt-to-capital ratios were the only slightly negatively skewed variable, explainable by the financial crisis 2008–2009. With respect to fixed-assets-to-equity-capital ratios, between 2007 and 2009, extreme values swinging from 892.56 % and -269.54 % surfaced. Both were caused from a firm in financial trouble that finally declared bankruptcy in 2009, Lyondell Basell. The company emerged from Chapter 11 in 2010 and the values normalised afterwards (Dealbook, 2009). Another suspicious value was found for Sojitz, as a result of a merger (Nichimen and Nissho Iwai formed Sojitz Holding) in 2005 (Sojitz Corporation, 2014). Both extreme values could be economically justified due to the crisis or extraordinary situations affecting the companies, and therefore were kept in the research sample.

These values can be explained by the approach of capturing the smallest possible entity focusing only on the chemical business. For example, BP Castrol and Bayer Cropscience, are subsidiaries established by their parent companies and do not issue debt themselves. As a result, the capital expenditures of their investment activity is reflected in the balance sheet of their parent companies, which were not considered in the sample.

4.3 Development during the Research Period

The mean values of the sample were also examined regarding their time sensitivity (Table 2) – albeit. The debt-to-capital and CAPEX-to-total-assets ratios did not show significant time trends. Significant changes for the year 2009 in the aftermath of the financial crisis had an impact on the valuation proxy Tobin’s Q, CAPEX-to-total-assets, the Altman Z-Score, and the market value development. It is evident that the Tobin’s Q ratio plunged by more than one point in 2008 with the respective drop in market valuation and Altman Z-Score in the year afterwards. This could be proof of a delayed reaction of those both variables. Additionally, it can be seen that the investment activity was reduced by 2 % from 2007–2008 and no rebound observable in the data has been observed. This indicates an increased risk awareness and reduced investments of the companies in the chemical sector. Support for this thesis was delivered by the risk score, which tracks the risk management practices of the companies. While in 2006 companies averaged a risk score of 8.5 points, these increased to more than 11 by 2016. This increase exceeds 2.5 points on average, thus supporting our suggestion that risk management is an increasingly important point on the agenda of companies with high market risk exposure.

Summary Statistics

Year	*Market Value*	*Risk Score*	*Fixed Assets/ Common Equity*	*Total Liabilities/ Total Capital*	*Capital Expenditures/ Total Assets*	*Tobin's Q*	*Altman Z-Score*
2006	0.2947	8.5231	0.9776	0.5641	0.0635	2.5837	1.8647
2007	0.1664	9.4507	1.0937	0.5701	0.0806	2.9058	1.8782
2008	0.1080	9.7568	1.0153	0.5932	0.0685	1.8063	1.9315
2009	-0.3601	10.0897	1.0393	0.5788	0.0569	2.0519	1.7693
2010	0.6923	10.5641	0.9631	0.5551	0.0507	2.5201	1.8909
2011	0.2812	10.6375	0.9085	0.5525	0.0551	2.1251	1.9487
2012	-0.0437	10.8148	0.8860	0.5556	0.0560	2.3152	1.9448
2013	0.0954	10.9146	0.8725	0.5404	0.0583	2.3257	1.9217
2014	0.1919	11.0741	0.9521	0.5517	0.0607	2.4998	1.9111
2015	0.1885	11.1707	0.9438	0.5486	0.0580	2.4890	1.8482
2016	-0.0838	11.0220	0.9579	0.5504	0.0539	2.6798	1.8054
Total	**0.1355**	**10.4331**	**0.9645**	**0.5599**	**0.0600**	**2.3896**	**1.8833**

Table 2: Yearly Averages - Regression variables

4.4 Risk Score Variables

Keeping this in mind, it might be worthwhile taking a closer look at the composition of the Risk Score (Table 3). The data suggest that almost all companies are actively hedging financial risk (interest rate risk, currency risk, credit risk) with financial derivatives. If we look at the hedging intensity that tracks only market price risk (here commodity risk) this statement changes. Less than half of the researched companies regularly hedge their commodity price exposure.

Potential explanations for this astonishing result were found by recent research that showed the influence of overconfidence of risk management decision making and the consequences for it (Tim R. Adam C. S., 2015). Additionally, evidence was found that commodity hedging does not always have positive implications for value creation (Vikas Raman, 2010). Both aspects deliver potential explanations for the companies' cautiousness regarding commodity hedging.

What might also be surprising are the results for the variables which are correlated with an institutional risk management approach. (Institutional ERM, formalized risk evaluation process, Risk Management Standard) Less than half of the companies have a standardised and formalised framework to manage risk, which would guarantee a regularly, objective revisiting of their risk appetite. Advanced tools like risk matrices and TLoD models are even less prominent. This impression is supported by the measuring, forecasting and exposure estimation practices. While most of the companies measure their risk, even though, only by sensitivity analysis, only very few forecast their business performance.

For the exposure estimation, a mixed picture can be drawn. More than half of the companies estimated their market risk exposure with mostly basic tools (Sensitivity analysis). But comprehensive exposure estimation with advanced empirical models to quantify aggregated monetary exposure remains an exception. For (geographical) diversification it can be remarked that the average company is internationally diversified with activities in more than one continent, reducing dependency on a single region or economy. Also, the diversification along business lines (market segments) shows that the average company operates in four different market segments, which implies a well-diversified product portfolio and gives the opportunity to offset downturns in single market segments.

	Obs.	*Mean*	*Median*	*Std. Dev.*	*Min*	*Max*
Institutional ERM	851	0.3114	0	0.4633	0	1
Formalized risk evaluation process	851	0.4289	0	0.4952	0	1
Risk management standard	851	0.1187	0	0.3236	0	1
CRO	851	0.1163	0	0.3208	0	1
Risk matrix	851	0.0505	0	0.2192	0	1
TLoD model	851	0.0106	0	0.1024	0	1
Risk measurement	851	0.9506	1	0.9917	0	3
Forecast model	829	0.2654	0	0.7783	0	3
Exposure estimation	851	0.7897	1	0.9758	0	4
Diversification	829	2.1001	2	0.6673	0	3
Business Lines	851	3.9036	4	1.5912	1	9
Hedging Intensity	840	0.5369	1	0.4989	0	1
Financial Hedging Intensity	851	0.9354	1	0.2460	0	1

Table 3: Summary Statistics - Risk Score Components

4.5 Correlation Coefficients

For the correlation between the explanatory (independent) variables, a threshold of +/- 0.3 was set if there was no economic importance which justified an implementation above this value (Table 4). The total liabilities-to-total capital and Tobin's Q ratio were kept despite a high correlation with the Altman Z-Score as a separate proxy for the leverage of a company and theoretical proxy for evaluation, respectively. It is evident that both debt-to-capital and Tobin's Q ratios are highly correlated with the Altman Z-Score, as it is a linear derivative of a similar ratio in the Altman Z-Score. (X4 Altman: Market Value of Equity/Book Value of

Liabilities). Even though it may decrease the significance of the regression model, the economic explanatory value of a proxy for bankruptcy, in the absence of credit ratings, outweighs the potential statistical drawbacks. The same principle applies to the fixed-assets-to-equity and debt-to- capital correlations. The insight of a leverage ratio outweighs the associated, statistical drawbacks.

