The Value of Enterprise Risk Management: Study of Lloyd's of London

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Abstract

The Enterprise Risk Management (ERM) framework has changed the fundamental approach to modelling, governance and reporting of risk at Lloyd's of London (Lloyd's). The objective of my study is to measure the extent of ERM activity at Lloyd's entities based on a Lloyd's-specific ERM score. In particular, I focus the attention on the drivers of ERM and the relationship between ERM activity and value performance. To the best of my knowledge, this is the first study in which this ERM topic is addressed at Lloyd's and presents an opportunity to provide empirical research about the drivers of ERM activity. My methodology includes a two-step least-squares regression approach to simultaneously model the drivers of ERM activity and the impact of ERM on value performance. Using a Lloyd's-specific ERM score, I find ERM activity to be positively related with *risk transfer*, *product diversification*, and *profit volatility* and negatively related to *premium growth*, *financial slack* and *syndicate size*. Additionally, I find a positive relationship between Lloyd's ERM activity and value performance. My selected model estimates a 8.6% increase in performance for syndicates with a high level of ERM activity. The model result is statistically significant and is robust to a range of analyses.

Keywords: Lloyd's of London; enterprise risk management; insurance; sample treatment

RELEVANCE FOR THE ACTUARIAL PROFESSION

The study was performed in the interest of the actuarial community - be it for industry practitioners or researchers using Enterprise Risk Management techniques. The study findings include statistical evidence showing the positive influence of ERM activity on performance at Lloyd's of London, and indicating the significance of various factors that are hypothesised to explain the ERM activity. The findings and conclusions in this study are assumed to be of immense value for actuaries.

The reader may use the study results as confirmation of using ERM techniques for the benefit of financial or non-financial companies. The targeted benefits can be plenty and can possibly range from managing adverse scenarios, improve risk allocations, mitigate counterparty credit risk default to managing emerging risks. These benefits have been evidenced in many prior ERM studies.

Further research in ERM is encouraged in light of the considerations in this study. The lack of an inherent ERM measure in the research literature may prevent companies from justifying investments into ERM projects. Further research using an alternative ERM measure for Lloyd's of London or other related industries remains desirable for the actuarial community, and any further evidence will support the actuary's role in the service of the public. More credibility can only be granted to ERM if more and substantial research is generated.

The ongoing discussion on climate change risk has arguably lend substantial weight to ERM (or vice versa). The approach is to take uncertainty fully into account by identifying, measure, control and monitor risks, especially for the ones that fall out of risk tolerance levels. The central elements of ERM can support the climate change risk framework in many companies, addressing disclosure requirements, scenario analysis and overall governance. The value of the ERM study findings would go beyond the actuarial profession and include a wider group of stakeholders in matters concerning climate change risks.

DECLARATION

I certify that all the work in this research project is my own and that I have acknowledged all materials and sources used in its preparation for this analytical work. I also express that the views and opinions in this paper are mine and does not reflect those of others.

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Contents

1 Introduction

"Enterprise Risk Management (ERM) is a process for identifying and prioritizing critical risks facing an organization, quantifying their impact on financial and strategic objectives, and implementing financial and organizational solutions to address them."

Definition of ERM by Casualty Actuarial Society

The definition of the Casualty Actuarial Society captures the essence of ERM. The ERM is about enabling companies to manage a range of risks in an integrated and inter-corporate manner, and to mitigate these risks effectively. There is a rich content of empirical research that investigates the ERM value from a corporate perspective, and the literature argues that ERM benefits companies from low earnings volatility, reduced financing costs, improved use of capital and synergies from risk management activities (Beasley et al, 2008 [8], Hoyt and Liebenberg, 2011 [34], Meulbroek, 2002 [52]). One of the most important aspects relates to the level of top down executive engagement and the consequential cascade of ERM culture throughout the firm, improving risk awareness and culture. In other words, directors' engagement in ERM could create significant value for companies (Farrell and Gallagher, 2015 [23]).

At Lloyd's of London (Lloyd's), the trigger to engage in ERM is particularly relevant as it has been influenced by regulatory market reforms (e.g. Solvency II) and the drive to meet regulatory standards[1]. A corporate drive is to maximise the returns for capital providers and investors, provided with the many positive opportunities from ERM. While the benefits of various risk management activities[2] are well documented (e.g. derivative hedging, risk transfer), there is a lot more progress made to these fundamental, yet traditional and silo-based approach to risk management. One major use case of ERM is the integration of decision making across all legal entities or underwriting classes in order to avoid the duplication of risk management activity (Hoyt and Liebenberg, 2011 [34]). A Lloyd's entity should be well-informed about the aggregate risk position by taking into account the inter-dependent risk profiles inherent in different underwriting activities. The advantages from the use of ERM would be improved allocation of resources, higher efficiency of capital use and return on capital (Hoyt and Liebenberg, 2011 [34], Meulbroek, 2002 [52]). The ERM concept is fully aligned with Lloyd's strategy and its message to its market participants (Lloyd's of London Annual Report,

[1] To name a few: Internal Model Approval Process (IMAP, 2013 [44]), ORSA reporting (Lloyd's: Own Risk and Solvency Assessment, 2015 [47]), *Use Test* (Lloyd's: Model Scope, Governance and Use, 2010 [42]), Model Validation (Lloyd's: Model Validation Guidance, 2014 [45])

[2] See Allayannis et al (2001 [4]), Zou (2010 [70]), Cummins and Weiss (2016 [18])

2019 [49]).

In the context of the ERM research literature, the objective of my study is to measure the extent of ERM activity for Lloyd's entities. I focus on the drivers of ERM and the relationship between ERM activity and value performance. I use a two-step least-squares regression approach to simultaneously model the drivers of ERM and the impact of ERM on value performance. My contributions to ERM research are three-fold: Firstly, I propose an original method to measure ERM activity using a Lloyd's-specific ERM score that reflects the performance of *directors' engagement*, *strategy*, *operations* and *compliance*. Secondly, I uncover the statistical relationships between the ERM activity and its drivers. Thirdly, I provide empirical evidence of ERM impact on Lloyd's performance. While the assessment of ERM activity within financial companies in general is of interest, my study concentrates on the Lloyd's market in order to control for differences from regulation and markets. My source of data comes from Lloyd's Syndicate Reports and Accounts (Lloyd's, 2019 [49]).

The remainder of the paper is structured as follows: Section 2 provides a literature review, followed by the methodology in section 3. In section 4 I discuss Lloyd's data set, Lloyd's-specific ERM score, and statistics for ERM and non-ERM syndicates[3]. Section 5 presents my model analysis results for ERM drivers and impact of ERM on performance, followed by robustness and sensitivity tests in section 6. Lastly, I address some limitations of this study (7.1), provide research recommendations (7.2) and conclude with some remarks (8).

[3]ERM syndicates are defined as Lloyd's entities with a high level of ERM activity and non-ERM syndicates with a low level of ERM activity.

2 Literature Review

This section gives a theoretical overview of the ERM literature and describes the recent research trend. Traditional risk management has been well studied on financial risks (e.g. financial hedging. See Allayannis et al (2001 [4]) or Hull (2003, [35])). However, it suffers from the limitation that risks are managed on a stand-alone basis even though risk structures have become inter-related and more complex in today's globalised world (Florio and Leoni, 2017 [26]). ERM is the natural evolution that offers a more integrated approach to assessment, quantification and management of risk for the entire financial organisation and functions (Gordon et al, 2009 [29]). It is considered more efficient and value maximising to aggregate risks into portfolios and hedge residual risks than dealing with risks on a standalone basis (McShane, 2011 [51]).

In the effort of coordination and strategic allocation of risk, the objective of ERM is the minimisation of variability of risk (Stulz, 1996 [36]), beyond the theory of financial hedging of individual risk. The corporate interests in ERM is not to reduce overall risk exposure but to strategically allocate risks to the company's advantage. In other words, a company may reduce exposure to certain business in which it has no competitive information gain, but to play its strength in other risk areas where it has an advantage (McShane, 2011 [51]). This means that risk exposure may possibly increase under ERM.

A company with a strong ERM function is willing to actively engage with stakeholders and to present high quality disclosure to the capital markets with respect to strategy, risk handling, and adequate risk policy (Meulbroek, 2002 [52]). Therefore, ERM enables the company to improve the disclosure of its risk profile and thus reduce the costs of public scrutiny and capital financing (Hoyt and Liebenberg, 2009 [34]). With regards to operational aspects, the theoretical benefit of ERM is to help companies make fully informed business decisions by weighing the upside as well as downside of risk across the corporate spectrum (Meulbroek, 2002 [52]; Nocco and Stulz, 2006 [53]).

Early research studies relate ERM implementation to the establishment of a risk committee and nomination of Chief Risk Officer(s) (Hoyt and Liebenberg, 2008 [33], 2009 [34]; Pagach et al, 2011 [55]; Pagach and Warr, 2010 [56]), which were assumed to be the primary drivers of ERM activity. Later studies investigate the ERM value creation in respect of shareholder wealth and maturity stages of ERM development (Farrell and Gallagher, 2015 [23] and 2019 [24]).

Categories in the research literature can broadly be identified as follows: (2.1) evaluation of drivers of ERM activity, (2.2) evaluation of ERM impact on company performance and (2.3) emerging trend of ERM research applied on specific themes.

2.1 Drivers of ERM activity

The ERM literature presents several methods of measurement of ERM activity:

- One measurement method relates to the hiring announcement of a CRO or risk-related keyword search of ERM activity (Hoyt and Liebenberg, 2008 [33] and 2011 [34]; Lechner and Gatzert, 2018 [38]; Lin et al, 2012 [41]; Pagach et al, 2011 [55]; Pagach and Warr, 2010 [56]). This method represents the first generation of ERM driver measurement. The results broadly suggest positive relationship between ERM activity and the presence of a risk function. However, the ERM measure falls short of providing any information about the degree of ERM development, nor does it indicate any timely arrival of ERM benefit.

- The use of industry surveys addresses the shortcomings of risk-related keyword searches by relying on responses from risk or audit professionals (Beasley et al, 2005 [9]; Farrell and Gallagher, 2015 [23] and 2018 [24]; Grace et al, 2010 [58]). For example, the risk survey from the Risk and Insurance Management Society consists of seven attributes, including directors' support, risk culture, risk appetite, and risk management. The benefit of a survey is gained from capturing various forward-looking attributes and translates perceived values of ERM to numerical scores, such as stages of ERM development. However, selection bias materialises as respondents may self-select their status as a company with ERM experience. For example, a risk manager likely approves of a company's engagement in ERM as opposed to an audit manager.

- A systemic approach to ERM evaluation is facilitated by the use of ERM agency ratings from independent companies such as Standard & Poor's (S&P, 2005 [63]) and A.M. Best (A.M. Best, 2013 [6]). These are companies with long-standing experience in providing credit rating and financial strength assessments. S&P offers insurers the service of ERM evaluation to become part of an insurer's overall rating. Using rank categories, S&P performs analyses to assess the extent how an insurer implements a systematic, strategic and sophisticated risk management system. The resulting benefit is a consistent and methodological scoring system. The score methodology includes risk

management culture, risk controls, emerging risk, strategic risk and modelling. The potential limitation is the transparency of its validated methodology and understanding. A number of studies embed the S&P's ERM rating in their research methodology, mainly concluding a positive effect of ERM on company value (Ai et al, 2018 [2]; Baxter et al, 2013 [7]; Bohnert et al, 2019 [12]; McShane et al, 2011 [51]).

- Gordon et al (2009 [29]) devise an ERM score akin to COSO's ERM framework (2004 [16]) for internal control and they introduce four objectives amalgamating to a joint ERM score: Strategy, Operation, Reporting and Compliance. The model measurement involves the matching of the insurer's ERM score with the share price performance, distinguished between high-performing and non-performing group of insurers. The result shows that there is positive and statistical significance for the high-performing insurers to deliver a higher ERM score and performance. The authors conclude that the ERM score represents a reasonable measure of the effectiveness of ERM despite the lack of breadth of assumptions, such as forward looking risk attributes (e.g. emerging risk management, risk appetite's alignment with strategy, risk modelling and evaluation).

With regards to the drivers of ERM, there is a consensus within the research literature that *financial size* is the most significant driver for ERM activity. The incentives to invest into ERM programmes depend on companies' growth ambitions and generous share compensation schemes for managers, which all lead to the willingness to improve risk controls (Bohnert et al, 2019 [12]; Baxter et al, 2013 [7]; Pagach et al, 2011 [55]). If directors are willing to take on risk then companies are more likely to commit to increased ERM activity. Empirical studies show that larger companies tend to have more mature ERM programmes (Farrell and Gallagher, 2015 [23]; Beasley et al, 2005 [9]).

