The Roles of Catastrophe (CAT) Bonds: Diversifier, Hedge, or Safe Haven?

Mr. Treepatchara Tasnavijitvong

An Independent Study Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Science in Finance
Department of Banking and Finance
Faculty Of Commerce And Accountancy
Chulalongkorn University
Academic Year 2023

การศึกษาบทบาทของตราสารหนี้ภัยพิบัติ: สินทรัพย์เพื่อกระจายความเสี่ยง สินทรัพย์เพื่อป้องกันความเสี่ยง หรือสินทรัพย์ปลอดภัย?

นายตรีพัชร ทัศนวิจิตรวงศ์

สารนิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต
สาขาวิชาการเงิน ภาควิชาการธนาคารและการเงิน
คณะพาณิชยศาสตร์และการบัญชี จุฬาลงกรณ์มหาวิทยาลัย
ปีการศึกษา 2566

Independent Study Title	The Roles of Catastrophe (CAT) Bonds: Diversifier, Hedge, or Safe Haven?
By	Mr. Treepatchara Tasnavijitvong
Field of Study	Finance
Thesis Advisor	Associate Professor BOONLERT JITMANEEROJ, Ph.D.

Accepted by the FACULTY OF COMMERCE AND ACCOUNTANCY, Chulalongkorn University in Partial Fulfillment of the Requirement for the Master of Science

INDEPENDENT STUDY COMMITTEE

.... Chairman
()

.... Advisor
(Associate Professor BOONLERT JITMANEEROJ, Ph.D.)

.... Examiner
(Associate Professor SIRA SUCHINTABANDID, Ph.D.)

.... Examiner
(Assistant Professor RUTTACHAI SEELAJAROEN, Ph.D.)

ตรีพัชร ทัศนวิจิตรวงศ์ : การศึกษาบทบาทของตราสารหนี้ภัยพิบัติ: สินทรัพย์เพื่อกระจายความเสี่ยง สินทรัพย์เพื่อป้องกันความเสี่ยง หรือสินทรัพย์ปลอดภัย?. (The Roles of Catastrophe (CAT) Bonds: Diversifier, Hedge, or Safe Haven?)
อ.ที่ปรึกษาหลัก : บุญเลิศ จิตรมณีโรจน์

การวิจัยนี้สำรวจบทบาทของตราสารหนี้ภัยพิบัติในฐานะสินทรัพย์เพื่อกระจายความเสี่ยง สินทรัพย์เพื่อป้องกันความเสี่ยง หรือสินทรัพย์ปลอดภัยทางการเงินในตลาดการเงินโลก โดยเน้นที่พฤติกรรมในช่วงวิกฤตการเงินโลกและวิกฤติโควิด-19 การศึกษาเผยให้เห็นว่าตราสารหนี้ภัยพิบัติ ซึ่งได้รับการยอมรับว่าเป็นสินทรัพย์ที่มีค่าเนื่องจากโครงสร้างที่เป็นเอกลักษณ์และความสามารถในการโอนความเสี่ยงจากภัยพิบัติได้รับความนิยมจากนักลงทุนสถาบัน เมื่อตรวจสอบประโยชน์ของการกระจายความเสี่ยงของตราสารหนี้ภัยพิบัติที่มีต่อสินทรัพย์แบบดั้งเดิมและวิเคราะห์ผลการดำเนินงานในช่วงวิกฤตและช่วงที่ไม่มีวิกฤต การศึกษาชี้ให้เห็นถึงตราสารหนี้ภัยพิบัติในฐานะเครื่องมือที่มีประสิทธิภาพสำหรับการจัดการความเสี่ยงและการกระจายความเสี่ยงในพอร์ตโฟลิโอ ผลการศึกษาแสดงให้เห็นถึงความสามารถของตราสารหนี้ภัยพิบัติในการเสนอความมั่นคงและการป้องกันในสภาวะตลาดที่ผันผวน ซึ่งการศึกษานี้ให้ข้อมูลที่มีค่าสำหรับผู้จัดการพอร์ตโฟลิโอและนักลงทุน นอกจากนี้ยังสำรวจบทบาทของตราสารหนี้ภัยพิบัติในสภาวะตลาดที่แตกต่างกัน มีส่วนช่วยในการเข้าใจศักยภาพในการจัดการพอร์ตโฟลิโอและการลดความเสี่ยงทั่วทุกสภาพทางเศรษฐกิจ.