	Market Value	*Risk Score*	*Fixed Assets/ Common Equity*	*Total Liabilities/ Total Capital*	*Capital Expenditures/ Total Assets*	*Tobin's Q*	*Altman Z-Score*
Market Value	*1*						
Risk Score	*-0.0428*	*1*					
Fixed Assets/ Common Equity	*-0.0478*	*-0.0733 ******	*1*				
Total Liabilities/ Total Capital	*-0.0038*	*0.0315*	*0.3827 ******	*1*			
Capital Expenditures/ Total Assets	*-0.0326*	*-0.0833 ***	*0.2059 ******	*-0.1363 ******	*1*		
Tobin's Q	*0.1576 ******	*-0.0725 ***	*0.0363*	*0.1552 ******	*-0.0234*	*1*	
Altman Z-Score	*0.1111 ******	*-0.0086*	*-0.2315 ******	*-0.3497 ******	*-0.062 **	*0.2886 ******	*1*

*Significance at *** 0.01% ** 0.05% * 0.1% level*

Table 4: Correlation Coefficients & Statistical Significance

5. Empirical Models

5.1 Verification of the Base Line Model

It is assumed that a fixed effects model fits best for the panel data collected. In the equation below the subscript t denotes the year while the subscripted i denotes the company.

$$\gamma_{i.t} = \alpha_i + \beta * x_{it} + u_{it}$$

Further. it is assumed that there are unobservable individual specific effects included in the sample that cannot be captured by the independent variables. Those are most likely related to company characteristics like the country of origin, the company culture, law environment., etc.

To avoid biases in the regression analysis those effects must be filtered out. With a random effect model, it would be assumed that there are no correlated individual-specific effects in the independent variables. This assumption is very unlikely for the data sample. To validate or reject this assumption of a for the empirical estimations. the Hausman specification test was performed. (Hausman, 1978) The test result rejected the H_0 hypothesis with a confidence level of 99% and therefore strongly preferred fixed effects models over a random effect model (Appendix 8.2.1). The following analysis is therefore executed with variations of a fixed effects model. As a result, it is assumed that slope parameters are constant over companies and over time, as well as intercepts are constant over time. but differ across companies. The model used, allowed for unobserved effects to correlate with the independent variables.

5.2 Regression Estimates

Dependent Variable: Market Value Change	*Fixed Effects*		*Random Effects*	
	Coefficient	*Standard Error*	*Coefficient*	*Standard Error*
Fixed Assets / Common Equity	*-0.2918 ****	*0.0616*	*-0.0791***	*0.0358*
Total Liabilities / Total Capital	*0.6738 **	*0.3579*	*0.1579*	*0.1475*
Capital Expenditures / Total Assets	*-0.2509*	*0.6999*	*0.4850*	*0.5144*
Tobin's Q	*0.1009****	*0.0187*	*0.0384****	*0.0114*
Altman Z - Score	*0.1953****	*0.0512*	*0.0426*	*0.0281*
Risk Score	*-0.0081*	*0.0111*	*-0.0054*	*0.0044*
Intercept	*-0.4864**	*0.2771*	*-0.0306*	*0.1152*
R^2 *within*	*0.1075*		*0.0935*	
Number of Observations	*801*		*801*	
Number of Groups	*82*		*82*	

*Significance at *** 0.01% ** 0.05% * 0.1% level*

Table 5: Regression Results - Fixed Effects vs. Random Effects

The starting point of the analysis is a fixed effects model for the panel data (Table5). Companies were grouped, and year dummies tracked as a time variable with a delta of one. This indicates that the yearly change in percentage was used as a measure. As there was evidence that the data panel shows sign of heteroscedasticity, indicated by the Modified Wald Test, robust standard errors were used to guarantee appropriate significance levels in the following fixed effects regressions. (cf. Appendix 8.2.2.)

The first approach included the five balance sheet ratios which contain risk-management related but also valuation oriented information. Those ratios were complemented by the risk score which is based on qualitative information from the annual reporting.

5.3 Time Fixed Effects

In a second step, year dummies were set to control for the influence of common effects within a year that affected all the companies in the sample (Table 6). This was especially important, as the ten-year time period of the dataset includes the global financial crisis during the years 2008 and 2009 with extraordinary effects on the shape of the worldwide economy. These years could have led to a bias in the analysis of the sample. The adjustment improved the model fit significantly, while before the "plain" fixed effects model could only explain 10% of the variations. controlling for time fixed effects led to 40% explanation value of the variance over time that can be explained by the regressors. The crash of the worldwide economy was also reflected in the regression outcome with a moderately negative effect on the market value in the year 2008, which stepped up in 2009.[2] In 2010 the rebound of the chemical sector is observable. While the model fit greatly improved by controlling for time fixed effect, the fundamental information content about the coefficients were not affected. Only the algebraic sign for the CAPEX-to-total assets ratio changed to a positive value, with no statistical significance. As soon as Region controls were added this effect diminished again and the explanatory value increases compared to the "plain" year controls by approximately 8%. All in all, the adjustments made for time and regions, confirm the results of the base model with no additional explanatory value added.

Dependent Variable:	*Market Value Change*		*Market Value Change*	
	Coefficient	*Robust Standard Error*	*Coefficient*	*Robust Standard Error*
Fixed Assets / Common Equity	*-0.2535****	*0.0599*	*-0.2301****	*0.0577*
Total Liabilities / Total Capital	*0.6376**	*0.3905*	*0.6362**	*0.3816*
Capital Expenditures / Total Assets	*0.0087*	*0.6850*	*-0.2456*	*0.7037*
Tobin's Q	*0.0831****	*0.0202*	*0.0882****	*0.0232*
Altman Z - Score	*0.1791****	*0.0626*	*0.1559***	*0.0650*
Risk Score	*-0.0026*	*0.0108*	*-0.0106*	*0.0112*
Intercept	*-0.3684*	*0.3050*	*-0.6061**	*0.3143*
R^2 *within*	*0.4040*		*0.4816*	
Number of Observations	*801*		*801*	
Number of Groups	*82*		*82*	
Year Controls		*YES*		*YES*
Region Controls		*NO*		*YES*

*Significance at *** 0.01% ** 0.05% * 0.1% level*

Table 6: Regression Results - Time Fixed Effects

5.4 Time Lags

Based on the nature of the data, published annual statements were researched, an additional approach introducing time lags could have led to more feasible results.