Additionally, it is argued that increasing *operational complexity* motivate companies to commit to high quality risk management. The number of underwriting products or the company presence across regulatory markets dictate the time and resources for effective risk management and reporting. It is the increased scope of risks and the lack of corporate coordination that demands the development of advanced controls and information processing needs (Baxter et al, 2013 [7]; Hoyt and Liebenberg, 2011 [34]; Lin et al, 2012 [41]).

2.2 ERM impact on company performance

The results from prior studies on ERM activity on performance have broadly been mixed. Positive insurance performance is in general associated with ERM activity (Hoyt and Liebenberg, 2008 [33] and 2011 [34]). The findings from a risk survey from respondents across industries and geographic markets suggest that companies with mature ERM systems exhibit superior performance (Farrell and Gallagher, 2015 [23]). In contrast, results from McShane et al (2011, [51]) appear muted and show that even if a positive relationship can be established between ERM activity and company value, no incremental increase in value is found if ERM programmes progress further. In another study, the use of ERM even suggests the reduction in insurers' performance (Lin et al, 2012 [41]).

I contend that the difference in model design or heterogeneity inherently found in data subsets may contribute to the varying conclusions in past papers. ERM authors are fully aware about the lack of consensus about a valid and reliable measure of ERM and the consequence would be the limit to the growth of ERM programmes (Hoyt and Liebenberg, 2011 [34]; McShane et al, 2011 [51]). More importantly, the notion of ERM development being a compliance exercise that neither improves risk management nor affects performance is a cause for concern (Florio and Leoni, 2017 [26]). The current response to such concerns is to provide new and substantial evidence on the effects of ERM adoption on value performance.

2.3 Emerging trend of ERM research

The emergence of ERM experience and regulatory reforms contribute to the ongoing research across geographic markets and varying views of potential ERM drivers. Following regulatory reforms in Italy, new corporate governance rules were adopted and the study from Florio and Leoni (2017 [26]) finds that companies with advanced levels of ERM implementation deliver superior performance. With regards to the increasing complexity of supply chains in Brazil, the study from Olivia (2016 [54]) presents a model of ERM analysis and maturity, using a comprehensive industry survey. Al-Nimer et al (2021 [3]) recognise the drive of corporate entrepreneurship in Jordan and show that ERM holding a mediating role has significant influence on the domestic market's business innovation and financial performance. For publicly listed German companies, Lechner and Gatzert (2018 [38]) use risk-related keyword searches to indicate ERM activity and demonstrate a positive link of ERM activity with company performance. Further empirical studies are performed on geographic markets such as Taiwan (Chen et al, 2020 [15]), China (Li et al, 2014 [39]) and Europe (Bohnert et al, 2019 [12]).

3 Methodology

This section introduces the treatment-effects model and discusses the drivers of ERM activity and the resulting ERM impact on value performance. There are strong justifications for applying a multi-variate regression models on a selection problem, such as the one in this study. The strengths and weaknesses of ordinary regression analysis are well-understood in the academic community and in spite of its shortcomings (e.g. normality assumptions) it has widely been used in applications that evaluate the predictive power of the linear relationships between variables. These models are applied on observational data and extend to numerous disciplines, including economics, finance or social science.

The regression models have the advantage that they can flexibly be adjusted to overcome shortcomings, such as statistical selection bias in this study[4]. The ERM literature widely adopts this type of least-squares regression approach, using a correction to the selection bias (refer to Ai et al, 2018 [2]; Baxter at al, 2013 [7]; Bohnert et al, 2019 [12]; Farrell and Gallagher, 2015 [23]; Hoyt and Liebenberg, 2011 [34]; Hoyt and Liebenberg, 2008 [33]; Lechner and Gatzert, 2018 [38]; Lin et al, 2012 [41]). This gives me comfort and confidence in following this regression approach for this study.

3.1 Treatment-Effects Model

My study approach to assessing ERM performance follows a two-step treatment-effects model, using a maximum-likelihood estimation. The "treatment" of my data set would be applied to the selection bias. This is a well-known phenomenon in sampling non-random data for evaluating behavioural relationships between variables [5].

The ERM literature has widely addressed this selection bias by incorporating a two-step equation, where the treatment equation addresses the selection bias and that in turn is incorporated into the outcome equation as an explanatory variable.

[4] The noteworthy research paper *"Shadow Prices, Market Wages, and Labour Supply"* presents a social economic model that generates wage offers and the probability of being employed from a female population, distinguished by employment status (Heckman, 1974 [31]). In 2000, James J. Heckman was awarded the Nobel Prize in Economic Sciences for the development of theory and methods for analysing selective samples. That prize was equally shared with Daniel L. McFadden. Source: https://www.nobelprize.org/prizes/economic-sciences/2000/summary/

[5] Heckman's paper "Shadow Prices, Market Wages, and Labour Supply" (1974 [31]) estimates the factors of wage offers but observed wages are only known from the female population in employment. As female workers are non-randomly selected from the population, determining these factors of wage offers based on this subset would introduce a selection bias.

Heckman (1976 [32]) notes that if the selection bias is unattended the regression results become skewed and produces a specification error. In particular, this may cause the least-squares estimator of the population variance to be downward biased (Farrell and Gallagher, 2015 [23]). Using a two-step treatment effects model would overcome this statistical bias.

Consequently, a second equation is used to 'treat' the statistical correction to the selection bias before it is embedded as an explanatory variable in the first equation. The additional advantage relates to the inclusion of some control variables that explain the variability of ERM activity and at the same time influence the Lloyd's performance. Through a two-step equation system, I am able to determine which part of the observable outcome is associated with the causal relationship, and which part is related to the sample being selected for the "treatment" (Toomet and Henningsen, 2008 [68]). The treatment-effects model consists of the following two-step equation system:

Treatment Equation:

$$ERM_{it}^{*} = \beta^{S} X_{it}^{S} + \epsilon_{it}^{S} \tag{1}$$

The realisation to fully engage in ERM activity for a particular syndicate i is expressed as follows:

$$ERM_{i} = \begin{cases} 1, & \text{if } \Sigma_t \; ERM_{it}^{*} > 1 \\ 0, & \text{otherwise.} \end{cases} \tag{2}$$

Outcome Equation:

$$P_{it} = \beta^{O} X_{it}^{O} + \theta \; ERM_{i} + \epsilon_{it}^{O} \tag{3}$$

where X_{it}^{S} and X_{it}^{O} are vectors of explanatory variables which are assumed to influence the variability of ERM activity and Lloyd's performance, respectively (please refer to 3.6 for a summary of all study variables). Associated with these explanatory variables, β^{S} and β^{O} are vectors of beta coefficients, which also include the intercept terms. ϵ_{it}^{S} and ϵ_{it}^{O} are error terms and assumed to be normally distributed with mean vector of zero, variance of σ^2 and 1, respectively, and covariance of ρ. P_{it} is a continuous variable, specified as the return on assets for

syndicate i across financial year t.

ERM_i is a binary variable and indicates whether positive ERM activity is assigned to the syndicate i. A positive ERM activity (=1) only occurs if the syndicate i experiences positive outcomes, equivalent to measuring positive values of the unobserved, endogenous variable ERM^*_{it} **in more than one time across all financial years t**. Otherwise, ERM_i takes the value of 0. Furthermore, ERM^*_{it} is a continuous variable and assumes a linear relationship with X^S_{it}. Note that equation 2 represents the base scenario in this study and is defined as the threshold of ERM count.

Consequently, the dependence of P_{it}, X^O_{it} and ERM_i can be expressed as follows:

$$E[\, P_{it} \mid ERM_i = 1] \;=\; E[\beta\, X^O_{it}] + E[\epsilon^O_{it} \mid \epsilon^S_{it} \geq -\beta^S\, X^S_{it}] \tag{4}$$

This equation 4 specifies the expectation of P_{it} over all financial years t, conditional on ERM_i=1. In other words, P_{it} takes on a continuous value according to equation 4 and otherwise 0 if $ERM_i = 0$. An alternative way to express the relationship is as follows:

$$P_{it} = \; \beta\, X^O_{it} + \rho\, \sigma\, \lambda(\beta^S\, X^S_{it}) + \omega_{it} \tag{5}$$

where $\lambda(.)= \phi(.)\ /\ \theta(.)$ is referred to the Inverse Mill's Ratio in the literature; and ϕ and θ are standard normal density and cumulative distribution function, respectively, and ω_{it} is a new error term, independent of X^O_{it} and X^S_{it}. The product coefficient $\rho\sigma$ can be estimated through ordinary least-squares regression. As the true λ is not statistically known, it is replaced by the estimated probit values of ERM_i from equations 1 and 2.

Since σ is strictly positive, the value of ρ reveals a linear relationship of P_{it} and ERM_i. If $\rho > 0$, then observations from the Treatment equation are inclined to have above average realised value of ϵ^O_{it}. In other words, this effect is considered a positive bias, as in ERM variable contributes positively to P. Lastly, the coefficients in the Treatment and Outcome equations can be evaluated through maximum-likelihood estimation.

The section 3.5 lays out the practical approach to estimating the equations 1, 2 and 3.

3.2 Discussion of Drivers of ERM

This subsection discusses the potential drivers of ERM and provides the relevant hypotheses.

Syndicate size associated with large financial companies should have sufficient assets to support the costs of ERM programmes, such as investments in recruitment, training as well as systems and software (Beasley et al, 2005 [9]). Large companies not only have the resource and scale to invest into ERM but also have the urgency to manage complex operations, especially in the face of socio-economic, financial and political challenges (Olivia, 2016 [54]). Thereby, financial size should have a positive effect on ERM activity.

Hypothesis: Large Lloyd's entities in terms of booked assets are more likely to be engaged in ERM activity.

Financial leverage at Lloyd's is associated with credit balances that arise out of insurance or reinsurance operations. When insurers experience volatile profits or financial distress due to a financially leveraged positions they likely invest in ERM programmes (Pagach and Warr, 2011 [55]). The goal is to reduce the chance of financial distress by utilising risk governance controls, monitoring systems and informed decision-making. Besides, ERM syndicates may benefit from improved debt conditions or financing terms as external capital markets perceive them as sound risk managers (Meulbroek, 2002 [52]). More *financial leverage* also means more volatility and risk of default, and hence leads to little resource to invest in an ERM programme (Baxter et al, 2013 [7]). However, *financial leverage* may not be that relevant at Syndicate level as credit balances are of short-term liability nature or held at the level of financial group holdings.

Hypothesis: Lloyd's entities with a high level of financial leverage are more likely to be engaged in ERM activity.

Product diversification is associated with the underwriting of numerous products that effectively help spread the risk within an underwriting portfolio. In the research literature, product and geographic diversification has widely been associated with operational complexity (Farrell and Gallagher, 2019 [24]). A poor diversification strategy may reduce performance if agency costs increase, resulting in inefficient allocation of resources to poorly performing products or misuse of budgets. It is argued that insurers with well-functioning ERM programmes can better manage the downside costs, in particular agency and coordination costs (Ai et al, 2018 [2]).

On the other hand, prior studies find that insurers with a high level of diversification will likely benefit from increased economies of scope, re-allocation of capital through intra-group risk transfers, reduction to default risk and thus enhanced credit rating (Cummins and Weiss, 2016 [18]; Liebenberg and Sommer, 2008 [40]; Schlütter and Gründl, 2012 [61]).

Hypothesis: Lloyd's entities with a high level of product diversification are more likely to be engaged in ERM activity.

Profit volatility: Prior study results are ambiguous with respect to profit volatility's influence on ERM activity. Financial companies achieve a reduction in profit volatility after successful implementation of ERM, resulting in a smooth earnings experience and a small likelihood of adverse outcomes (Pagach and Warr, 2010 [56]). On the other hand, increased profit volatility may lead to greater chance of additional capital injections (i.e. Lloyd's Coming-into-Line process), and hence require better risk management functions (Baxter et al, 2013 [7]).

Hypothesis: Lloyd's entities experiencing a high level of profit volatility are more likely to be engaged in ERM activity.

Financial slack: Syndicates hold a sufficient level of financial slack (cash and short-term investments relative to total assets) in order to pay for claims and expenses. If sufficient financial slack is available, companies experience low level of profit volatility and therefore reduce the probability of financial distress (Hoyt and Liebenberg, 2011 [34]).

Hypothesis: Lloyd's entities with sufficient financial slack are more likely to be engaged in ERM activity.

Premium growth: Lloyd's generated an average growth of 5% each year in premium income between 2009 and 2019 (Lloyd's of London Annual Report, 2019 [49]). This growth is driven by innovative products (e.g. cyber risk protection products) and increased Lloyd's underwriting capacity. The ERM management and risk control would enable companies to expand business and investment into more profitable growth opportunities as companies consider financial distress less likely and have stable operations (Pagach and Warr, 2010 [56]). Additionally, Farrell and Gallagher (2015 [23]) find that organisations with high quality ERM functions deliver positive sales growth across all industry sectors.