สาขาวิชา	การเงิน	ลายมือชื่อนิสิต ....
ปีการศึกษา	2566	ลายมือชื่อ อ.ที่ปรึกษาหลัก ....

6484040926 : MAJOR FINANCE
KEYWORD: Catastrophe bonds, Diversifier, Hedge, Safe haven, DCC GARCH

Treepatchara Tasnavijitvong : The Roles of Catastrophe (CAT) Bonds: Diversifier, Hedge, or Safe Haven?. Advisor: Assoc. Prof. BOONLERT JITMANEEROJ, Ph.D.

This research investigates the role of Catastrophe (CAT) Bonds as diversification tools, hedges, and safe havens in global financial markets, with a focus on their behavior during the global financial crisis and the Covid-19 crisis. The study reveals that CAT bonds, recognized as a valuable asset class for their unique structure and ability to transfer catastrophic risks, have gained prominence among institutional investors. By examining the diversification benefits of CAT bonds in relation to traditional assets and analyzing their performance in crisis and non-crisis periods, the research highlights CAT bonds as effective tools for risk management and portfolio diversification. The findings demonstrate CAT bonds' ability to offer stability and protection in volatile market conditions, providing valuable insights for portfolio managers and investors. Additionally, the study explores the role of CAT bonds in different market conditions, contributing to the understanding of their potential in portfolio management and risk mitigation across various economic landscapes.

Field of Study:	Finance	Student's Signature ....
Academic Year:	2023	Advisor's Signature ....

ACKNOWLEDGEMENTS

My sincerest appreciation goes to everyone who played a pivotal role in my academic journey and contributed to the success of my research endeavor. The support, advice, and encouragement I received from each one of you have been fundamental in this endeavor.

I would like to extend my deepest gratitude to my advisor, Assoc. Prof. Boonlert Jitmaneeroj, Ph.D., whose expertise, understanding, and patience, added considerably to my graduate experience. Your guidance and mentorship have been invaluable in shaping both my academic work and my growth as a researcher.

I am also deeply thankful to my committee members, Assoc. Prof. Sira Suchintabandid, Ph.D., and Asst. Prof. Ruttachai Seelajaroen, Ph.D. Your insightful feedback and consistent support have been pivotal in refining my research and enhancing my understanding.

A heartfelt thank you to my classmates. The journey we shared has been filled with encouragement, learning, and invaluable camaraderie. Our discussions and collaborations have been integral to not just my academic development but also to making this experience truly enriching and memorable.

To my family and friends, I am profoundly grateful for your unconditional love, support, and constant encouragement. Your sacrifices, faith in me, and presence - be it for academic discussions or for providing much-needed breaks - have been fundamental to my journey. This accomplishment is as much a testament to your support as it is to my efforts.

I am deeply grateful for your essential role in my academic journey and for your priceless contributions that have led to the successful completion of this project.

Treepatchara Tasnavijitvong

TABLE OF CONTENTS

CHAPTER 1: INRODUCTION

1.1 Background

Over the past decade, there has been a notable increase in the utilization of catastrophe (CAT) bonds, with institutional investors increasingly recognizing them as a valid and valuable asset class choice. These specialized bonds have gained prominence due to their unique structure, which enables investors to access insurance-linked securities and participate in the transfer of catastrophic risks. As a result, CAT bonds have emerged as an alternative investment option, offering attractive features such as diversification, risk management, and potentially high returns. While previous research has explored the diversification benefits of CAT bonds in the context of global equity markets, there is a gap in understanding their role as hedgers and safe havens, particularly during periods of financial crises. This research study aims to fill this gap by investigating the hedging, diversification, and safe haven properties of CAT bonds in the equity market during two distinct crises: the global financial crisis and the Covid-19 crisis. By examining the performance and behavior of CAT bonds during these challenging market conditions, this study aims to provide valuable insights into their effectiveness as risk management tools and their potential to enhance portfolio diversification strategies.