Investors, markets and analysts needed time to process and price annual published information. Additionally, it was assumed that companies which increased their market risk management need time to set up the new systems, train their employees and get used to new risk-related procedures. Hence, time-lags were introduced in a couple of ways.

[2] With respect to the theory that risk management only materialize in time when it is needed, the regressions were also executed, isolated for crisis years (2007-2009). No statistical significant change of the regression coefficients could be observed.

Firstly, the independent variables were lagged up to three years (Table 7) to check for a delayed reaction of all coefficients. It was evident that a one-year lag decreased the quality of the regression model. In the contrast, a two-year lag delivered better results and improved the model fit compared to the base model. For a three-year lag, the quality of the regression model sharply declined which indicates too much noise in the data after a time of three years. Also, the number of observations was reduced to almost one-third, which could indicate overextension of the data.

Dependent Variable: Change in	$Market\ Value_{t+1}$		$Market\ Value_{t+2}$		$Market\ Value_{t+3}$	
	Coefficient	*Robust Standard Error*	*Coefficient*	*Robust Standard Error*	*Coefficient*	*Robust Standard Error*
Fixed Assets / Common Equity	-0.0634	0.1146	0.2626***	0.0831	0.0492	0.0694
Total Liabilities / Total Capital	-0.0890	0.4953	0.7691	0.5364	0.6164	0.5064
Capital Expenditures / Total Assets	-2.9359***	0.5226	-1.3282*	0.8874	-0.0575	0.9531
Tobin's Q	0.1277***	0.0348	-0.1803***	0.0242	-0.0158	0.0221
Altman Z - Score	-0.1514*	0.0766	0.1297*	0.0671	0.2027***	0.0674
Risk Score	-0.0081	0.0106	-0.0041	0.0146	0.0093	0.0182
Intercept	0.4678*	0.2785	-0.2462	0.3919	-0.7193*	0.3413
R^2 *within*	0.0920		0.1467		0.0221	
Number of Observations	736		669		593	
Number of Groups	82		82		82	

*Significance at *** 0.01% ** 0.05% * 0.1% level*

Table 7: Regression Results - Leaded Market Value

Secondly, time lags were introduced for the risk score variable (Table 8). to verify the assumption of a time delay regarding the introduction of newly implemented risk management tools. While investors could observe and interpret performance ratios (risk related ratios) immediately, it took time for them to understand and evaluate the potential impact of new risk management procedures used by the respective companies. This assumption did not hold, as can be seen by the explanatory power already decreasing with the implementation of a one-year lag and turning worse when implementing higher time lags. When controlling for all time lagged risk score variables at the same time this effect increased, and the explanatory power of the regression model diminished.

One exception marks a time lag of four years. In this case the data indicates a questionable, strong negative impact of risk management. It is supposed that this result is based on other effects that influence the market valuation of a company. considering the long period that passed by, as this effect cannot be confirmed by any other time-lag implemented.

Dependent Variable: Market Value Change	$Risk\ Score_{t-1}$	$Risk\ Score_{t-2}$	$Risk\ Score_{t-3}$	$Risk\ Score_{t-4}$	$Risk\ Score_{t-5}$
	Coefficient (Robust Standard Error)	Coefficient (Robust Standard Error)	Coefficient (Robust Standard Error)	Coefficient (Robust Standard Error)	Coefficient (Robust Standard Error)
Fixed Assets / Common Equity	-0.2854*** (0.0624)	-0.3214*** (0.0710)	-0.2245*** (0.0581)	-0.2124** (0.0994)	-0.1992** (0.0769)
Total Liabilities / Total Capital	0.8533* (0.4779)	0.7907* (0.4743)	0.2702 (0.5367)	0.2084 (0.5138)	-0.0545 (0.5835)
Capital Expenditures/ Total Assets	-0.7690* (0.3268)	0.0914 (0.6711)	-0.0732 (0.8451)	0.3309 (0.9870)	1.4052* (0.8423)
Tobin's Q	0.0991*** (0.0201)	0.1020*** (0.0223)	0.0897*** (0.0249)	0.1067*** (0.0294)	0.0833*** (0.0249)
Altman Z - Score	0.2203*** (0.0635)	0.2006*** (0.0692)	0.1947*** (0.0803)	0.0560 (0.0698)	0.1387** (0.0575)
(lagged) Risk Score	-0.0061 (0.00097)	-0.0097 (0.0149)	0.0036 (0.0175)	-0.0963*** (0.0177)	-0.0092 (0.0060)
Intercept	-0.6315* (0.3378)	-0.5393 (0.3863)	-0.4407 (0.4225)	0.8254** (0.4061)	-0.1459 (0.3627)
R^2 within	0.1071	0.0954	0.0849	0.1942	0.1036
Number of Observations	734	665	589	511	434
Number of Groups	82	82	82	82	82

*Significance at *** 0.01% ** 0.05% * 0.1% level*

Table 8: Regression Results - Lagged Risk Score

5.5 Marginal Effects

The examination of a non-linear relationship between the risk score and the market value development was included in the next part of the analysis (Table 9). It was assumed that the relationship between market value and the risk score was U-shaped.

Dependent Variable: Market Value Change

	Coefficient	Robust Standard Error
Fixed Assets / Common Equity	-0.2963***	0.0673
Total Liabilities / Total Capital	0.6799*	0.34163
Capital Expenditures / Total Assets	-0.2864	0.6597
Tobin's Q	0.1009***	0.0187
Altman Z - Score	0.1941***	0.0607
Risk Score	-0.0323	0.0247
$Risk\ Score^2$	0.0011	0.0010
Intercept	-0.3622	0.3415
R^2 within	0.1080	
Number of Observations	801	
Number of Groups	82	

*Significance at *** 0.01% ** 0.05% * 0.1% level*

Table 9: Regression Results - Marginal Effects

This implies that the risk score must exceed a critical level before positive effects could be observed. Economically, it could be argued that the costs of risk management tools outweighed the benefits until this critical level is exceeded. After this point is reached, additional tools exhibited positive impact on market development. As evident as this might appear, in the researched sample no statistically significant evidence could be derived to validate this thesis.