Hypothesis: Lloyd's entities with a positive premium growth are more likely to

be engaged in ERM activity.

Risk transfers is a core insurance activity and has been well studied in the past. In context of ERM, reinsurance as a risk mitigation tool has a strong relationship with risk-taking behaviour and risk capital (Nocco and Stulz, 2006 [53]). If an insurer takes on more risk (e.g. due to premium growth), it would not only typically increase its capital to reflect the additional risk but also takes up more reinsurance protection against sudden adverse claims. According to Mankai and Belgacem (2016 [50]), reinsurance acts as a substitute for capital, especially for weakly capitalised companies.

The desire to have reinsurance protection is greater for companies with catastrophe risk exposure. Findings suggest that insurers tend to transfer their excess exposure to non-affiliated counterparties as opposed to affiliated (or intra-group) companies (Cummins and Weiss, 2016 [18]). That is because catastrophe exposure is more detrimental to standalone, non-life insurers as claims shocks may lead to an increase in insolvency risk (Li et al, 2014 [39]).

At Lloyd's, the use of risk and economic capital models (i.e. internal models) provides valuable insights into inter-dependent risk structures and complex reinsurance structure. A simple economic capital model that is applied to the insurance operations is associated with higher revenue efficiency and returns (Grace et al, 2010 [58]).

Hypothesis: Lloyd's entities with a high level of risk transfers are more likely to be engaged in ERM activity.

3.3 Discussion of Impact of ERM on Value Performance

This subsection discusses the impact of Lloyd's ***ERM activity*** **on value performance** and provides context of the control variables. The central hypothesis of my study is as follows:

Hypothesis: Lloyd's entities with a high level of ERM activity experience positive value performance.

My study examines the "average" profile of a syndicate and includes control variables relevant to Lloyd's syndicate performance. These include: *financial leverage*, *syndicate size*, *premium growth*, *product diversification*, *directors' tenure*, *director as % of gross written premium* (size of board of directors relative to gross written premium), *profit volatility*, *investment returns*, and *coverage ratio*.

Financial size is found to have varying effects on company value. Positive effects include higher economies of scale, greater negotiating power, more diversified portfolio and lower insolvency risk (Che et al, 2017 [14]; Li et al, 2014 [39]; Liebenberg and Sommer, 2008 [40]; McShane et al, 2011 [51]). In contrast, agency problems, inefficient use of resources or increasing regulatory burden may influence company value negatively (Allayannis and Weston, 2001 [4]; Lang et al, 1996 [36]; Lechner et al, 2018 [38]). Companies that adopt a comprehensive ERM function consider financial distress to be less likely due to efficient management of lower tail outcomes, and hence are expected to expand existing business and invest in growth opportunities (Pagach and Warr, 2010 [56]).

Prior study findings about ***financial leverage*** show that it has an ambiguous effect on company performance. If an insurer takes on additional borrowings, it is likely to attach a positive net present value to new investment projects (Li et al, 2014 [39]). This would result in a positive relationship between leverage and performance. On the other hand, highly leveraged companies may experience financial distress as leverage limits its flexibility to spend, especially in pursuit of additional profitable investment projects (Pagach and Warr, 2011 [55]). This would lead to a negative relationship. In respect of Lloyd's of London, leverage is frequently associated with a credit balance that may arise due to insurance or reinsurance operations (see *Lloyds Syndicate Reports and Accounts on https://www.lloyds.com*).

Product diversification deals with the management of underwriting various products. Studies find mixed effects from product diversification on insurer value. Lin et al (2012 [41]) states that insurers with a greater proportion of premium written in property risk are more inclined to operate with higher diversified base

of products and with higher level of reinsurance protection, implying the extensive pooling of risk and reinsurance as a mitigation tool against short-tail risk volatility. This would also be regarded as an efficient use of capital as insurers benefit from increased diversification benefits (EIOPA TechSpec part I, 2014 [20]). Ai et al (2018 [2]) find ERM companies benefit from product diversification in terms of performance as compared to single-entity risk management approaches. However, this benefit can be more than offset by operational complexity of an insurer as it depends on the number of insurance products, and hence it is exposed to a greater range of complex risks (Baxter et al, 2013 [7]; Hoyt and Liebenberg, 2008 [33]). Diversification may reduce performance if agency costs increase or if there is inefficient cross-subsidisation of poorly performing businesses (Berger and Ofek, 1995 [10]; Liebenberg and Sommer, 2008 [40]).

In the particular case of Lloyd's, I apply the Herfindahl-Hirschman index (HHI) to measure the diversification ratio for the following lines of business: Aviation, Casualty, Energy, Life, Marine, Motor, Property and Reinsurance. HHI is intended to measure the level of competition in a given industry, by summing the squared share of products relative to total written premium. If the *HHI* is one then the syndicate derives its premium from one single product, whereas if *HHI* increases towards zero the syndicate becomes more diversified.

Directors' engagement in ERM: The effectiveness of the ERM function and resulting value implications are influenced by the support of Lloyd's directors who ultimately have the oversight over risk governance, risk culture, strategy and reporting (COSO, 2017 [17]). Prior studies find a positive relationship of ERM and corporate governance, which in particular relates to the presence of a CRO, number of independent directors, and length of directors' tenure (Baxter et al, 2013 [7]; Beasley et al, 2005 [9]). The control variables are ***directors' tenure*** and ***director as % of gross written premium*** (size of board of directors relative to gross written premium).

Additionally, the study includes the remaining control variables: ***profit volatility***, ***investment returns*** and ***coverage ratio*** and a ***dummy time variable***.

3.4 Motivation for Robustness and Sensitivity Tests

Some limitations to my model methodology can be identified by inter-syndicate correlation, potential model bias towards years before Solvency II inception and threshold of ERM counts. These limitations provide motivation to investigate in more detailed analyses (see 6). This section describes the motivational points for robustness and sensitivity tests.

My sample data consists of multiple observations, and thus may be correlated through time and the syndicates with overlapping risk exposure (e.g. multiple syndicates under one Lloyd's Managing General Agent). The list of limitations is not exhaustive and I attempt to discuss the key ones as follows:

- With respect to **inter-syndicate correlation**, my least-squares regression model assumes syndicates to operate independently even though in reality MGA operations have influence on at least one syndicate. Prior studies introduce effects of company-level clustering, which deals with the estimation of standard errors for inter-company correlation (see Bohnert et al (2019 [12])). The results from the robustness test (6.1) supports my assumption of independence, justifiably supporting the robustness of my model results.

- With respect to **model bias towards years before Solvency II inception**, my model includes observation years 2014 and 2015 and financial years after the initiation of Solvency II. The concern is about the emergence of model bias towards the work performance of Solvency II compliance. The results from the robustness test (6.2) reduces the concern of model bias.

- The **threshold of ERM counts** in our research methodology provides some limitation. In particular, it is the model results sensitivity to the threshold of $\Sigma_t \; ERM^*_{it} > 1$. ERM counts represent the number required for a Lloyd's syndicate i to fully demonstrate ERM activity (i.e. $ERM_i = 1$). At this threshold > 1, there are 34 (out of 96) Lloyd's syndicates demonstrating ERM activity if its ERM score exceeds zero in at least 2 out of 6 observation years. Increasing this threshold incrementally reduces the number of ERM syndicates. The sensitivity test (section 6.3) shows that the contribution of the ERM variable to performance varies between 6.0% to 14.2%. However, despite this variable outcome, the results appear to be robust in terms of statistical significance.

The comprehensive selection of ERM drivers and control variables in my study

originate from the ERM literature[6]. In particular, the variables in my study include *syndicate size*, *financial leverage*, *product diversification*, *profit volatility* and *premium growth*. The choices of variables are further constrained by the availability of Lloyd's data. Therefore, proxies have been selected whenever possible. For example, *solvency capital requirements* for each syndicate are not publicly disclosed and my model uses *claims reserves* as a proxy. A larger and more detailed set of Lloyd's data may address this limitation.

3.5 Step-by-Step Estimation Approach

This subsection sets out the step-by-step estimation approach, providing assistance to the reader to walk through the practical estimation as discussed in Treatment-Effects Model 3.1. The steps are specified as follows:

1. Estimate the beta coefficients β^S in the Treatment equation 1 by regressing ERM^*_{it} on vector X^S_{it}. The endogenous variable ERM^*_{it} is set equal to the Lloyd's-specific ERM score for syndicate i and financial year t. This step ensures the relationship function f is established between ERM activity and ERM drivers that are assumed to explain the variability of such ERM activity.

$$\begin{aligned}\mathbf{ERM} = f(\, &Syndicate\,Size, Financial\,Leverage, Product\,Diversification,\\ &Profit\,Volatility, Financial\,Slack, Premium\,Growth, Risk\,Transfer)\end{aligned} \tag{6}$$

2. Set the binary outcome to ERM_i by observing the counts of syndicate i that measures the number of positive ERM^*_{it} values across the financial years t. Consistent with the threshold of ERM count of 1 in equation 2, set ERM_i to 1 if the counts are more than 1. Otherwise, set ERM_i to 0 if counts are either 0 or 1. This steps assigns either a positive or no ERM activity to each syndicate.

3. Estimate the beta coefficients β^O in the Outcome equation 3, by regressing P_{it} on vector X^O_{it} and binary variable ERM_i, and allowing for the error term impact from the regression on vector X^S_{it} in the Treatment equation 1. This step captures the essential relationship function g of ERM activity, ERM drivers, control variables and Lloyd's performance:

[6]Please refer to Ai et al (2018 [2]), Baxter at al (2013 [7]), Bohnert et al (2019 [12]), Farrell and Gallagher (2015 [23]), Hoyt and Liebenberg (2011 [34]), Hoyt and Liebenberg (2008 [33]), Lechner and Gatzert (2018 [38]), Lin et al (2012 [41])

$$\textbf{Return on Assets} = g(\, ERM \mid Capital\,to\,Assets, Directors' Tenure, Directors\,as\,\%\,Gross\,Written\,Premium, Syndicate\,Size, Financial\,Leverage, Product\,Diversification, Profit\,Volatility, Premium\,Growth, Investment\,Return, Dummy\,Time\,variable) \tag{7}$$

4. Derive the regression coefficients and associated standard errors for both the Treatment 1 and Outcome equation 3. Determine the p-value for each variable, using two-sided sample t-tests.

   Note the performance of the step-by-step estimation utilises the R packages "olsrr" and "sampleSelection". The former can be applied to ordinary regression analysis, such as the regressing the vector X_{it}^{O} in the Treatment equation 1. The latter relates to sample selection models that can be applied on selection problems, such as regressing the Treatment equation 1 and Outcome equation 3 simultaneously. For further information on the use of the R package "sampleSelection", refer to Toomet and Henningsen (2008 [68]).

   Note that step 2 is a manual adjustment that can be performed on a Microsoft Excel spreadsheets.

3.6 Study variables

The figure below summarises the study variables, their definitions and use in the Treatment and Outcome equations. Note that the variables selected for this study are based on the availability of Lloyd's data, and cross-checked with extant research literature.

Variable	Definition	Treatment Equation	Outcome Equation
Lloyd's-specific ERM Score	Defined as $\mathbb{R}$; If value exceeds 0, the syndicate is engaged in ERM activity. If value is less than 0, the syndicate shows lower ERM activity.	✓ (response)	
Return On Assets	Syndicate profits divided by book value of assets		✓ (response)
Coverage Ratio	Financial assets divided by claims reserves (net of reinsurance)		✓
Risk Transfer	Premium cost in exchange of reinsurance protection	✓	
Financial Slack	Cash and cash equivalent divided by book value of assets	✓	
Directors' Tenure	Coefficient of Variation (Number of Directors)		✓
Directors as % of Premium	Directors expressed as % of gross written premium		✓
Product Diversification	1 minus (Herfindahl–Hirschman Index)^2	✓	✓
Financial Leverage	Creditors divided by gross written premium	✓	✓
Premium Growth	Change in book value of assets	✓	✓
Investment Returns	Investment return divided by financial assets		✓
Profit Volatility	StdDev(profits divided by book value of assets)	✓	✓
Syndicate Size	Natural logarithm of book value of assets	✓	✓
Time variable	Dummy variable included to control for financial years		✓

Figure 1: Variable Definition

Even though the availability of variables is limited, I feel comfortable with the variables used in this study, as they represent a breadth of explanatory influences and cover the essential areas of interest in the ERM literature.