The interest in securitizing insurance risks and the issuance of CAT bonds grew after the devastating impact of Hurricane Andrew in 1992. The first successful issuance of CAT bonds occurred in 1994, followed by the introduction of derivatives on a catastrophe index in 1995. However, the market experienced a setback with the failure of the Kamp Re 2005 Ltd. CAT Bond prior to Hurricane Katrina, resulting in a loss of $190 million for investors. Global catastrophe insured losses have shown a significant increase over time, with losses exceeding $30 billion per year since the early 1990s. This trend has continued, and losses consistently surpassed the $100 billion mark since 2003, with some years even observing losses over $200 billion. In response to this escalating risk, insurance markets have sought innovative solutions, with CAT bonds emerging as a prominent alternative risk financing tool. Since their development in the early 1990s, CAT bonds have steadily grown in popularity and provided a substantial source of risk capital for insurers and reinsurers. The CAT bond market expanded from $633 million in 1997 to nearly $7 billion in 2007, with some temporary slowdown due to the subprime financial crisis in 2008-2009. However, despite this setback, the CAT bond market has experienced significant growth over the past decade. Despite this setback, the CAT bond market has grown significantly over the past decade. According to the Artemis Deal Directory, the average annual issuance of CAT bonds has been around $9.7 billion. By the end of 2022, the outstanding CAT bonds market size reached a new year-end high of $37.9 billion, indicating sustained growth.

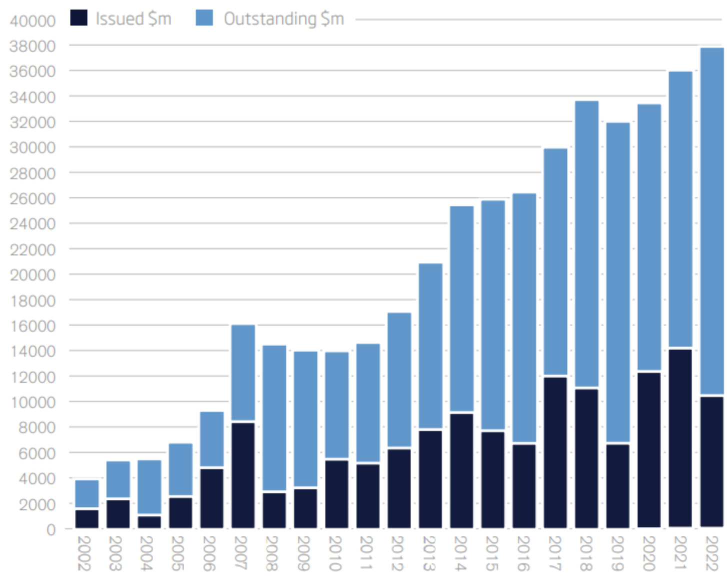


Figure 1. CAT bond issuance / outstanding 2002 - 2022

The bars in the figure represent the total amount of CAT bonds issued / outstanding by year for the period from 2002 to 2022 (in US$ million) *Source: Artemis.bm (2022)*

The standard structure of a CAT bond involves a special purpose vehicle (SPV) or insurer that enters into a reinsurance agreement with a sponsor or counterparty. Under this agreement, the sponsor pays premiums to the SPV, and in return, insurance coverage is provided through the issuance of securities. Investors contribute principal amounts, which are deposited into a collateral account and typically invested in highly rated money market funds. Investors receive coupon payments that include interest generated from the collateral and sponsor premiums. However, The coverage focuses on specific perils (such as wildfires, windstorms, or earthquakes) and territories where these events occur, providing protection against costly natural disasters globally. Traditionally, bonds covering risks in the United States, Japan, and Europe have dominated the market, but there is an increasing trend of issuing bonds for emerging markets like China to address natural catastrophe risks. In the event of a qualifying trigger event that satisfies predetermined conditions, including the specific perils and territories, the SPV will liquidate the collateral to make payments and reimburse the counterparty according to the terms of the catastrophe bond transaction. If no trigger event occurs, the collateral is liquidated at the end of the bond term, and investors receive repayment.