5.6 Risk Score Dummy

The last step of the risk score analysis marked a regression with a risk score dummy variable (Table 10). The sample was split into two categories: Companies with high risk management scores (above the median of 10) and companies with risk score values below this threshold. To test the assumption outlined before, risk management needed to pass a critical level to actively contribute to the company's performance. The same effects shown in the baseline model could be observed. Three-out-of-six included explanatory variables remained statistically significant. The significance of the leverage ratio turned insignificant, while it is not possible to derive any further effect on the relationship between (high/low) risk scores and market value development. This dummy model marked the end of the empirical research. In the next chapter, the empirical results are discussed regarding their economic information content.

Dependent Variable: Market Value Change

	Coefficient	*Robust Standard Error*
Fixed Assets / Common Equity	*-0.1544****	*0.0451*
Total Liabilities / Total Capital	*0.3253*	*0.3394*
Capital Expenditures / Total Assets	*-0.5221*	*0.6947*
Tobin's Q	*0.1121****	*0.0186*
Altman Z - Score	*0.1932****	*0.0513*
High Low Risk Score	*0.0052*	*0.0711*
Intercept	*-0.5154***	*0.2372*
R^2 *within*	*0.0973*	
Number of Observations	*801*	
Number of Groups	*82*	

High Low Risk Score is a dummy variable for companies with a Score above the Median of 10. the variable takes a value of 1 for companies below the median the variable takes a value of 0
*Significance at *** 0.01% ** 0.05% * 0.1% level*

Table 10: Regression Results - Risk Score Dummy

6. Discussion of the Empirical Results

For the base model. five balance sheet ratios were estimated accompanied by the qualitative based risk score. The balance sheet ratios provided some explanatory value and indicated the risk awareness of investors. In other words, while financial markets remunerated companies with solid risk-related performance ratios, this rationale could not be applied to the risk score variable based on quantitative information indicating how companies manage risk.

6.1 Ratios

Regarding the ratios, it is possible to conclude that some of them seem to had a bigger impact on market value development while others seem not to be that important for investors.

The fixed assets -to- common equity ratio captured the source of financing of assets for long-term usage. It is evident on a 99% confidence level that the markets punished chemical companies that funded their investments in fixed assets with a high degree of debt.

An explanation for these findings is increased creditors interest, increased interest expenses and also the risk of bankruptcy. Assets that were not financed by equity could not be collateralised or sold in the case of bankruptcy, which increased the risk of shareholders suffering significant losses. On average, a one percent higher ratio led to a 0.29 % decline in market value. While the exact value varied across the different adaptions of the baseline model, overall the effects were statistically significant, with the exception of the time-lagged regression.

Surprisingly, the Total Liabilities to Total Capital (leverage) showed the opposite sign, on a confidence interval of at least 90%. Only for the last adaption – the split of the sample into high and low risk scores – was this effect not observable. While it might be surprising that a higher leverage seemed to positively affect the company's market value development, especially when taking the fixed assets to common equity ratio into account, a potential explanation might be the assumption of financial markets that the average chemical company could increase their performance by unlocking potential tax shield benefits that outweighed the potential bankruptcy costs (Franco Modigliani, 1959) – although, to a certain degree, the results for the feasibility of assets contradict this inference.

The CAPEX to total assets ratio shows the investment activities of a firm in their capital stock. In this sample, this ratio also had a negative algebraic sign, even though statistical significance was not given, so no solid statement can be derived. Only for a one-year lag statistical significance could be achieved. In this case, a comparable strong negative effect has been observed.

The third ratio, Tobin's Q, was introduced as a theoretical measure for over or undervaluation of the companies in the sample. Referring to the summary statistics, it must be mentioned that the samples' median showed a value of 2. Usually, values above 1 already indicate an overvaluation. An explanation for the relatively high company valuation in the sample could be the monetary policy of the leading national banks in the aftermath of the financial crisis. To fight the drain of liquidity in the banking sector, the worldwide leading central banks started an expansive monetary policy that flooded the financial markets. This led to diminishing interests in the worldwide bond markets and boosted share prices. This was a result of the search for interest by investors. Another explanation could be the nature of the Tobin's Q ratio and its interpretation. There is evidence that Tobin's Q ratio is not only a proxy for the fair value of a company; it can also be an indicator of superior future performance, as new studies have shown (Liang Fu, 2016). By introducing time lags, it became possible to confirm this effect in our sample. Nevertheless, Tobin's Q ratio had a strong, statistically significant effect on the market valuation of the researched companies, with an average increase around 10bp. per one-point increase in Tobin's Q in most of the models.

The Altman Z-Score was introduced as a proxy for credit risk in the absence of credit rating for most of the companies in the sample. It can be remarked that there was statistically significant evidence investors took credit risk into account as an increase in the Altman Z-Score had a positive effect on the market value development on average of 19.5 bp. Markets seemed to remunerate companies with solid credit ratings. This result was also not violated by the adaption of region controls, marginal effects or controlling for time fixed effects. Only by the introduction of time lags was a statistically significant negative effect observable – albeit, with a questionable explanatory contribution.

6.2 Risk Score

The Risk Score variable measured the impact of risk management or in other words highlights how precisely a company manages risk. As the effects were not statistically significant, the only possible statement that can be derived from the empirical sample data is that companies' risk management had a limited effect on market value development. Financial markets and investors seemed to assess their risk appetite and the associated selection of investments via fundamental analysis and ratios. Strictly qualitative risk assessment seemed to play a more important role for regulatory authorities.

Another explanation could have been the time delay of risk management contributing towards company performance. Risk management-related benefits might only have been realised when risks materialised. This would indicate that risk management played off its strengths only during a crisis (i.e., economically volatile scenarios) while remaining mainly a cost factor in a stable economic environment. Given that the sample included a very volatile time period – the financial crisis in 2008–09 and the subsequent worldwide economic recession – this seems unlikely.

What could be a more feasible explanation is based on the risk-return trade-off theory. Companies which invest in risk management become safer and therefore investors require smaller returns for their (less) risky investments which finally leads to a more stable but lower growth rate of their respective market valuations.

7. Conclusion

While several economically plausible adjustments were done, none of them provided statistical significance that allows one to draw convincing arguments in favour of a positive effect of more sophisticated risk management frameworks on market value development for chemical firms. Investors base their investment decisions on a multitude of company criteria they consider – of which risk management is only one. In the aftermath of the financial crisis of 2008 and the following recession years, risk and risk management experienced a more prominent role in financial and decision-making and for investors as an investment criterion (Luigi Guiso, 2018). Nevertheless, the hypothesis that chemical industry companies with stronger risk management perform better in crisis scenarios can be rejected.