The list of desirable but not available variables include: **geographic diversification, share of institutional and insider ownership, credit rating of capital providers, market share, level of board independence from risk management, use of derivatives, age of business, frequency and amount of dividend payments,** and **the presence of an economic capital model**. The list is not exhaustive.

4 Descriptive Statistics

This section discusses the Lloyd's data set (4.1) and Lloyd's-specific ERM score (4.2). Additionally, it provides summary statistics and significance level on the central estimates.

Based on Lloyd's-specific ERM score, I examine relevant activities between ERM and non-ERM syndicates and discuss the following: (a) time series (4.4), (b) trend (4.5), and (c) score composition (4.6). Lastly, I investigate the presence of (d) multi-collinearity 4.7 in my data set.

4.1 Lloyd's Data Set

The Lloyd's data set consists of 96 live syndicates and 510 syndicate-year observations as at financial year-end 2019. The information is sourced from publicly accessible syndicate reports and accounts. The observation period is from the financial year 2014 to 2019 that covers the pre- and post-implementation period of Solvency II. Notably, the data set includes the effects from extreme adverse market events, such as natural catastrophes. While this may skew the data due to heightened claims volatility, my study controls for profit volatility and consider the observation period as a favourable setting for examining the impact of ERM and performance.

The data collection process mainly relies on Lloyd's rules of reporting which is consistent, robust and adequate for the interest of this study. The derived variables are ratios (set out in 3.6) and values are sourced from the financial balance sheets and profit and loss accounts for all syndicates reported as at financial year-end 2019. A high-level reconciliation of the Lloyd's data set with the annual published financial reports has shown some minor discrepancies. In my understanding, this can be explained by the omission of syndicates which closed before the financial year-end 2019. Note that some variables of interest are not readily available, such as the number of active directors or directors' tenure. These had to be extracted from additional annual financial reports. Overall, the process generates a sufficient number of relevant variables for the study analysis.

The underwriting operations are generally performed by Lloyd's Managing General Agents (MGAs) who particularly carry out the managing, modelling and reporting work for at least one syndicate. However, Lloyd's reports are provided at syndicate level. This becomes a conflict for MGAs who have more than one syndicate under management as some ERM drivers of associated syndicates – such as directors' tenure or written premium – do not interact independently. For example, my data set assumes two independent syndicates from the same MGA even

though only one board of director is responsible for this particular MGA. I test these assumptions by using a robustness test in subsection 6.1, in which I aggregate the data at an MGA level. I find no material differences to my original finding for syndicates. Thereby, the assumptions of independently operating syndicates do not limit my study findings.

My study applies the Return on Assets (ROA) as the response variable in my research model. I argue that the use of ROA is sufficient as my study about Lloyd's is retrospective-looking with reference to years before and after the Solvency II initiation. The research literature applies the response variable as both the ROA or Tobin's Q for the company value proxy. The two measures of performance are intended to assess historical performance (ROA) and future investors' expectations (Tobin's Q). ROA is an accounting-based measure, reflecting retrospective profitability, whereas Tobin's Q is a ratio that compares the market value of a company's asset to their replacement cost and represents investors' value expectation. Tobin's Q cannot be used in a Lloyd's setting as syndicates are not publicly traded entities. The ROA measure has the shortcoming that it neither evaluates potential expected market value from ERM implementation, nor it is shielded from directors' potential accounting manipulation. However, it is an efficient measure for how well a company does, especially under stressed business scenarios. Business drivers, such as risk transfers and shock losses, should directly impact a syndicate's accounting profitability as Tobin's Q may not translate to a direct impact. The ROA has been widely used in the literature for company value as a response variable, especially for privately-owned and non-publicly listed organisations (Ai et al, 2016 [2]; Baxter et al, 2013 [7]; Farrell and Gallagher, 2019 [24]; Lin et al, 2012 [41]).

4.2 Lloyd's-Specific ERM Score

My study introduces an original approach to measuring ERM activity at Lloyd's, using publicly accessible Lloyd's disclosure information. While there are many alternative measures of ERM scores for measuring ERM activity, to the best of my knowledge my Lloyd's study is the first to construct an ERM score based on the method used by Gordon et al (2009 [29]).

The relevance of directors' engagement to ERM is reflected in my ERM score. In particular, I deem a long directors' tenure to constitute a high level of ERM activity. This is because directors who stay on the board long enough are able to ensure business continuity and have greater accountability of the business strategy, as opposed to a newly trained director. I deem my selection of director's engagement as reasonable and this is supported by previous findings: Baxter et al (2013 [7]) find that directors' tenure to be positively associated with the quality of ERM function. Measures of ERM such as through keyword searches of CRO or risk-related words strongly indicate positive ERM activity (Beasley et al, 2005 [9]; Hoyt and Liebenberg, 2008 [33] and 2011 [34]; Lechner and Gatzert, 2018 [38]; Lin et al, 2012 [41]; Pagach and Warr, 2010 [56]).

The limitation to my wider approach is the lack of readily available data such as frequency of risk meetings, number of actionable items, or the risk function's direct reporting line to the board of directors.

Directors' tenure score: The board of directors has an oversight role of ERM, and provide reasonable assurance to stakeholders about risk culture, organisational strategy, competence and compliance with law and regulations (COSO, 2004 [16]). The measure of *directors' tenure score* is defined as follows:

$$\text{Directors' Tenure Score} = \left[\frac{StDev(Change\ in\ Number\ of\ Directors)}{Number\ of\ Directors\ at\ start\ of\ period\ t}\right]^{-1} \quad (8)$$

where the score is an average over the preceding 3-year reporting years and StDev is the standard deviation.

In addition, ERM score contains the effect from *strategy*, *operations* and *compliance* (as suggested by COSO, 2004 [16]. The ERM score[7] is defined as a joint effect metric that is the sum of the four normalised ERM measures:

[7]Gordon et al (2009 [29]) additionally included the *reporting* variable. As *reporting* is not applicable to Lloyd's it is omitted from my ERM score.

$$\text{ERM score} = \textit{directors' tenure score} + \textit{strategy} + \textit{operations} + \textit{compliance} \quad (9)$$

A syndicate with a high ERM score indicates a high level of ERM activity. In contrast, a syndicate with a low ERM score highlights low ERM activity. I describe ERM syndicates with a high level of ERM activity as ERM syndicates, and otherwise as non-ERM syndicates. The remaining three ERM measures are defined as follows:

Strategy: Each syndicate has a strategy of how it positions itself in the Lloyd's market relative to its peers and it should aim to gain competitive advantage whilst implementing its business strategy. Hence, a syndicate should benefit from reduced risk of default and improve its overall performance. A successful strategy would then be reflected in the reduced systemic risk profile relative to the wider operating market. The main benefit of ERM is to diversify and reduce sizable risks by managing a portfolio with respect to all sources of risk (Gordon, 2009 [29]; Hoyt and Liebenberg, 2008 [33]). Consequently, the measurement of strategic success is the syndicate's ability to reduce its financial beta relative to the Lloyd's market:

$$\text{Strategy} = -[\ \beta_t - \beta_{t-1}] \quad (10)$$

where β = Covariance(Syndicate profits, Lloyd's of London profits) divided by Variance(Lloyd's of London profits), measured over the preceding 3 reporting years; t is denoted by the financial year.

Operations: Operational efficiency is measured as the relationship of resources deployed and underwriting premium. A syndicate is operationally more efficient if it achieves a large amount of premium income relative to a given level of resources deployed. In the context of Lloyd's of London, I apply wage, social security and pension-related costs as proxies for resources deployed. This measure is defined as follows:

$$\text{Operations} = \frac{Underwriting\ Premium_t}{Wage,\ social\ security\ and\ pension\text{-}related\ costs_t} \quad (11)$$

Compliance: If a syndicate complies with laws and regulations (e.g. Solvency II), the risk of default should be considered low (Gordon et al, 2009 [29]) and thereby the indirect costs of regulatory scrutiny would also be reduced. Gordon et al (2009 [29]) find the compliance measure to be correlated with audit fees. For Lloyd's, I include audit fees and the expense on consultancy services. Audit fees include the service relating to auditing financial statements, certification, and due-diligence reviews. Consultancy services highlight the effort to implement projects relating to – among many others – Solvency II projects.

$$\text{Compliance} = \frac{Audit\ Fee_t + Consultancy\ Services\ Cost_t}{Total\ Assets_t} \tag{12}$$

4.3 Summary Statistics for ERM and Non-ERM Syndicates

I compare the statistics for the 34 identifiable ERM syndicates[8] and 62 non-ERM syndicates.

Central statistics have been computed based on the mean and median for each variable and statistical tests for differences between the two groups are provided. For the mean statistic, I apply the two-side sample t-test assuming the same variance. For the median statistic, I use the Wilcoxon rank sum test (or Mann-Whitney) test in order to test whether the two sample groups share the same distribution. I outline the differences in syndicates in figure 2.

The statistics on the mean and median measure for *return on assets* are higher for ERM syndicates. The two-sided sample t test and Wilcoxon rank-sum test reject the hypothesis (p-value $< 0.1\%$ significance level) that the two sample groups are drawn from the same distribution. In other words, the evidence supports the notion that ERM syndicates experience a higher *return on assets*.

With regards to the remaining variables, the results show that ERM syndicates tend to be smaller (*syndicate size*) and have a less diversified risk portfolio (*product diversification*). They likely experience more volatile profits (*profit volatility*), retain a lower level of cash and cash-equivalent assets relative to total assets (*financial slack*), and deliver lower premium growth (*premium growth*). Lastly, ERM syndicates tend to have directors staying on a shorter time period (*directors' tenure*) and a larger number of directors responsible for the insurance portfolio (*directors as % gross written premium*).

The findings of the remaining variables (such as *coverage ratio* [9], *risk transfer*, *financial leverage* and *investment returns*) show little to no statistical significance, with respect to the mean statistics and two-sided sample t-tests.

[8] ERM syndicates are defined as Lloyd's entities with a high level of ERM activity (i.e. $ERM_i = 1$). In constrast, non-ERM syndicates have a low level of ERM activity (i.e. $ERM_i = 0$)

[9] one outlier is removed from the data set

	Mean				Median			
Variable	**ERM = 1**	**ERM = 0**	**Diff**	**p-Value**	**ERM = 1**	**ERM = 0**	**Diff**	**p-Value**
Return on assets	*0.01*	*(0.03)*	*0.04****	*< 0.1%*	*0.02*	*0.0012*	*0.02****	*< 0.1%*
Coverage ratio	*2.67*	*2.15*	*0.52*	*45%*	*1.72*	*1.54*	*0.18****	*< 0.1%*
Risk transfer	*0.24*	*0.23*	*0.01*	*64%*	*0.18*	*0.21*	*(0.03)*	*24%*
Directors' tenure	*0.08*	*0.10*	*(0.02)****	*0.6%*	*0.07*	*0.09*	*(0.02)***	*2%*
Directors as % GWP	*0.04*	*0.11*	*(0.07)*	*68%*	*0.08*	*0.03*	*0.04****	*< 0.1%*
Product diversification	*0.44*	*0.55*	*(0.11)****	*< 0.1%*	*0.52*	*0.67*	*(0.14)*	*60%*
Financial leverage	*1.35*	*0.28*	*1.07*	*20%*	*0.21*	*0.22*	*(0.01)*	*85%*
Premium growth	*0.16*	*0.21*	*(0.06)***	*4.3%*	*0.09*	*0.08*	*0.0042****	*< 0.1%*
Investment returns	*0.013*	*0.011*	*0.002*	*40%*	*0.0104*	*0.0108*	*(0.0004)*	*86%*
Profit volatility	*0.06*	*0.04*	*0.02****	*< 0.1%*	*0.04*	*0.03*	*0.01****	*< 0.1%*
Slack	*0.06*	*0.08*	*(0.02)****	*< 0.1%*	*0.05*	*0.07*	*(0.02)****	*< 0.1%*
Syndicate Size	*5.25*	*6.35*	*(1.1)****	*< 0.1%*	*5.45*	*6.65*	*(1.2)****	*< 0.1%*

Figure 2: Differences in mean and median for syndicates with low ERM activity (ERM = 0) and high ERM activity (ERM = 1)

*Statistical significance denoted by *, **, and *** for 10%, 5% and 1% level, respectively*

4.4 (a) ERM Time Series

I assess the observed ERM score for both ERM and non-ERM syndicates over the observation period 2014 to 2019. My findings reveal that ERM syndicates on average experience incremental increases in activities. This may explain a high level of risk management activity, following years of investments in the infrastructure and reforms to risk governance. For the non-ERM syndicates, the ERM score is more variable, displaying mostly negative scores across the observation period.