Diversification is a fundamental principle in investment decision-making, as it allows investors to construct portfolios that maximize returns while minimizing risk. Markowitz's Modern Portfolio Theory highlights the benefits of diversification by emphasizing the importance of adding assets with lower correlations to an existing portfolio. While the concept of diversification is widely studied across various asset classes, recent literature has explored the potential diversification benefits of CAT bonds. These bonds, which provide insurance against catastrophic events, have traditionally been classified as zero-beta assets with weak correlation to other financial assets. However, a growing body of research challenges this notion and suggests that CAT bonds offer diversification advantages. Gürtler, Hibbeln et al. (2016) find a positive correlation between corporate bond spreads and CAT bond premiums, questioning their zero-beta characteristic. More recently, Demers-Bélanger and Lai (2020) investigate the diversification benefits of CAT bonds during critical periods, showing their ability to enhance portfolio performance. These findings underscore the importance of considering CAT bonds for diversification purposes and their potential to improve portfolio outcomes.

Similar to the diversification benefits, hedging and safe havens are concepts that have been extensively explored in financial literature, with particular emphasis on their relevance in times of market stress. Baur and Lucey (2010) define a diversifier as an asset with a weak positive correlation, a hedge as an asset uncorrelated or negatively correlated, and a safe haven as an asset uncorrelated or negatively correlated during times of crisis. Examining the properties of CAT bonds, several studies have shed light on their behavior and role in portfolio management. Carayannopoulos and Perez (2015) emphasize the impact of the subprime financial crisis on CAT bonds, revealing weaknesses in the trust account's composition and collateral assets. Drobetz, Schröder et al. (2020) provide insights into CAT bonds as diversifiers, hedges, and safe havens, finding them effective diversifiers and strong safe havens after crises, but not effective hedges. Understanding the diversifier, hedger, and safe haven properties of CAT bonds is essential for informed portfolio management strategies, particularly during market stress and turbulence.

By exploring the diversification potential of CAT bonds and their correlation with other financial assets, this research aims to provide valuable insights for investors and portfolio managers. Understanding the role of CAT bonds as diversifiers rather than hedgers and safe havens is crucial for effective portfolio management and optimizing risk-return trade-offs. The findings from this study can inform investment strategies and contribute to the overall understanding of diversification in global financial markets.

1.2 Objective and research questions

The objective of this research is to investigate the diversification benefits offered by CAT bonds in the context of global financial markets. The study aims to explore the behavior of CAT bonds during crises and across different levels of market development. Specifically, the research aims to:

1. Examine the diversification benefits between CAT bonds and traditional assets.,
2. Investigate the role of CAT bonds as diversifiers, hedge or safe havens.

In summary, this research aims to provide valuable insights into the diversification benefits of CAT bonds, their behavior during periods of crises, and their role as diversifiers, hedgers, and safe havens. By investigating these aspects within the context of global financial markets and considering different levels of market development, this research seeks to enhance the understanding of CAT bonds' potential in portfolio management and risk mitigation.

1.3 Contribution

The research makes three significant contributions to the existing literature on CAT bonds. Firstly, it highlights CAT bonds as an effective diversification tool for investment portfolios. By examining their role in different market conditions, the study demonstrates the diversification benefits that CAT bonds can offer to investors. This finding is valuable for portfolio managers seeking to enhance risk management and improve the overall performance of their portfolios.

Secondly, the research identifies the properties of CAT bonds as diversifiers, hedges, or safe havens. By analyzing their behavior during crises and non-crisis periods, the study sheds light on how CAT bonds can potentially serve as a source of stability and protection in times of market volatility. This understanding of CAT bonds' risk-mitigating properties is crucial for investors aiming to construct resilient portfolios and navigate uncertain market conditions effectively.

Lastly, the study contributes to the existing literature by enhancing our understanding of the role of CAT bonds in different levels of market development. By examining both developed and emerging markets, the research provides insights into the diversification potential of CAT bonds across various economic landscapes. This information is valuable for investors looking to diversify their portfolios in different market environments and for policymakers aiming to promote the growth and adoption of CAT bonds within their respective markets.

CHAPTER 2: LITERATURE REVIEW

2.1 Diversification Benefits

Markowitz's Modern Portfolio Theory revolutionized investment decision-making by emphasizing the benefits of diversification. According to Markowitz, adding stocks with lower correlation to an existing portfolio can reduce overall risk. This principle allows investors to construct optimal portfolios with maximum returns and minimum risk. While the diversification concept is widely practiced using various academic methods, Chong, Miffre et al. (2009) examines the conditional correlations between real estate investment trust (REIT) returns and equity, bond, and commodity returns. The findings indicate that the correlations between REITs and equity returns have increased over time, suggesting a greater integration between the real estate and equity markets. However, the correlations with bond and commodity returns have decreased, indicating a more segmented relationship with these markets. The study also reveals that correlations tend to rise during periods of above-average volatility, suggesting potential diversification benefits for investors. Notably, the correlations between U.S. government securities and REIT returns decrease during periods of high interest rate risk, implying that allocating more towards real estate can help reduce portfolio risk. Additionally, REITs can serve as a partial hedge against commodity price risk. These findings highlight the changing dynamics and potential diversification qualities of REIT investments in relation to other asset classes.