In the statistical analysis, however, significant effects were observed for risk-related ratios derived from balance sheet data. Investors seemed to include them in their investment decisions. Therefore, chemical companies with "better" ratios experienced higher valuations on financial markets (market value). This statement can be validated by the statistical significant explanatory variables for feasibility (fixed assets-to-common equity), leverage (total liabilities-to-total capital), the valuation and forecast proxy of business performance (Tobin's Q) and the proxy for bankruptcy risk (Altman Z-Score). The empirical evaluation suggests a focus of investors on a (risk-related) ratio analysis. Investors seem to care about the outcome of the risk profile and management of companies but not how those outcomes are accomplished.

The researched sample does not allow drawing any conclusions in this respect, given that it was not possible to extract an industry standard since the quality of risk management and the associated reporting varied widely through the sample. Nearly all companies hedge financial risks and monitor their (derivative) portfolio risk and exposure by sensitivity analysis at a minimum. What is also evident is that chemical companies enhanced their risk management efforts during the researched period of ten years. This indicates an increased awareness to the theme risk in strategic decision-making outside the financial industry, where the most mature risk management tools and frameworks can be found. Even though financial markets and investors do not seem to care that much about the companies' approach regarding the risk management, financial markets and investors do not seem to care that much about the companies' approach regarding risk management, when considering the information collected to build the risk score. However, investors value positively financial ratios that reflect the companies' risk profile. So, even though investors do not seem to explicitly value the details of the risk management policies pursued by firms, they clearly value the outcomes of those policies.

Bibliography

Adriano A. Rampini. A. S. (2014). Dynamic risk management. *Journal of Financial Economics. 111*. 271 -296.

Altman. E. I. (2000). *Predicting Financial Distress of Companies: Revisiting the Z - Score and ZETA ® Models.* New York: Stern School of Business New York University.

André P. Liebenberg. R. E. (2003). The Determinants Of Enterprise Risk Management: Evidence From The Appointment Of Chief Risk Officers . *Risk Management and Insurance Review. 6*(1). 37-52.

Andrew Ellul. V. Y. (2013). Stronger Risk Controls. Lower Risk: Evidence from U.S. Bank Holding Companies. *Journal of Finance. 68*(5). 1757-1803.

Brian W. Nocco. R. M. (2006). Enterprise Risk Management: Theory and Practice. *Journal of Applied Corporate Finance. 18*(4). 8-20.

Charles Smithson. R. A. (2005). Does Risk Management Add Value? A Survey of the Evidence. *Journal of Applied Corporate Finance. 17*(3). 8-17.

Chartered Institute of Internal Auditors. (2015. 12 10). *Chartered Institute of Internal Auditors.* Retrieved April 15. 2018. from https://www.iia.org.uk/resources/audit-committees/governance-of-risk-three-lines-of-defence/

Clifford W. Smith. R. M. (1985). The Determinants of Firms' Hedging Policies. *Journal of Financial and Quantitative Analysis. 20*(4). 391-405.

Committee of Sponsoring Organizations of the Treadway Commission. (2004). *Enterprise Risk Management — Integrated Framework. Executive Summary.* -: COSO.

David A. Carter. D. A. (2006. December 7). Hedging and Value in the U.S. Airline Industry. *Journal of Applied Corporate Finance. 18*(4). 21-33.

David A. Carter. D. A. (2017). A Review of the Literature on Commodity Risk Management (Accepted Manuscript). *Journal of Commodity Markets*.

David de Angelis. S. A. (2016). Input Hedging. Output Hedging. and Market Power. *Journal of Economics & Management Strategy. 26*(1). 123 -151.

Dealbook. (2009. January 6). *The New York Times*. Retrieved May 8. 2018. from Lyondell Files for Bankruptcy - The New York Times: https://dealbook.nytimes.com/2009/01/06/lyondellbasell-us-unit-files-for-bankruptcy/

Deloitte. (2014). *Pricing in the Chemical Industry Boost your pricing power.* Deloitte.

Dolde. W. (1993. Fall). The Trajectory of Corporate Financial Risk Management . *Journal of Applied Corporate Finance . 6*(3). 33-41.

Federal Reserve Bank of St. Louis. (2018). *Producer Price Index by Commodity for Chemicals and Allied Products: Industrial Chemicals*. Retrieved May 5. 2018. from Federal Reserve Bank of St. Louis - Economic Research: https://fred.stlouisfed.org/series/WPU061

Francisco Pérez-González. H. Y. (2013). Risk Management and Firm Value: Evidence from Weather Derivatives. *The Journal of Finance. 68*(5). 2143 - 2176.

Franco Modigliani. M. H. (1959). The Cost of Capital. Corporation Finance. and the Theory of Investment: Reply . *The American Economic Review. 49*(4). 655-669.

George Allayannis. J. P. (2001). The Use of Foreign Currency Derivatives and Firm Market Value. *The Review of Financial Studies. 14*(1). 243-276.

GM Bodnar. G. H. (1998. Winter). 1998 Wharton Survey of Financial Risk Management by US Non-Financial Firms . *Financial Management. 27*(4). 70-91 .

Gordon M. Bodnar. E. G. (2011). *Managing Risk Management.* SSRN.

Gregory W. Brown. P. R. (2006. November). Are Firms Successful at Selective Hedging? . *The Journal of Business. 79*(6). 2925-2949 .

Haushalter. D. G. (2000). Financing Policy. Basis Risk. and Corporate Hedging: Evidence from Oil and Gas Producers. *The Journal of Finance. 55*(1). 107-152.

Hausman. J. A. (1978). Specification Tests in Econometrics. *Econometrica. 46*(6). 1251-1271.

ICIS. (2017). *Special Report ICIS Top 100 Chemical Companies.* London: ICIS.

John R. Graham. D. A. (2002 . December 12). Do Firms Hedge in Response to Tax Incentives? *Journal of Finance. 57*(2). 815-839.

KA Froot. D. S. (1993. December). Risk management: Coordinating corporate investment and financing policies. *The Journal of Finance. 48*(5). 1629-1658.

Liang Fu. R. S. (2016). Tobin’s q Ratio and Firm Performance. *International Research Journal of Applied Finance. 7*(4). 1-10.

Luigi Guiso. P. S. (2018. June). Time Varying Risk Aversion. *Journal of Financial Economics. 128*(3). 403-421.

Martin F. Grace. J. T. (2014). The Value of Investing in Enterprise Risk Management. *The Journal of Risk and Insurance. 9999*(9999). 1-28.