The distance between the 25% upper and lower confidence interval represents a crude measure of variability. The ERM syndicates show a narrower distance in almost all the years, whereas non-ERM syndicates reduce the distance over time. The observation of time series indicates a positive development where ERM syndicates operate at a high level of ERM activity and non-ERM syndicates improve its performance throughout the observation period. The trend may indicate a convergence towards a state of maturity of ERM activity.

The figures 3 and 4 summarise the series and variability of the ERM score for both ERM and non-ERM syndicates.

ERM Score for ERM Syndicates

Year	2014	2015	2016	2017	2018	2019
Mean	*0.4*	*0.2*	*0.3*	*0.5*	*0.5*	*0.6*
25% CI - Lower	*(1.3)*	*(0.5)*	*(0.6)*	*(0.6)*	*(0.4)*	*(0.4)*
25% CI - Upper	*1.3*	*0.8*	*0.7*	*0.9*	*0.9*	*0.9*
Distance	*2.54*	*1.22*	*1.29*	*1.54*	*1.27*	*1.31*

ERM Score for non-ERM Syndicates

Year	2014	2015	2016	2017	2018	2019
Mean	*(1.2)*	*0.2*	*(0.3)*	*(0.5)*	*(0.0)*	*(0.2)*
25% CI - Lower	*(1.9)*	*(1.2)*	*(0.9)*	*(1.3)*	*(0.9)*	*(0.9)*
25% CI - Upper	*0.8*	*1.1*	*0.5*	*0.1*	*0.8*	*0.5*
Distance	*2.70*	*2.37*	*1.41*	*1.46*	*1.74*	*1.44*

Figure 3: Lloyd's-specific ERM Score

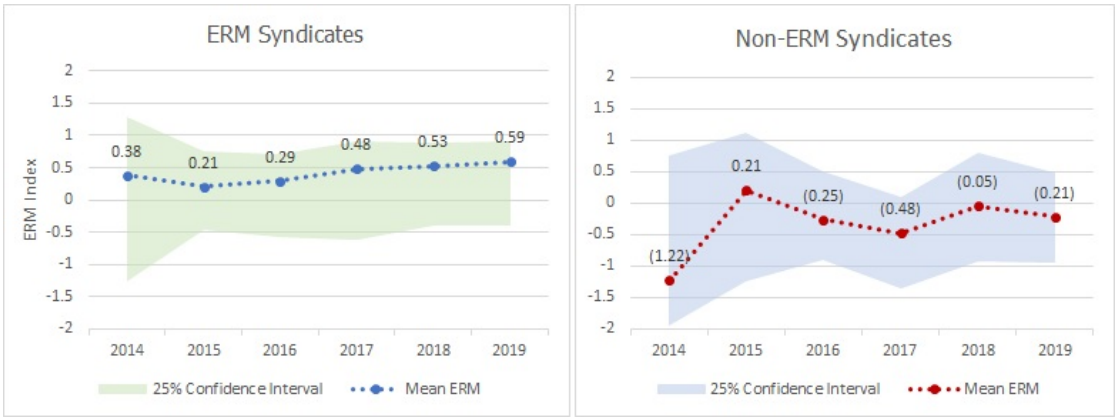

Figure 4: Lloyd's-specific ERM Score on Graph

4.5 (b) ERM Trend

Next I assess the ERM activity (using ERM^*_{it}) across Lloyd's syndicates and financial years (as can be seen in the figure 5) and evaluate the emerging trend over the observation period, based on counts of $ERM^*_{it} > 0$.

Similar to the (a) time series, ERM syndicates demonstrate a somewhat consistent count of ERM activity, ranging between 22 and 31 counts (for 34 ERM syndicates). For non-ERM syndicates, the count of activity is lower and increases gradually from 2 in 2016 to 21 in 2019. The drop in 2016 for both groups may indicate the re-allocation of resources away from ERM implementation following the Solvency II introduction in 2016.

The increasing share of the total count of activity for non-ERM syndicates in recent years reinforces the perception that ERM has gained prominence in the business strategy as the ERM activity trend increases over time. It appears non-ERM syndicates play catch-up after embracing the value of ERM. The alternative reason may be due to regulatory pressure to improve risk management practices that result in positive ERM activity.

Year	2014	2015	2016	2017	2018	2019	Total
ERM Syndicates	*24*	*31*	*25*	*26*	*22*	*26*	*154*
% of Total	*69%*	*82%*	*93%*	*81%*	*59%*	*55%*	*71%*
Non-ERM Syndicates	*11*	*7*	*2*	*6*	*15*	*21*	*62*
% of Total	*31%*	*18%*	*7%*	*19%*	*41%*	*45%*	*29%*
Total	***35***	***38***	***27***	***32***	***37***	***47***	***216***

Figure 5: Counts of ERM activity

4.6 (c) ERM Score Composition

The figure 6 provides insights into the composition of the Lloyd's-specific ERM score. I consider the standalone variability of each ERM measure - *strategy*, *operations*, *compliance* and *directors' tenure score* - in terms of the standard deviation for the entire observation period and measure the percentage proportion of each ERM measure relative to the total sum.

The reason for this simplified illustration is based on the notion that if a measure is more volatile then it tends to record lower or higher values and hence has more influence on the ERM score. It is possible to apply an alternative risk measure, such as a specific percentile. However, the data set is relatively small and I argue that the standard deviation is an adequate measure for this type of analysis.

Most notably, I identify that the *directors' tenure score* contributes the most to both ERM syndicates at 52% and non-ERM syndicates at 44%. This reinforces the perception that the board of directors play a central role in the ERM implementation as the Lloyd's-specific ERM score is dependent on directors' engagement. Additionally, it should be noted that while the costs from audit and consultancy services (*compliance*) remain a significant driver for non-ERM syndicates (at 36%), ERM syndicates have a lower share of compliance costs. Therefore, ERM syndicates have a greater share of *strategy* and *operations*.

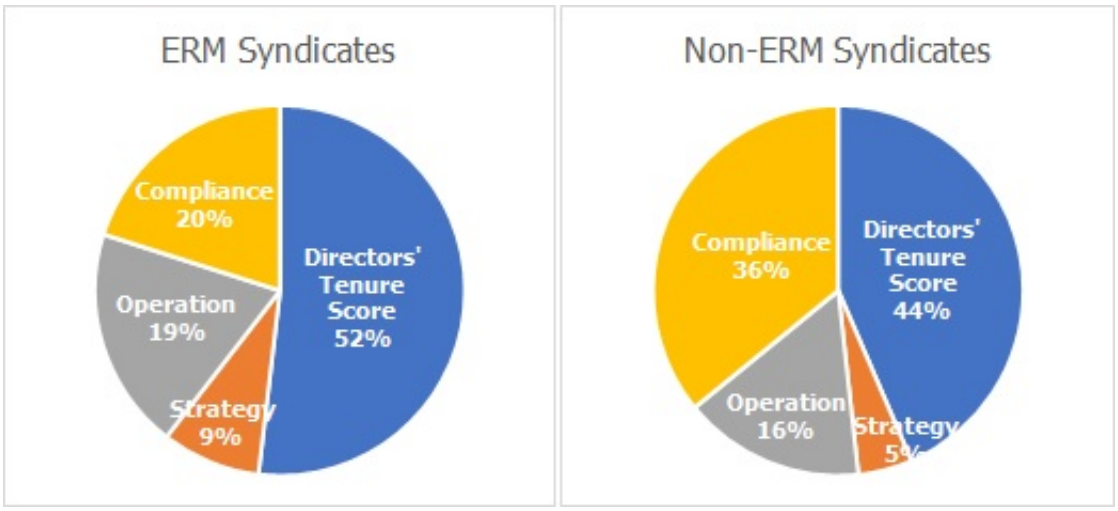

Figure 6: Contribution to ERM score for ERM and non-ERM syndicates

4.7 (d) Multi-Collinearity

Using the Pearson correlation analysis and Variance Inflation Factor (VIF) in order to determine the degree of multi-collinearity, I find no material presence of multi-collinearity. Thereby, I deem interactions between variables to pose an issue in my regression model, and the assumption of independence is valid.

The Pearson correlation analysis includes all 96 syndicates in my sample. As shown in figure 7, *syndicate size* is highly correlated with *product diversification* at 58%, *premium growth* at -27%, and *profit Volatility* at -32%. High correlation rates suggest the possibility of multi-collinearity and may generate model bias. Thereby, I apply the Variance Inflation Factor (VIF) for further analysis.

Multi-collinearity can commonly occur in multi-regression analysis if at least two independent variables are highly correlated with each other. The problem arises in the fitting of betas for each independent variable in my regression model, where variances of the respective betas can potentially be skewed. This may lead to inaccurate fitting of betas, and thereby model results (Farrar et al, 1967 [22]). The literature resorts to resolving this problem by analysis with VIF in order to support the decision to drop or merge variables. VIF is estimated from a least-squares regression, in which the independent variable in question is expressed as a function of other independent variables. A tolerance level of > 10 means high level of multicollinearity and has been considered a reasonable cut-off point (Gordon et al, 2009 [29]; Hoyt and Liebenberg, 2011 [34]).

Figure 8 shows the VIF estimates ranging from 1.03 to 1.9. The highest VIF is 1.9 for *syndicate size* which is low when compared against the tolerance level of 10 (Gordon et al, 2009 [29]). Therefore, multi-collinearity does not pose an issue in my ERM study.

Pearson Correlation	Capital-to-Assets	Risk Transfer	Director Variability	Directors as % GWP	Product Diversification	Financial Leverage	Premium Growth	Investment returns	Profit Volatility	Financial Slack
Capital-to-Assets										
Risk Transfer	(1%)									
Director Variability	(1%)	8%								
Directors as % GWP	12%	(20%)	(0%)							
Product Diversification	(21%)	7%	(5%)	(1%)						
Financial Leverage	(1%)	21%	1%	33%	(9%)					
Premium Growth	12%	16%	5%	5%	(11%)	(3%)				
Investment returns	8%	(1%)	(2%)	(3%)	(3%)	(1%)	(23%)			
Profit Volatility	(0%)	(16%)	(8%)	4%	(22%)	(4%)	28%	(15%)		
Financial Slack	(11%)	(8%)	(6%)	(2%)	11%	(1%)	5%	(7%)	(4%)	
Syndicate Size	(25%)	25%	1%	(9%)	58%	(3%)	(27%)	11%	(32%)	(9%)

Colour code	(100%)	(75%)	(50%)	(25%)	-	25%	50%	75%	100%

Figure 7: Pearson Correlation Analysis

Variable	VIF
Coverage Ratio	1.1
Risk Transfer	1.4
Directors' Tenure	1.03
Directors as % GWP	1.3
Product Diversification	1.6
Financial Leverage	1.3
Premium Growth	1.3
Investment returns	1.1
Profit Volatility	1.2
Financial Slack	1.1
Syndicate Size	1.9

Figure 8: Variance Inflation Factors

5 Model Results

This section presents the outputs from the two-step treatment-effects model (as laid out in section *Methodology* 3) with reference to 5.1 ERM drivers and 5.2 impact of ERM activity on performance. My findings show that Lloyd's ERM activity is affected by a number of variables to a great degree and has a positive effect on Lloyd's performance.

5.1 ERM Drivers

The drivers of ERM are assessed using a probit regression model (see equation 1). The results of the probit regression are shown in figure 9 and are compared against the hypotheses from subsection 3.2.

Variable	Estimate	Std Error	Hypothesised effects	Model Outcome
Risk Transfer	*0.60*	*0.12 ****	+	+ *****
Product Diversification	*0.23*	*0.084 ****	+	+ *****
Financial Leverage	*< 0.1%*	*0.002*	+	+
Premium Growth	*(0.45)*	*0.066 ****	+	- *****
Profit Volatility	*1.37*	*0.37 ****	+	+ *****
Financial Slack	*(1.29)*	*0.29 ****	+	- *****
Syndicate Size	*(0.18)*	*0.017 ****	+	- *****
Constant	*1.34*	*0.10 ****		

Number of observations	*510*
R-squared	*0.264*
F-statistic (p-value)	*25.7 (<0.1%)*

Figure 9: Results from Treatment Equation

*Statistical significance denoted by *, **, and *** for 10%, 5% and 1% level, respectively*

My findings reveal that ***syndicate size*** has a significant negative impact on ERM activity at the 1% significance level. This means Lloyd's syndicates with a small size of assets are likely to be engaged in ERM activity. This puts it in contrast to prior study results which overwhelmingly suggest that financial size is positively related to the engagement of ERM (see Baxter et al, 2013 [7]; Bohnert et al, 2019 [12]; Farrell and Gallagher, 2015 [23]; Hoyt and Liebenberg, 2011 [34]; Lechner and Gatzert, 2018 [38]; Lin et al, 2012 [41]; Pagach et al, 2011 [55]).