Recent empirical studies have presented findings that question the zero-beta characteristic of CAT bonds. One such study by Gürtler, Hibbeln et al. (2016) reveals a positive correlation between corporate bond spreads and CAT bond premiums. According to Litzenberger, Beaglehole et al. (1996), there is a weak correlation between the returns of CAT bonds and other financial assets. As a result, they have classified CAT bonds as zero-beta assets. Hoyt and McCullough (1999) examines PCS Catastrophe Insurance Options and confirms that they behave as zero-beta assets, meaning they are uncorrelated with movements in the capital markets. The options provide diversification benefits and can improve reward-to-variability ratios in investment portfolios. The findings support their use as a means to efficiently diversify portfolios and reduce overall risk. The study suggests the potential for investment funds based on these options, which would increase market liquidity and provide additional diversification opportunities. Clark, Dickson et al. (2016), Kish (2016) and Sterge and van der Stichele (2016) offer compelling evidence supporting the notion that CAT bonds offer diversification benefits when incorporated into a portfolio consisting of stocks, bonds, commodities, and real estate. The inclusion of CAT bonds in a multi-asset portfolio not only enhances diversification but also mitigates drawdown measures and tail risk across different market environments. discover that CAT bond funds outperform other asset classes such as bonds and hedge funds. Their analysis reveals that the return drivers of CAT bond funds are best captured by a multi-factor perils model, which excludes the traditional equity and bond market factors typically associated with traditional asset classes. Braun (2016) discovers that CAT bond funds outperform other asset classes such as bonds and hedge funds. Their analysis reveals that the return drivers of CAT bond funds are best captured by a multi-factor perils model, which excludes the traditional equity and bond market factors typically associated with traditional asset classes. Mariani and Amoruso (2016) emphasized the limited correlation between the CAT bonds market and traditional markets. They also noted that CAT bonds exhibit lower volatility and relatively stable returns. Despite these unique features, there has been little focus on exploring the potential of utilizing CAT bonds for diversification purposes. Recently, Demers-Bélanger and Lai (2020) investigate the diversification benefits of including CAT bonds in investment portfolios composed of traditional assets and common factors. Their findings reveal that CAT bonds enhance the time-varying Sharpe ratio and maximum diversification ratio of portfolios, particularly during critical periods such as crises and high volatility. However, their second-order stochastic dominance efficiency tests indicate that portfolios without CAT bonds cannot be rejected as efficient, suggesting the importance of considering the entire distribution of returns.

To conclude, Recent studies have examined the diversification potential of CAT bonds and their correlation with other financial assets. While earlier research classified CAT bonds as zero-beta assets with weak correlation, more recent findings challenge this notion. Studies indicate a positive correlation between CAT bond premiums and corporate bond spreads, suggesting potential diversification benefits. CAT bonds have been shown to improve portfolio reward-to-variability ratios and exhibit low volatility and stable returns. Including CAT bonds in multi-asset portfolios enhances diversification, mitigates risk, and can outperform other asset classes. These findings highlight the importance of considering CAT bonds for diversification purposes and their potential to enhance portfolio performance during critical periods.

In addition, apart from reviewing the diversification benefits of CAT bonds, other studies explore diversification benefits among different levels of market development. Driessen and Laeven (2007) find that investing abroad offers the largest benefits in emerging markets, emphasizing the significance of global diversification for investors in both developed and emerging markets. Purkayastha, Manolova et al. (2012) highlight the diversity of findings in the relationship between diversification and firm performance, suggesting related diversification is preferable in developed economies, while unrelated diversification is more appropriate in emerging economies. Basher and Sadorsky (2016) compare the effectiveness of different GARCH models for hedging in emerging markets, while Kiymaz and Simsek (2017) focus on the performance of US mutual funds investing in emerging market equities and bonds. These studies underscore the potential benefits of global diversification, the importance of industry-specific analysis, and the potential for higher risk-adjusted returns with diversified emerging market funds.