Bibliography

N.K Chidambaran. C. S. (2001. May). Credit enhancement through financial engineering: Freeport McMoRan's gold-denominated depositary shares. *Journal of Financial Economics. 6*(2-3). 487-528.

Peter Mackay. S. B. (2007). The Value of Corporate Risk Management. *The Journal of Finance. 62*(3). 1379 - 1418.

Peter Mackay. S. B. (2010). Corporate Risk Management: What Can We Learn from Financial Statements? *Australasian Banking and Finance Conference.*

Pirrong. C. (2015). Risk Management by Commodity Trading Firms: The Case of Trafigura. *Journal of Applied Finance. 27*(1). 19 - 26.

Robert E. Hoyt. A. P. (2011). The Value of Enterprise Risk Management . *The Journal of Risk and Insurance. 78*(4). 795-822.

Sheng Hong. C. M. (2015). *McKinsey on Chemicals: Oil-price shocks and the chemical industry: Preparing for a volatile environment.* McKinsey & Company.

Sojitz Corporation. (2014. April 16). *https://www.sojitz.com/history/en/company/sojitz/.* Retrieved May 3. 2018. from The Sojitz History Museum- Sojitz Corporation.

Stein. M. C. (2002). Auditing Risk Management: Fine in Theory but who can do it in Practice? *International Journal of Auditing. 6*. 119-131.

Stulz. R. M. (2008. December 16). Risk Management Failures: What Are They and When Do They Happen? *Journal of Applied Finance . 20*(4). 39-48.

Tim R. Adam. C. S. (2006). Hedging. speculation. and shareholder value. *Journal of Financial Economics. 81*. 283 - 309.

Tim R. Adam. C. S. (2008). Can Companies Use Hedging Programs to Pro t from the Market? Evidence from Gold Producers. *Journal of Applied Corporate Finance. 20*(4). 86 - 97.

Tim R. Adam. C. S. (2015). Managerial Overconfidence and Corporate Risk Management (Accepted Manuscript). *Journal of Banking & Finance.* -(-). -.

Tufano. P. (1996). Who Manages Risk? An Empirical Examination of Risk Management Practices in the Gold Mining Industry. *The Journal of Finance. 51*(4). 1097 - 1137.

Vikas Raman. C. S. (2010). Is Hedging Bad News? Evidence from Corporate Hedging Announcements. *unpublished*.

Yanbo Jin. P. J. (2006). Firm Value and Hedging: Evidence from U.S. Oil and Gas Producers. *The Journal of Finance. 61*(2).

8. Appendix

8.1 Sample Overview

NAME	Sales 2016 in $m.	Assets 2016 in $m.	Employees (consolidated)	Country of Origin	Chemical Industry	Alive after 2016
AGRIUM INC	13.578.772	17.136.126	27810	Canada	x	Merged with Potash in 2017
AIR PRODUCTS & CHEMS	9.524.400	17.862.600	15300	USA	x	x
AKZO NOBEL N.V.	15.593.915	16.672.538	45800	Netherlands	x	x
ALPEK SA DE CV	5.079.800	5.129.082	5284	Mexico	x	x
ARKEMA SA	8.276.407	9.752.650	19000	France	x	x
ASAHI KASEI	17.097.549	19.306.120	33720	Japan		x
ASHLAND GLOBAL	4.948.000	9.520.000	6442	USA	x	x
BASF SE	63.212.635	81.262.561	113830	Germany	x	x
BAYER CORPSCIENCE AG	545.835	362.004	13083	Germany	x	x
BP CASTROL K.K	63.212.635	132.777	74500	UK	x	x
BP PLASTICS HLDG BHD	79.160	58.956	-	Malaysia	x	x
BRASKEM S.A.	12.642.395	13.306.754	7656	Brasil	x	x
CELANESE CORPORATION	12.642.395	8.198.000	7592	USA	x	x
CF INDUSTRIES HOLDINGS INC	3.685.000	15.131.000	2900	USA	x	x
CLARIANT AG	5.856.276	8.079.797	18000	Switzerland	x	x
DAICEL CORP	3.962.984	4.927.166	10173	Japan	x	x
DIC CORPORATION	6.619.432	6.411.486	20034	Japan	x	x
DOW CHEMICAL COMPANY	48.158.000	76.432.000	56000	USA	x	Merged with DuPont in 2017
E. I. DU PONT DE NEMOURS COMPANY (DUPONT)	24.594.000	36.656.000	46000	USA	x	Merged with Dow Chemical in 2017
EASTMAN CHEMICAL CO	9.008.000	15.457.000	15000	USA	x	x
ECOLAB INC	13.152.800	18.237.900	47565	USA	x	x
EVONIK INDUSTRIES AG	13.984.766	20.301.636	28430	Germany	x	x
EXXON MOBIL CORPORATION	197.518.000	330.314.000	71100	USA		x
FMC CORPORATION	3.282.400	5.894.500	7000	USA	x	x
GIVAUDAN SA	4.670.397	6.264.923	11000	Switzerland	x	x
GS HOLDINGS CORP	10.583.952	16.864.726	-	South Korea	x	x
HANWHA CHEMICAL CORP	7.705.738	11.450.082	-	Japan	x	x
HENKEL AG AND	20.555.365	29.546.827	51350	Germany	x	x
HONEYWELL INTERNATIONAL	39.302.000	53.799.000	-	USA		x
HUNTSMAN CORPORATION	9.657.000	8.793.000	15000	USA	x	x
ICL ISRAEL CHEMICA	5.236.644	8.236.181	12272	Israel	x	x
INDORAMA VENTURES	7.183.001	7.226.092	14000	Thailand	x	x
INTERNATIONAL FLAVORS&FRAGRANCES	3.116.350	3.878.348	7300	USA	x	x
JOHNSON MATTHEY PLC	15.218.020	5.731.313	12214	UK	x	x
JSR CORP	3.406.527	4.548.616	7055	Japan	x	x
K&S AG	3.796.712	10.465.618	14530	Germany	x	x
KANEKA CORPORATION	4.891.005	5.042.714	8400	Japan	x	x
KONINKLIJKE DSM N.V.	8.699.289	13.843.073	15000	Japan	x	x
KURARAY CO., LTD.	4.274.066	6.327.836	7550	Japan	x	x
L'AIR LIQUIDE SA	19.919.175	48.258.975	67000	France	x	x
LANXESS AG	8.456.543	10.363.357	19200	Germany	x	x
LG CHEMICAL LIMITED	17.193.865	16.908.889	29573	South Korea	x	x
LINDE AG	18.615.599	38.102.226	59715	Germany	x	x
LONZA GROUP AG	4.138.555	6.800.771	14500	Switzerland	x	x
LYONDELLBASELL INDUSTRIES	29.041.984	24.209.725	13000	USA	x	x
MERCK KGAA	16.502.287	40.870.181	68000	Germany		x
MEXICHEM SAB DE CV	5.619.400	10.164.229	22000	Mexico	x	x
MITSUBISHI CHEMICALS HOLDING	33.677.744	35.230.448	69291	Japan	x	x
MITSUBISHI GAS CHEM	5.228.171	6.493.692	5445	Japan	x	x
MITSUI & CO., LTD.	41.645.538	95.298.438	13423	Japan	x	x
MONSANTO INDIA	80.633	78.154	-	India	x	Ongoing Acquisition with Bayer 2018
NATIONAL INDUSTRIALIZATION COMPANY (TASNEE	4.052.030	11.492.595	7000	Saudi Arabia	x	x
OCCIDENTAL PETROLEUM	10.196.000	43.109.000	11200	USA		x
ORICA LIMITED	3.801.596	4.619.567	11500	Australia		x
PETRONAS CHEMICALS	3.382.543	7.684.182	4659	Malaysia	x	x
POLYONE CORP	3.339.800	2.723.300	6000	USA	x	x
PPG INDUSTRIES INC	14.751.000	15.615.000	47000	USA	x	x
PRAXAIR, INC.	10.534.000	19.147.000	26000	USA	x	x
PTT GLOBAL CHE	9.848.394	11.082.868	42000	Thailand	x	x
RELIANCE INDUSTRIES	41.173.828	90.257.431	250000	India		x
RPM INTERNATIONAL	4.813.649	4.756.270	14000	USA	x	x
SASOL LIMITED	11.303.049	25.314.575	30100	South Africa	x	x
SAUDI BASIC INDUSTRIES (SABIC)	35.416.102	84.095.076	35000	Saudi Arabia	x	x
SEKISUI CHEMICAL CO.	9.657.478	8.202.236	15601	Japan	x	x
SHERWIN-WILLIAMS CO	11.855.602	6.752.521	42550	USA	x	x
SHIN-ETSU CHEMICAL	11.273.845	21.966.409	17892	Japan	x	x
SHOWA DENKO K.K.	5.912.253	8.135.861	10864	Japan	x	x
SIAM CEMENT PUBLIC	11.945.615	15.058.032	53728	Thailand		x
SINOPEC SHANGHAI	10.120.557	5.194.472	-	China		x
SOJITZ CORP	14.605.988	18.051.117	17917	Japan		x
SOLVAY SA	12.524.999	25.543.177	26887	Belgium	x	x
SUMITOMO CHEMICAL CO	18.514.480	23.331.296	31094	Japan	x	x
SYMRISE AG	3.188.846	5.107.583	8944	Germany	x	x
SYNGENTA AG	12.665.277	18.609.650	27810	Switzerland		x
TAIYO NIPPON SANSO	5.651.127	6.880.020	15860	Japan		x
TEIJIN LIMITED	6.965.714	7.215.917	19292	Japan		x
THE MOSAIC COMPANY	7.162.800	16.004.300	8500	USA	x	x
THE VALSPAR CORP	4.190.552	4.293.376	11083	USA	x	Acquired by Sherwin-Williams in 2017
TOSOH CORP	6.639.675	6.427.096	12292	Japan	x	x
WACKER CHEMIE AG	5.935.947	7.701.617	13811	Germany	x	x
WESTLAKE CHEM CORP	5.075.456	10.877.727	8800	USA	x	x
YARA INTERNATIONAL	11.192.082	13.856.584	12883	Norway	x	x