Figure 2 reveals the average profile of an ERM syndicate that not only delivers a higher return on assets but also exhibit a reduced diversification of products,

lower premium growth and higher profit volatility. These financial characteristics suggest syndicates with a smaller asset base and *a defensive risk profile* to be likely engaged in ERM.

Both ***product diversification*** and ***risk transfer*** have a positive effect on ERM activity at Lloyd's (at 1% significance level). Selling an increased number of products translates to more complex operations and information processing between product lines, which in turn demands the development of advanced corporate controls (Baxter et al, 2013 [7]; Lin et al 2012 [41]). Operational complexity also increases with respect to *risk transfer* as more resources are required to evaluate the cost and benefit of reinsurance protection and to monitor the counterparty credit risk exposure (i.e. event of one or more reinsurers being unable to service reinsurance claims payments). Lin et al (2012 [41]) indicate that insurers facing high reinsurance costs have the opportunity to consolidate various portfolio risks in order to reduce the amount of risk to be ceded. This provides the potential to save costs from the standpoint of reinsurance purchase.

While my results show that *risk transfer* is positively associated with ERM activity, the paper findings from Hoyt and Liebenberg (2011 [34]) show ERM activity to be negatively related to reinsurance use. The authors argue that companies have less need for ERM if their reinsurance strategy sufficiently reduces profit volatility. However, I view my findings to be reasonable given Lloyd's support in economic models for reinsurance use (Lloyds: Internal Model SCR, 2013 [44]).

I find evidence of positive association of ***profit volatility*** with ERM activity, in line with the findings in Hoyt and Liebenberg (2011 [34]) and Farrell and Gallagher (2015 [23]). Higher *profit volatility* usually leads to increased risk of financial distress and hence the need for improved risk management controls. By performing ERM activities, insurers are able to reduce the probability of bad outcomes and smooth profits over time.

Premium growth shows a significantly negative impact on ERM activity. This suggests that ERM syndicates focus on regulatory compliance and ERM investments rather than business expansion. Prior studies do not consider growth as a major driver for ERM activity, where study outcomes show little to no statistical significance on ERM activity (Farrell and Gallagher, 2015 [23]; Lin et al, 2012 [41]; Pagach et al, 2011 [55]; Pagach and Warr, 2011 [56]).

There is no sufficient evidence for ***financial leverage*** to be a driver of ERM activity. This suggests that credit balances from insurance or reinsurance operations do not make a material impact on ERM activity. The cashflow are perceived

to be of short-term nature, which diminishes the importance of credit balances. Additionally, credit balances may be reported at the level of group holding and not at syndicate level. Prior studies find sufficient evidence of *financial leverage* having a negative effect on ERM activity (Bohnert et al, 2019 [12]; Baxter et al, 2013 [7]; Hoyt and Liebenberg, 2008 [33] and 2011 [34]).

The next section discusses the results from the impact of ERM activity on performance.

5.2 Impact of ERM Activity on Performance

The results from the treatment-effects model are discussed in this subsection and presented in figure 10 below. The ERM drivers (as discussed in subsection *ERM drivers* 5.1) are included in the Treatment Equation 1, whereas the ERM variable and control variables on performance are in the Outcome Equation 3. Notably, the results from the Treatment Equation are comparatively equal to the probit regression model in previous subsection 5.1 in terms of significance, sign and magnitude if allowing for some minor changes due to model fitting error.

Variable	Treatment Equation		Outcome Equation	
	Estimate	St.Error	Estimate	St.Error
ERM			*0.086*	*0.09 ****
Coverage Ratio			*0.001*	*0.0014*
Risk Transfer	*1.88*	*0.43 ****		
Directors' Tenure			*(0.08)*	*0.11*
Directors as % GWP			*0.001*	*0.002*
Product Diversification	*0.77*	*0.30 ****	*(0.05)*	*0.033 **
Financial Leverage	*0.0055*	*0.086*	*(0.0004)*	*0.0005*
Premium Growth	*(1.42)*	*0.22 ****	*(0.15)*	*0.029 ****
Investment Returns			*0.84*	*0.25 ****
Profit Volatility	*4.58*	*1.25 ****	*(0.36)*	*0.13 ****
Financial Slack	*(3.72)*	*0.84 ****		
Syndicate Size	*(0.58)*	*0.064 ****	*(0.018)*	*0.008 ***
Constant	*2.57*	*0.32 ****	*0.16*	*0.048 ****
Number of observations	*510*			
Log-likelihood	*(75.3)*			
F-statistic (p-value)	*11.8 (<0.1%)*			

Figure 10: Treatment Effects Model

*Statistical significance denoted by *, **, and *** for 10%, 5% and 1% level, respectively*

My main finding yields that the coefficient of ERM (***ERM activity***) is positive and statistically significant (at the 1% level), resulting in the acceptance of my hypothesis of ERM impacting Lloyd's performance 3.3. The outcome shows that syndicates with ERM activity deliver an ERM premium of 8.6% on average.

My study outcome is consistent with the majority of ERM papers. When compared to *return on assets* as the response variable, the ERM variable is shown to be statistically significant at 2.44% across all maturation levels by Farrell and

Gallagher (2019 [24]) and 1% by Baxter et al (2013 [7]). Under Tobin's Q as the response variable, the finding from Hoyt and Liebenberg (2011 [34]) shows an outperformance of 20%. In contrast, one notable study from Lin et al (2012) suggests a significantly negative ERM effect of -5% (measured at Tobin's Q), attributing to the stock market's negative reaction to implementation costs associated with ERM.

Syndicate size is negatively related to performance, which is consistent with the result in the Treatment Equation. It indicates that small syndicates tend to outperform on return on assets, whereas the opposite is true for larger syndicates as they are likely faced with agency problems and operational inefficiencies. The results are consistent with some prior studies (Farrell et al, 2019 [24]; Florio and Leoni, 2017 [26]; Lechner and Gatzert, 2018 [38]; Tahir et al, 2011 [67]). On the other hand, some papers show that the outcome is true for a positive relationship between *syndicate size* and performance (Li et al, 2014 [39]; Lin et al, 2012 [41]).

The operational complexity is associated with ***product diversification***, which negatively impacts value performance in my study (albeit at a less significant level $< 5\%$). Farrell and Gallagher (2019 [24]) find that diversification has a negative effect on performance across all companies. Yet if the differentiation for higher ERM maturity is taken into account, they reveal a positive effect of diversification on value performance.

In my study, the group of ERM syndicates shows an average *Herfindahl-Hirschman index* of 0.6 compared to non-ERM syndicates of 0.4 across the observation period. In other words, ERM syndicates are less diversified, suggesting that syndicate outperformance is derived from a lower level of diversification and lower level of operational complexity.

Investment returns is a major driver for a syndicate's performance (positively significant at the level of 1%), which confirms the view that investment returns are a meaningful source of profits in the observation period. Lloyd's entities may demonstrate achievements in generating positive investment returns that complement profits from underwriting operations (Lloyd's Annual Reports, 2019 [49]).

There is no sufficient evidence to suggest that control variables, such as ***directors' tenure*** and ***directors' as % of gross written premium***, affect syndicate performance. The results suggest that the presence of directors does not translate to higher value performance. These findings are consistent with Florio and Leoni (2017 [26]), outlining dedicated CRO and risk committee do not necessarily influence performance.

Profit volatility and ***premium growth*** are negatively associated with performance at a significance level $< 1\%$. With reference to the remaining control variables, I cannot find sufficient evidence to support *returns on assets* from ***coverage ratio*** and ***financial leverage***.

5.3 Summary of Model Outcomes

The figure 11 below summarises the model outcomes and associated significance levels.

Treatment Equation		
ERM Drivers	**Hypothesised impact on ERM Activity**	**Model Outcome**
Syndicate Size	+	- ***
Financial Leverage	+	+
Product Diversification	+	+ ***
Profit Volatility	+	+ ***
Financial Slack	+	- ***
Premium Growth	+	- ***
Risk Transfer	+	+ ***

Outcome Equation		
Variable	**Hypothesised impact on Lloyd's performance**	**Model Outcome**
ERM	+	+ ***

Figure 11: Hypotheses and Model Outcome

*Statistical significance denoted by *, **, and *** for 10%, 5% and 1% level, respectively*

6 Robustness and Sensitivity Tests

In this section, I perform some robustness tests on my main findings and provide model sensitivity results for my methodology. The robustness tests include scenarios that relate to Lloyd's Managing General Agents (as opposed to syndicate results) and the timely introduction of Solvency II. In addition, the sensitivity test includes an alternative threshold of ERM count.

6.1 Inter-syndicate Correlation: MGAs vs. Syndicates

The Lloyd's of London market consists of MGAs[10] that manage day-to-day operations, including – to name a few – underwriting services, claims handling, accounting as well as strategic planning for syndicates. An MGA is able to oversee one or more syndicate accounts. Due to inter-syndicate dependency inherent in each MGA, a robustness test is required against the main assumption in my study model, namely that data for each syndicate is independently and identically distributed. Consequently, I apply an alternative methodology that groups data at MGA level.

The research literature introduces controls for inter-company dependency as each observations in a data set can belong to companies with form of relationship[11]. To allow for model inter-company dependency, additional estimation is made for standard errors between companies (see for further information: Ai et al, 2016 [2]; Bohnert et al, 2019 [12]; Hoyt and Liebenberg, 2011 [34]).

[10] Managing General Agents

[11] The literature defines this effect as *company-level data clustering*

Variable	Treatment Equation		Outcome Equation	
	Estimate	St.Error	Estimate	St.Error
ERM			*0.027*	*0.35 ****
Coverage Ratio			*0.0001*	*0.00003*
Risk Transfer	*(3.2)*	*0.78 ****		
Directors' Tenure			*0.012*	*0.077*
Directors as % GWP			*0.019*	*0.010*
Product Diversification	*(3.3)*	*0.76 ****	*(0.043)*	*0.03*
Financial Leverage	*(0.0005)*	*0.004*	*(0.0015)*	*0.0009*
Premium Growth	*(0.84)*	*0.36 ***	*(0.032)*	*0.021*
Investment Returns			*0.81*	*0.27 ****
Profit Volatility	*(5.09)*	*1.9 ****	*(0.72)*	*0.16 ****
Financial Slack	*4.2*	*2.4 **		
MGA Size	*(0.96)*	*0.12 ****	*(0.011)*	*0.01*
Constant	*9.4*	*1.12 ****	*(0.15)*	*0.06679 ***
Number of observations	*318*			
Log-likelihood	*(95.6)*			

Figure 12: Robustness Test: MGA vs Syndicates

*Statistical significance denoted by *, **, and *** for 10%, 5% and 1% level, respectively*

The test results show that the ERM value is positive and significant (at 1% level) and contributes 2.7% to MGA *return on assets* (vs. 8.6% at Syndicate level). *investment returns* and *profit volatility* remain the drivers for profitability (at 1% level). This finding is consistent with my main results in 5.2. The results from the ERM equation shows some material differences with respect to the variables such as *profit volatility*, *product diversification* and *risk transfer*, posting opposite signs (negative and significant at 1% level), as compared to key findings in figure 5.2. The reason may be due to effects on grouped data at MGA level when syndicates data offset each other. For example, a loss-making syndicate reducing the gains from another profitable syndicate would help the MGA deliver a less volatile profit account. Hence, the *profit volatility* variable reduces and becomes less of a driver of ERM. This also applies to *product diversification* and *risk transfer*.

Similar to my main findings, financial size of assets (*MGA Size*) and *premium growth* show a negative influence on ERM activity (at 1% significance). There is little to no statistical support to *financial slack* and *financial leverage*. In summary, the robustness test on inter-syndicate correlation confirms my findings of ERM activity having a positive impact on MGA performance.

6.2 Observation since Solvency II Inception

This scenario test excludes the data observations of financial years 2014 and 2015 and provides the model results based on financial years after the initiation of Solvency II. This test explores whether there has been any model bias towards the performance under Solvency II compliance as investments and resources deployed in the years before Solvency II may skew the model results.