2.2 Hedger, diversifier, and safe haven

The concepts of hedging, diversification, and safe havens have gained significant attention in recent decades. The global financial crisis and the impressive performance of gold have further fueled interest in investigating gold's potential as a safe haven asset during market downturns. In their study, Baur and Lucey (2010) have presented empirical findings indicating that gold has a tendency to retain its value when stock markets in Germany, the UK, and the US encounter substantial negative returns. The findings reveal that gold serves as a hedge against stocks on average and acts as a safe haven during extreme stock market conditions. However, the safe haven property of gold is short-lived, lasting for approximately 15 trading days. Beyond this period, holding gold as a safe haven investment after an extreme negative shock results in losses. The study suggests that investors tend to buy gold during times of market turmoil and sell it when confidence is restored and volatility decreases. Future research could explore additional stock and bond markets and examine the role of exchange rates in relation to the safe haven hypothesis. In addition, Baur and Lucey (2010) defined the properties as below :

Hedge : A hedge is defined as an asset that is uncorrelated or negatively correlated with another asset or portfolio on average.

Diversifier : A diversifier is defined as an asset that is positively (but not perfectly correlated) with another asset or portfolio on average.

Safe haven : A safe haven is defined as an asset that is uncorrelated or negatively correlated with another asset or portfolio in times of market stress or turmoil.

Subsequently, Baur and McDermott (2010) examines the role of gold as a safe haven asset in the global financial system. The findings indicate that gold acts as a hedge and a safe haven for major developed markets but not for certain emerging markets. Gold can reduce losses during extreme negative market shocks and has the potential to stabilize the financial system. However, its safe haven effect is weaker during gradual market trends. Gold also shows a safe haven characteristic during specific crisis periods, particularly for developed markets. The relationship between gold and global uncertainty reveals that it serves as a safe haven for increased uncertainty but not under extreme uncertainty. Overall, gold plays a valuable role in mitigating losses and providing protection in specific market conditions.

Apart from gold, other alternative assets were being studied following the approach proposed by above. Ratner and Chiu (2013) explores the risk-reducing benefits of credit default swaps (CDS) in U.S. stock market sectors from 2004 to 2011. The analysis indicates that CDS serve as effective hedges against risk in all sectors and provide safe haven characteristics during extreme stock market volatility and financial crises, although the strength of the safe haven attribute varies across sectors. Holding CDS indexes in all sectors appears to reduce default risk and mitigate stock sector risk. However, the level of safe haven protection varies, with some sectors showing stronger safe haven properties than others. Overall, CDS can be valuable tools for managing risk in the stock market, but their effectiveness as safe havens may depend on sector and market conditions. Bouri, Molnár et al. (2017) This study investigates the potential of Bitcoin as a hedge and safe haven asset against major world stock indices, bonds, oil, gold, the general commodity index, and the US dollar index. The empirical findings suggest that Bitcoin is not a reliable hedge but can be used for diversification purposes. However, it exhibits strong safe haven characteristics only during extreme down movements in Asian stocks on a weekly basis. The study highlights the need for caution due to the liquidity limitations of Bitcoin and the time-varying nature of its diversification, hedge, and safe haven properties. Further research is encouraged to explore these dynamics in more detail. Bekiros, Boubaker et al. (2017) find that gold is a diversifier but not a hedge or safe haven for BRICS stock markets. The study reveals time-scale co-movement patterns between gold and BRICS markets, with higher dependence during bad times. Gold's diversifying potential decreases in the long run as it becomes more integrated into portfolios. The findings have implications for risk diversification and portfolio hedging strategies in BRICS markets.