8.2 Robustness Tests

8.2.1 Hausman specification test

Coefficients

(b) fe	(B) re	(b-B) Difference	Sqrt (diag(V_b-V_B)) S.E.
-0.2918	-0.0791	-0.2127	0.0502
0.6737	0.1579	0.5159	0.3261
-0.2509	0.4850	-0.7359	0.4747
0.1009	0.0384	0.0626	0.0149
0.1953	0.0426	0.1527	0.0428
-0.0081	-0.0054	-0.0027	0.0101

b = consistent under Ho and Ha; obtained from xtreg
B = inconsistent under Ha. efficient under Ho; obtained from xtreg

H0: difference in coefficients not systematic; Random Effects Model
Ha: difference in coefficients systematic; Fixed Effects Model

Test:

chi2 (6)= (b-B) ' [(V_b-V_B) ^(-1)] (b-B)

= 58.61

Prob>chi2 =0

8.2.2 Modified Wald Test

Modified Wald test for group wise Heteroscedasticity in Fixed Effect Regression Model

H0: sigma(i)^2 = sigma^2 for all i		*H0: Homoscedasticity*
		Ha: Heteroscedasticity
chi2 (82) =	*2868.52*	
Prob>chi2 =	*0.0001*	

8.3 Stata Code

PART I - Data preparation
PART II - Summary Statistics
PART III - Regression Models
PART IV - Robustness Tests

PART I – Data preparation
(The following steps are repeated before each regression. they will not be repeated in the explanations)

```
//Converting string variables to numeric
. destring MV TobinsQ AltmanZScore FixedAssetsCommonEquity CapitalExTotalAssets TotalLiabilitesTotalCapital RiskScore. replace force

//Group the companies according to their name for observation 1-902
. list Name no in 1/902. sepby(Name)
//Generate a new numeric variable instead of the string variable company name
. egen Firm = group(Name)
//List the observations company (groups)
. list Name Firm in 1/902. sepby(Name)
//Set firm. the new numeric variable. as identifier for the group variable. no called firm
. xtset Firm
//Set Year as time variable
. tsset Firm Year
```

PART II – Summary Statistics

Explanatory Variables

```
//Converting string variables to numeric
. destring MV TobinsQ AltmanZScore FixedAssetsCommonEquity CapitalExTotalAssets TotalLiabilitesTotalCapital RiskScore. replace force

//Summary statistics for the explanatory variables. options: Observations. Mean. Median. Skewness. Kurtosis. Minimum. Maximum and Standard Deviation
. tabstat MV TobinsQ AltmanZScore FixedAssetsCommonEquity CapitalExTotalAssets TotalLiabilitesTotalCapital RiskScore. s(n mean median skewness kurtosis min max sd)
```

Risk Score variables

```
//Converting string variables to numeric
. destring Institutional_ERMbinary Formalized_risk_evaluation_proce RM_standardCOSO CRO Risk_matrix TLoD_model Risk_measurement Forecast_model Exposure_estimation D
> iversification BusinessLines Risk. replace force

//Summary statistics for the risk score variables. options: Observations. Mean. Median. Skewness. Kurtosis. Minimum. Maximum and Standard Deviation
```