Variable	Treatment Equation		Outcome Equation	
	Estimate	St.Error	Estimate	St.Error
ERM			*0.106*	*0.06 ****
Coverage Ratio			*0.01*	*0.003*
Risk Transfer	*1.9*	*0.4 ****		
Directors' Tenure			*(0.17)*	*0.14*
Directors as % GWP			*0.00055*	*0.003*
Product Diversification	*0.87*	*0.3 ****	*(0.0049)*	*0.04*
Financial Leverage	*0.07*	*0.16*	*(0.012)*	*0.033*
Premium Growth	*(1.9)*	*0.2 ****	*(0.11)*	*0.037 ****
Investment Returns			*0.65*	*0.27 ***
Profit Volatility	*6.7*	*1.4 ****	*(0.26)*	*0.16*
Financial Slack	*(3.9)*	*0.9 ****		
Syndicate Size	*(0.49)*	*0.07 ****	*(0.022)*	*0.011 ***
Constant	*1.7*	*0.3 ****	*0.059*	*0.064*
Number of observations	*356*			
Log-likelihood	*(61.8)*			

Figure 13: Robustness Test: Only data used since Solvency II Inception

*Statistical significance denoted by *, **, and *** for 10%, 5% and 1% level, respectively*

The test results provide the evidence that the ERM value remains positive and significant (at 1% level) and contributes 10.6% to syndicate *return on assets* (vs. 8.6% in main finding 5.2). In addition, I highlight *syndicate size* remains negative and significant (at 5% level), and *investment returns* remain the material driver of profitability. The Treatment Equation is similar to my main finding, in magnitude and sign.

One notable change relates to *profit volatility* that is not statistically significant. This can be explained by the face that the overall observation period of 2014 to 2019 has been mostly profitable for syndicates, whereas financial years 2017 and 2018 were heavily impacted by losses due to numerous catastrophe events. Consequently, the robustness test eliminating the year 2014 and 2015 implies that the

sample data lack the profitable financial accounts, and hence increase the variance of *profit volatility*.

The overall robustness tests reinforce my view that the main results on ERM and value performance are reasonably robust.

6.3 Threshold of ERM Counts

A potential area of limitation is the model sensitivity to the selected threshold of $\Sigma_t\ ERM^*_{it} > 1$ that determines whether a Lloyd's syndicate has any ERM activity (refer to equation 2). At this threshold, the base model identifies 34 ERM syndicates (out of a total of 96) if the ERM score is non-zero in more than one time across all financial years t. The sensitivity test describes the incremental increase in the threshold. This has the effect of reducing the number of ERM syndicates from 34 to 28 for a threshold of $\Sigma_t\ ERM^*_{it} > 2$, 23 for a threshold of $\Sigma_t\ ERM^*_{it} > 3$, and 14 for a threshold of $\Sigma_t\ ERM^*_{it} > 4$. Figure 14 shows the sensitivity test results for the Treatment and Outcome Equation for increasing thresholds.

The most notable finding is the ERM variable that varies in the range of 6.0% and 14.2%, and that has a positive effect on Lloyd's performance across all choices of thresholds. On both the Treatment and Outcome Equation, the results about the variables broadly remain statistically significant with minor changes in the regression coefficients and standard errors. Two observations can be made here: (1) support to the base model results for ERM positively impacting performance and (2) the model results remain robust.

The log-likelihood estimates indicate the goodness-of-fit and assist in the model selection, where a value closer to zero indicates an improved fitting. I would expect with the reduction in ERM syndicates the model fitting to deteriorate (and log-likelihood estimate to reduce further). This is because fewer ERM syndicates will be measured against Lloyd's performance, thus reducing model fitting performance. However, to my surprise, the best-fitted model is the one with the fewest ERM syndicates (14), and 14.2% ERM contribution to performance (i.e. threshold ERM > 4). The standard error reduces from a high of 0.19 to a minimum of 0.05. This can be explained by the concentration of ERM syndicates at Lloyd's that consistently demonstrate ERM activity throughout the observation period.

The outcome of the sensitivity analysis demonstrates that the main model findings are robust and there is no sufficient evidence to suggest the model results are influenced by the threshold of ERM counts.

	Treatment Equation							
Variable	**Threshold ERM > 1**		**Threshold ERM > 2**		**Threshold ERM > 3**		**Threshold ERM > 4**	
	Estimate	**St.Error**	**Estimate**	**St.Error**	**Estimate**	**St.Error**	**Estimate**	**St.Error**
Risk Transfer	*1.88*	*0.43 ****	*0.16*	*0.4*	*(1.43)*	*0.55 ***	*(1.19)*	*0.54 ***
Product Diversification	*0.77*	*0.30 ****	*1.06*	*0.33 ***	*1.29*	*0.35 ****	*0.74*	*0.39 **
Financial Leverage	*0.0055*	*0.086*	*0.01*	*0.02*	*(0.10)*	*0.20*	*(0.11)*	*0.21*
Premium Growth	*(1.42)*	*0.22 ****	*(1.3)*	*0.22 ****	*(1.5)*	*0.29 ****	*(1.5)*	*0.34 ****
Profit Volatility	*4.58*	*1.25 ****	*5.8*	*1.32 ****	*7.3*	*1.46 ****	*8.7*	*1.49 ****
Financial Slack	*(3.72)*	*0.84 ****	*(5.2)*	*0.03 ****	*(9.0)*	*1.58 ****	*(11.1)*	*1.92 ****
Syndicate Size	*(0.58)*	*0.064 ****	*(0.6)*	*0.06 ****	*(0.4)*	*0.07 ****	*(0.44)*	*0.08 ****
Constant	*2.57*	*0.32 ****	*2.7*	*0.34 ****	*2.2*	*0.36 ****	*1.7*	*0.40 ****

	Outcome Equation							
Variable	**Threshold ERM > 1**		**Threshold ERM > 2**		**Threshold ERM > 3**		**Threshold ERM > 4**	
	Estimate	**St.Error**	**Estimate**	**St.Error**	**Estimate**	**St.Error**	**Estimate**	**St.Error**
ERM	*0.086*	*0.09 ****	*0.069*	*0.12 ****	*0.060*	*0.19 ****	*0.142*	*0.05 ****
Coverage Ratio	*0.001*	*0.0014*	*0.0003*	*0.0015*	*0.004*	*0.002*	*0.003*	*0.003*
Directors' Tenure	*(0.08)*	*0.11*	*(0.15)*	*0.11*	*(0.23)*	*0.13*	*(0.78)*	*0.27*
Directors as % GWP	*0.001*	*0.002*	*0.003*	*0.002*	*(0.08)*	*0.04*	*(0.12)*	*0.09*
Product Diversification	*(0.05)*	*0.033 **	*(0.059)*	*0.037*	*(0.07)*	*0.04*	*(0.15)*	*0.07 ***
Financial Leverage	*(0.0004)*	*0.0005*	*(0.0006)*	*0.0005*	*0.026*	*0.035*	*0.025*	*0.049*
Premium Growth	*(0.15)*	*0.029 ****	*(0.17)*	*0.030 ****	*(0.18)*	*0.05 ****	*(0.28)*	*0.09 ****
Investment Returns	*0.84*	*0.25 ****	*0.96*	*0.28 ****	*0.79*	*0.32 ***	*0.97*	*0.46 ***
Profit Volatility	*(0.36)*	*0.13 ****	*(0.31)*	*0.14 ***	*(0.47)*	*0.17 ****	*(0.36)*	*0.27*
Syndicate Size	*(0.018)*	*0.008 ***	*(0.02)*	*0.01 **	*(0.04)*	*0.01 ****	*(0.08)*	*0.02 ****
Constant	*0.16*	*0.048 ****	*0.18*	*0.051 ****	*0.36*	*0.08 ****	*0.52*	*0.14 ****
Number of obs	*510*		*510*		*510*		*510*	
Log-likelihood	*(75.3)*		*(91.5)*		*(83.4)*		*(69.9)*	
ERM Syndicates	*34*		*28*		*23*		*14*	

Figure 14: Sensitivity Test: Threshold of ERM counts

*Statistical significance denoted by *, **, and *** for 10%, 5% and 1% level, respectively*

7 Some Limitations and Recommendations

7.1 Some Limitations

When evaluating ERM at Lloyd's, I identify four potential limitations. The first relates to the lack of research consensus of a valid and reliable measure of ERM (McShane et al, 2011 [51]). While the general research study outcomes are broadly mixed and of varying magnitude, the consequence may reduce the credibility of ERM evidence for the industry. The research literature has a wide range of approaches to evaluating ERM, namely through the risk-related keywords search, risk survey, or third-party ERM-rating system (see for more details in Literature Review 2). My study approach to evaluating ERM is the use of a Lloyd's-specific ERM score – akin to the ERM index from Gordon et al (2010 [29]). My methodology using a Lloyd's-specific ERM score is one possible method to adequately mirror the true ERM performance. However, the adequacy of my ERM score is based on how I interpret the extant literature and I deem them as comprehensive.

The second limitation relates to Lloyd's market structure and the use of return on capital as a response variable. Lloyd's does not issue any shares and hence a fair valuation based on a secondary market is not feasible. Consequently, a link between fair valuation of ERM and the associated value inherent in each Lloyd's entity cannot be established. In contrast, publicly traded companies provide fair valuation based on market prices that can be linked with any ERM activity and forward-looking attributes (see Bohnert et al, 2019 [12]; Farrell and Gallagher, 2015 [23]). My study is restricted to the return on assets as the response variable, whereas many prior studies apply Tobin's Q - which provides some forward-looking attributes. Any results comparison with the literature using the Tobin's Q remain constrained.

Third, one of my study assumptions is based on the independence and stationary distribution for each Lloyd's entity. Some assumptions can be relaxed to allow for data features, such as inter-syndicate dependency. Secondary order effects of variables or advanced econometric methods may have been considered in my study. However, the initial results from the robustness and sensitivity tests in section 6 suggest that my study results are reasonably robust without the need of further model changes or variations.

Fourth, data accessibility and availability remain a challenge that prevents the study from reaching depth and breadth. The lack of detailed disclosure makes it difficult to set homogeneous subgroups of data. The one missing data item relates to catastrophe claims exposure. Unfortunately, Lloyd's syndicate reports and accounts do not disclose detailed level of claims. Consequently, my study does not include any analysis relating to any such effects from catastrophe. In order to address this shortcoming to an extent, my study controls for profit volatility and

financial year. Future research may address this limitation.

7.2 Recommendations

The academic community has increasingly been finding sophisticated ways to evaluate ERM activity and maturity. One of my contributions is the use of a Lloyd's-specific ERM score to evaluate ERM - akin to a study from Gordon et al (2009 [29]). The focus is on the design of the Lloyd's-specific ERM score that measures Lloyd's *directors' engagement* in ERM, *strategy*, *operations* and *compliance*. I consider these ERM measures as relevant for assessing any ERM activity as directors' tenure is a significant driver of ERM engagement (Baxter et al, 2013 [7]). Alternative methods and the ones in relation to ERM maturity should be considered in future research at Lloyd's. Recommended approaches for ERM score refinement include the recent use of (a) risk surveys (e.g. RIMS RMM self-assessment survey from Farrell and Gallagher (2015 [23])), and (b) systematic ERM rating frameworks (e.g. S&P ERM rating [63]). Self-reported assessment surveys may provide an informed level of knowledge about the risk organisation, culture and strategy when presented to risk professional. A closed market environment such as Lloyd's is favourable for this type of information gathering exercise.

My study model does not take into account the maturity or intensity of ERM at Lloyd's. This may be another focus area in future research. The research study has shown mixed results in the focus area of ERM maturity. Farrell and Gallagher (2015 [23]) find from the risk survey that companies with progressive engagement in ERM increase their value by around 25%. On the other hand, there is evidence that company performance increases if ERM activity is observed but only to a certain maturity level of ERM (McShane et al, 2011 [51]).

Intra-group risk transfers are of particular interest, especially considering the diversification benefits and resulting economic advantage within insurance group holdings (Filipovic and Kupper, 2007 [25]; Gatzert and Schmeiser, 2008 [27]; Schlütter and Gründl, 2012 [61]). Intra-group risk transfers are commonly used by insurance group holdings, enabling them to favourably change the capital structure and pass on undesirable risks (e.g. property risk). ERM should assist insurance groups to improve the return and risk profile by allocating resources and capital between affiliated companies (Cummins and Weiss, 2016 [18]).

Finally, the focus area is on the integration of ERM functions with climate change risk. The objective is to enable companies not only to model various climate-related risks (e.g. physical, liability or transition) but also to integrate company processes into government and institutional frameworks with respect to sustainability and climate change risk. ERM as the integral function of an insurer should be capable of supporting directors and risk professionals to expand and meet Environmental, Social and Governance standards. More can be done to

evaluate the value that ERM can bring in order to positively influence the climate change debate.

8 Concluding Remarks

My study contributes to the Enterprise Risk Management (ERM) literature by examining the drivers of ERM and the impact of ERM on performance at Lloyd's of London. The main findings suggest syndicates with a high level of ERM activity increase 8.6% on return on assets, which supports my hypothesis that the presence of Lloyd's ERM activity positively affects performance. My two-step least-squares regression model simulates the drivers of ERM and at the same time the impact of ERM on Lloyd's value performance. Based on my Lloyd's specific ERM score, ERM activity is positively related with *risk transfer*, *product diversification* and *profit volatility* and negatively related to *premium growth*, *financial slack* and *syndicate size*.