. tabstat Institutional_ERMbinary Formalized_risk_evaluation_proce RM_standardCOSO CRO Risk_matrix TLoD_model Risk_measurement Forecast_model Exposure_estimation D
> iversification BusinessLines Risk. s(n mean median skewness kurtosis min max sd)

//Generate Mean values for the explanatory variables according to the time variable Year and generate a new variable Mean XXX

. egen MEAN=mean(RiskScore). by(Year)
. egen MEANFACE=mean(FixedAssetsCommonEquity). by(Year)
. egen MEANTLTC=mean(TotalLiabilitesTotalCapital). by(Year)
. egen MEANCAPEX=mean(CapitalExTotalAssets). by(Year)
. egen MEANTQ=mean(TobinsQ). by(Year)
. egen MEANALTMAN=mean(AltmanZScore). by(Year)

//Generate a summary table of the Mean variable according to the time variable year
. tabstat MEANMV MEANRS MEANFACE MEANTLTC MEANCAPEX MEANTQ MEANALTMAN. by(Year)

Correlation Coefficients & Statistical significance

// Generate a Correlation table for the explanatory variables and provide the associated statistical significance (t-values)
.pwcorr MV TobinsQ AltmanZScore FixedAssetsCommonEquity CapitalExTotalAssets TotalLiabilitesTotalCapital RiskScore. sig

PART III - Regression – Models

Fixed Effect regression
/Run a Fixed Effects Regression with the variables: DV: Market Value IV: FixedAssetsCommonEquity. CapitalExTotalAssets. TotalLiabilitesTotalCapital. TobinsQ AltmanZScore and RiskScore ; using robust standard errors

. xtreg MV FixedAssetsCommonEquity CapitalExTotalAssets TotalLiabilitesTotalCapital TobinsQ AltmanZScore RiskScore.fe robust

Time Fixed Effects Regression

//Run a Time Fixed Effects Regression. generate time dummies (factor variable) for each year ; using robust standard errors
. xtreg MV FixedAssetsCommonEquity CapitalExTotalAssets TotalLiabilitesTotalCapital TobinsQ AltmanZScore RiskScore i.Year.fe robust

Time Fixed Effects Regression & Region dummies

//Run a (Time) Fixed Effects Regression with Year and Region dummies. combine both factor variables ; using robust standard errors
. xtreg MV FixedAssetsCommonEquity CapitalExTotalAssets TotalLiabilitesTotalCapital RiskScore TobinsQ AltmanZScore i.Year#i.RegionDummie.fe robust

Time Lags

//Set Year as time variable
. tsset Firm Year

//Generate the variable Lag1RS by lagging the variable Risk Score by 1-time entity
. gen Lag1RS =l.RiskScore
//Generate the variable Lag2RS by lagging the variable Risk Score by 2-time entities
. gen Lag2RS =l2.RiskScore
//Generate the variable Lag3RS by lagging the variable Risk Score by 3-time entities
. gen Lag3RS =l3.RiskScore
//Generate the variable Lag4RS by lagging the variable Risk Score by 5-time entities
. gen Lag4RS =l4.RiskScore
//Generate the variable Lag5RS by lagging the variable Risk Score by 5-time entities
. gen Lag5RS =l5.RiskScore

//Run a Fixed Effects Regression ; using robust standard errors
.xtreg MV FixedAssetsCommonEquity TotalLiabilitesTotalCapital CapitalExTotalAssets TobinsQ AltmanZScore RiskScore Lag1RS Lag2RS Lag3RS Lag4RS Lag5RS.fe robust

Time Leads

//Set Year as time variable
. tsset Firm Year

//Generate the variable Lead1MV by leading the variable Marek Value by 1-time entity
. gen Lead1MV =f.MV
//Generate the variable Lead2MV by leading the variable Marek Value by 2-time entities
. gen Lead2MV =f2.MV
//Generate the variable Lead2MV by leading the variable Marek Value by 2-time entities
. gen Lead3MV =f3.MV
//Generate the variable Lead2MV by leading the variable Marek Value by 2-time entities
. gen Lead4MV =f4.MV
//Generate the variable Lead2MV by leading the variable Marek Value by 2-time entities
. gen Lead5MV =f5.MV

//Run a Fixed Effects Regression with leaded market value as dependent variable ; using robust standard errors
.xtreg Lead1MV FixedAssetsCommonEquity TotalLiabilitesTotalCapital CapitalExTotalAssets TobinsQ AltmanZScore RiskScore.fe robust

Marginal Effects of the Risk Score variable

//Generate the variable sq_RiskScore by squaring the variable RiskScore
.gen sq_RiskScore = RiskScore^2

//Run a Fixed Effects Regression with the explanatory variables RiskScore and squared RiskScore ; using robust standard errors

. xtreg MV FixedAssetsCommonEquity TotalLiabilitesTotalCapital CapitalExTotalAssets TobinsQ AltmanZScore RiskScore sq_RiskScore.fe robust

Risk Score Dummies

//Run a Fixed Effects Regression with the explanatory variables High_LowRS (prepared in Excel: 1 for values above median/ 0 for values below median) ; using robust standard errors
. xtreg MV FixedAssetsCommonEquity TotalLiabilitesTotalCapital CapitalExTotalAssets TobinsQ AltmanZScore High_LowRS .fe robust

PART IV – Robustness Tests

Hausman Test for: Fixed Effects or Random Effects
(H0: RE Model / Ha: FE Model)

//Run a Random Effects Regression with the (base) model
. xtreg MV FixedAssetsCommonEquity TotalLiabilitesTotalCapital CapitalExTotalAssets TobinsQ AltmanZScore RiskScore.fe

//Run a Random Effects Regression with the (base) model
. xtreg MV FixedAssetsCommonEquity TotalLiabilitesTotalCapital CapitalExTotalAssets TobinsQ AltmanZScore RiskScore.re

//Store the estimates of the Fixed Effects Regression
. estimate store fe

//Store the estimates of the Random Effects Regression
. estimate store re

//Run the Hausman specification test for Fixed Effects vs. Random Effects
. hausman fe re

Modified Wald test for group wise Heteroscedasticity in Fixed Effect Regression Model
(H0: Homoscedasticity / Ha: Heteroscedasticity)

.xtreg MV FixedAssetsCommonEquity TotalLiabilitesTotalCapital CapitalExTotalAssets TobinsQ AltmanZScore RiskScore.fe

.xttest3