The Lloyd's-specific ERM score that measures ERM activity, based on *directors' tenure score*, *strategy*, *operations* and *compliance* compares to the construct from Gordon et al (2009 [29]). Like prior ERM research, the primary limitation in this study is how adequately the Lloyd's-specific ERM score mirrors the true ERM performance. I have selected the ERM measures based on the way I interpret the extant literature.

Whilst being mindful of the limitations, the study findings should be regarded as preliminary rather than definitive. My study results provide relevant insights into the drivers of ERM and the relationship between ERM activity and value performance at Lloyd's. Future research suggests alternative methods of capturing ERM activity, such as the use of surveys, or measuring the maturity of ERM functions. I am certain ERM will remain the focus area in the academic community and industry as it provides a robust risk management framework, especially for the support of sustainability issues and climate change risk.

9 References

[1] Aebi, V., Sabato, G., and Schmid, M. Risk management, corporate governance, and bank performance in the financial crisis. *Journal of Banking & Finance 36*, 12 (2012), 3213–3226.

[2] Ai, J., Bajtelsmit, V., and Wang, T. The combined effect of enterprise risk management and diversification on property and casualty insurer performance. *Journal of Risk and Insurance 85*, 2 (2018), 513–543.

[3] Al-Nimer, M., Abbadi, S. S., Al-Omush, A., and Ahmad, H. Risk management practices and firm performance with a mediating role of business model innovation. observations from jordan. *Journal of Risk and Financial Management 14*, 3 (2021), 113.

[4] Allayannis, G., and Weston, J. P. The use of foreign currency derivatives and firm market value. *The review of financial studies 14*, 1 (2001), 243–276.

[5] Altuntas, M., Berry-Stölzle, T. R., and Hoyt, R. E. Dynamic determinants of enterprise risk management adoption in the property-liability insurance industry: evidence from germany. *Journal of risk management 123*, 17 (2011), 1234–1244.

[6] A.M.Best. Risk management and the rating process for insurance companies. *www.ambest.com* (2013).

[7] Baxter, R., Bedard, J. C., Hoitash, R., and Yezegel, A. Enterprise risk management program quality: Determinants, value relevance, and the financial crisis. *Contemporary Accounting Research 30*, 4 (2013), 1264–1295.

[8] Beasley, M., Pagach, D., and Warr, R. Information conveyed in hiring announcements of senior executives overseeing enterprise-wide risk management processes. *Journal of Accounting, Auditing & Finance 23*, 3 (2008), 311–332.

[9] Beasley, M. S., Clune, R., and Hermanson, D. R. Enterprise risk management: An empirical analysis of factors associated with the extent of implementation. *Journal of accounting and public policy 24*, 6 (2005), 521–531.

[10] Berger, P. G., and Ofek, E. Diversification's effect on firm value. *Journal of financial economics 37*, 1 (1995), 39–65.

[11] Bohnert, A., Gatzert, N., Hoyt, R. E., and Lechner, P. The relationship between enterprise risk management, value and firm characteristics based on the literature. *Zeitschrift für die gesamte Versicherungswissenschaft 106*, 3-4 (2017), 311–324.

[12] Bohnert, A., Gatzert, N., Hoyt, R. E., and Lechner, P. The drivers and value of enterprise risk management: evidence from erm ratings. *The European Journal of Finance 25*, 3 (2019), 234–255.

[13] Che, X., and Liebenberg, A. P. Effects of business diversification on asset risk-taking: Evidence from the us property-liability insurance industry. *Journal of Banking & Finance 77* (2017), 122–136.

[14] Che, X., Liebenberg, A. P., Liebenberg, I. A., and Powell, L. S. Decomposing diversification effect: evidence from the us property-liability insurance industry. *Insurance markets and companies*, 8 (2017), 16–28.

[15] Chen, Y.-L., Chuang, Y.-W., Huang, H.-G., and Shih, J.-Y. The value of implementing enterprise risk management: Evidence from taiwan's financial industry. *The North American Journal of Economics and Finance 54* (2020), 100926.

[16] COSO. Enterprise risk management – integrated framework, committee of sponsoring organisation. *www.coso.org* (2004).

[17] COSO. Enterprise risk management – integrated framework, committee of sponsoring organisation. *www.coso.org* (2017).

[18] Cummins, J. D., and Weiss, M. A. Equity capital, internal capital markets, and optimal capital structure in the us property-casualty insurance industry. *Annual Review of Financial Economics 8* (2016), 121–153.

[19] Eckles, D. L., Hoyt, R. E., and Miller, S. M. Reprint of: The impact of enterprise risk management on the marginal cost of reducing risk: Evidence from the insurance industry. *Journal of Banking & Finance 49* (2014), 409–423.

[20] EIOPA. Eiopa technical specification for the preparatory phase (part i). *https://www.eiopa.europa.eu* (2014).

[21] Eling, M., Klein, R., and Schmit, J. T. A comparison of insurance regulation in the us and the european union. *Competition and the Future of Property and Casualty Insurance Markets* (2009).

[22] Farrar, D. E., and Glauber, R. R. Multicollinearity in regression analysis: the problem revisited. *The Review of Economic and Statistics* (1967), 92–107.

[23] Farrell, M., and Gallagher, R. The valuation implications of enterprise risk management maturity. *Journal of Risk and Insurance 82*, 3 (2015), 625–657.

[24] Farrell, M., and Gallagher, R. Moderating influences on the erm maturity-performance relationship. *Research in International Business and Finance 47* (2019), 616–628.

[25] Filipovic, D., Kupper, M., et al. *On the group level swiss solvency test.* University of Technology, Sydney, 2007.

[26] Florio, C., and Leoni, G. Enterprise risk management and firm performance: The italian case. *The British Accounting Review 49*, 1 (2017), 56–74.

[27] Gatzert, N., and Schmeiser, H. Combining fair pricing and capital requirements for non-life insurance companies. *Journal of Banking & Finance 32*, 12 (2008), 2589–2596.

[28] Gatzert, N., and Schmeiser, H. On the risk situation of financial conglomerates: does diversification matter? *Financial Markets and Portfolio Management 25*, 1 (2011), 3–26.

[29] Gordon, L. A., Loeb, M. P., and Tseng, C.-Y. Enterprise risk management and firm performance: A contingency perspective. *Journal of accounting and public policy 28*, 4 (2009), 301–327.

[30] Greene, W. Fixed effects and bias due to the incidental parameters problem in the tobit model. *Econometric reviews 23*, 2 (2004), 125–147.

[31] Heckman, J. Shadow prices, market wages, and labor supply. *Econometrica: journal of the econometric society* (1974), 679–694.

[32] Heckman, J. J. The common structure of statistical models of truncation, sample selection and limited dependent variables and a simple estimator for such models. In *Annals of economic and social measurement, volume 5, number 4*. NBER, 1976, pp. 475–492.

[33] Hoyt, R. E., and Liebenberg, A. P. The value of enterprise risk management: Evidence from the us insurance industry. In *unpublished paper, accessed at: http://www. aria. org/meetings/2006papers/Hoyt_Liebenberg_ERM_070606. pdf* (2008).

[34] Hoyt, R. E., and Liebenberg, A. P. The value of enterprise risk management. *Journal of risk and insurance 78*, 4 (2011), 795–822.

[35] Hull, J. C. *Options futures and other derivatives*. Pearson Education India, 2003.

[36] Lang, L., Ofek, E., and Stulz, R. Leverage, investment, and firm growth. *Journal of financial Economics 40*, 1 (1996), 3–29.

[37] Lang, L. H., and Stulz, R. M. Tobin's q, corporate diversification, and firm performance. *Journal of political economy 102*, 6 (1994), 1248–1280.

[38] Lechner, P., and Gatzert, N. Determinants and value of enterprise risk management: empirical evidence from germany. *The European Journal of Finance 24*, 10 (2018), 867–887.

[39] Li, Q., Wu, Y., Marshall, A., Chipulu, M., and Ojiako, U. Enterprise risk management and firm value within china's insurance industry. *Acta Commercii 14*, 1 (2014), 1–10.

[40] Liebenberg, A. P., and Sommer, D. W. Effects of corporate diversification: Evidence from the property–liability insurance industry. *Journal of Risk and Insurance 75*, 4 (2008), 893–919.

[41] Lin, Y., Wen, M.-M., and Yu, J. Enterprise risk management: Strategic antecedents, risk integration, and performance. *North American Actuarial Journal 16*, 1 (2012), 1–28.

[42] Lloyd's. Lloyd's of london model scope, governance and use 2010. *www.lloyds.com* (2010).

[43] Lloyd's. Lloyd's of london scr guidance 2011. *www.lloyds.com* (2011).

[44] Lloyd's. Lcr specification: Internal model scr. *www.lloyds.com* (2013).

[45] Lloyd's. Lloyd's of london model validation guidance, 2014. *www.lloyds.com* (2014).

[46] Lloyd's. Lloyd's annual report 2015. *www.lloyds.com* (2015).

[47] Lloyd's. Lloyd's of london orsa guidance 2015. *www.lloyds.com* (2015).

[48] Lloyd's. Lloyd's annual report 2016. *www.lloyds.com* (2016).

[49] Lloyd's. Lloyd's of london annual reports. *www.lloyds.com* (2019).

[50] Mankai, S., and Belgacem, A. Interactions between risk taking, capital, and reinsurance for property–liability insurance firms. *Journal of Risk and Insurance 83*, 4 (2016), 1007–1043.

[51] McShane, M. K., Nair, A., and Rustambekov, E. Does enterprise risk management increase firm value? *Journal of Accounting, Auditing & Finance 26*, 4 (2011), 641–658.

[52] Meulbroek, L. K. Integrated risk management for the firm: a senior manager's guide. *Available at SSRN 301331* (2002).

[53] Nocco, B. W., and Stulz, R. M. Enterprise risk management: Theory and practice. *Journal of applied corporate finance 18*, 4 (2006), 8–20.

[54] Oliva, F. L. A maturity model for enterprise risk management. *International Journal of Production Economics 173* (2016), 66–79.

[55] Pagach, D., and Warr, R. The characteristics of firms that hire chief risk officers. *Journal of risk and insurance 78*, 1 (2011), 185–211.

[56] Pagach, D. P., and Warr, R. S. The effects of enterprise risk management on firm performance. *Available at SSRN 1155218* (2010).

[57] Petersen, M. A. Estimating standard errors in finance panel data sets: Comparing approaches. *The Review of financial studies 22*, 1 (2009), 435–480.

[58] Philips, R., Grace, M., Leverty, J., and Shimpi, P. The value of investing in enterprise risk management. *Robinson College of Business, Georgia State University, Atlanta* (2010).

[59] Powell, L. S., and Sommer, D. W. Internal versus external capital markets in the insurance industry: The role of reinsurance. *Journal of Financial Services Research 31*, 2-3 (2007), 173–188.

[60] Powell, L. S., Sommer, D. W., and Eckles, D. L. The role of internal capital markets in financial intermediaries: Evidence from insurer groups. *Journal of Risk and Insurance 75*, 2 (2008), 439–461.

[61] Schlütter, S., and Gründl, H. Who benefits from building insurance groups? a welfare analysis of optimal group capital management. *The Geneva Papers on Risk and Insurance-Issues and Practice 37*, 3 (2012), 571–593.

[62] Shiu, Y.-M. Reinsurance and capital structure: Evidence from the united kingdom non-life insurance industry. *Journal of Risk and Insurance 78*, 2 (2011), 475–494.

[63] S&P. Criteria, insurance, general: Evaluating the enterprise risk management practices of insurance companies. *www.standardandpoors.com* (2005).

[64] S&P. Criteria, insurance, general: Evaluating the enterprise risk management practices of insurance companies. *www.standardandpoors.com* (2007).

[65] S&P. Criteria, insurance, general: Evaluating the enterprise risk management practices of insurance companies. *www.standardandpoors.com* (2013).

[66] S&P. Criteria, insurance, general: Evaluating the enterprise risk management practices of insurance companies. *www.standardandpoors.com* (2016).

[67] Tahir, I. M., and Razali, A. R. The relationship between enterprise risk management (erm) and firm value: Evidence from malaysian public listed companies. *International journal of economics and management sciences 1*, 2 (2011), 32–41.

[68] Toomet, O., Henningsen, A., et al. Sample selection models in r: Package sampleselection. *Journal of statistical software 27*, 7 (2008), 1–23.

[69] Wagner, C. H. Simpson's paradox in real life. *The American Statistician 36*, 1 (1982), 46–48.

[70] Zou, H. Hedging affecting firm value via financing and investment: evidence from property insurance use. *Financial Management 39*, 3 (2010), 965–996.