Moving to the properties specifically CAT bonds, Cummins and Weiss (2009) provide an overview of the convergence between the insurance/reinsurance industry and financial markets. They examined the correlation between the CAT bonds market and other financial markets from 2002 to 2008. They discovered that during normal market conditions, CAT bonds could be regarded as zero-beta assets, implying they were not significantly correlated with other markets. However, the researchers also found that during crisis periods, there was a notable dependency between the CAT bonds market and other financial markets, indicating a significant correlation. Carayannopoulos and Perez (2015) investigate the behavior of CAT bond returns during the subprime financial crisis. They replicated the study conducted by Cummins and Weiss (2009) observed that the subprime financial crisis had a strong impact on catastrophe bonds due to weaknesses in the trust account's composition and structure. The collateral assets used in the trust account were discovered to be of lower quality than initially anticipated, and counterparties involved in swap agreements faced substantial credit risk or even defaulted during the crisis. Similarly, Gürtler, Hibbeln et al. (2016) found that catastrophe bond premiums were influenced by capital market developments, specifically measured by corporate bond spreads. This positive relationship became significantly reinforced after the Lehman Brothers bankruptcy, which triggered the financial crisis. Specifically examine the properties of CAT bonds, Drobetz, Schröder et al. (2020) explore the role of CAT bonds as hedges, diversifiers, and safe havens for various asset classes. The findings suggest that CAT bonds are effective diversifiers but not effective hedges. They also act as strong safe havens only during the post-crisis period, particularly against extreme stock market declines. The study provides important insights for institutional investors regarding hedging strategies and portfolio adjustments during market stress. CAT bonds offer valuable diversification benefits within multi-asset portfolios. These findings align with the research conducted by Carayannopoulos and Perez (2015) as well as Gürtler, Hibbeln et al. (2016).

CAT bonds have unique characteristics that make them attractive for portfolio diversification. They are considered zero-beta assets during normal market conditions, indicating little to no correlation with other markets. However, during crisis periods, CAT bonds exhibit a significant dependency on other financial markets, suggesting a correlation. Despite this, CAT bonds offer valuable diversification benefits and act as safe havens, particularly after crises. Understanding the role of CAT bonds in hedging, diversification, and as safe haven assets is crucial for effective portfolio management.

CHAPTER 3: HYPOTHESIS DEVELOPMENT

Previous studies have consistently shown that CAT bonds exhibit a certain level of independence from global bond and equity markets. Due to their unique exposure to catastrophic events, CAT bonds display distinct return patterns compared to traditional assets i.e. equity and bond. Building on this understanding, the hypothesis put forward in this study suggests that CAT bonds can serve as effective diversifiers against global bonds and equities. The objective of this research is to provide valuable insights into the diversification benefits offered by CAT bonds within the context of global financial markets, while also exploring their behavior during periods of crises and across different levels of market development. Additionally, the study aims to investigate the role of CAT bonds as diversifiers rather than hedgers and safe havens.

Hypothesis 1: The diversification benefits exist between CAT bond and traditional assets, with diversification benefit depending on market condition (crisis and non-crisis) and level of market development (emerging and developed market).

The literature indicates that CAT bonds exhibit unique characteristics that make them potential diversifiers within investment portfolios. Previous studies have challenged the notion of CAT bonds as zero-beta assets and have found positive correlations between CAT bond premiums and corporate bond spreads, suggesting potential diversification benefits. Studies by Clark, Dickson et al. (2016), Kish (2016), Sterge and van der Stichele (2016), and Braun (2016) provide compelling evidence supporting the notion that catastrophe bonds offer diversification benefits when incorporated into a portfolio consisting of stocks, bonds, commodities, and real estate. These studies highlight that the inclusion of CAT bonds in a multi-asset portfolio enhances diversification and mitigates drawdown measures and tail risk across different market environments. Furthermore, Demers-Bélanger and Lai (2020) find that including CAT bonds in investment portfolios composed of traditional assets and common factors enhances the time-varying Sharpe ratio and maximum diversification ratio of portfolios, particularly during critical periods such as crises and high volatility. The studies also emphasize that CAT bonds exhibit lower volatility and relatively stable returns, which contribute to their potential as diversification assets. Additionally, the research conducted by Cummins and Weiss (2009) and Carayannopoulos and Perez (2015) suggests that CAT bonds demonstrate a correlation with other financial markets during crisis periods, indicating their potential as diversification assets during such times.

Previous studies have provided insights into the benefits of international portfolio diversification in both developed and emerging markets. Driessen and Laeven (2007) found that the largest benefits of investing abroad were observed in emerging markets, even after considering currency effects and short-sales constraints. The study highlighted that investing outside the investor's home region contributed significantly to these diversification benefits. Furthermore, the research indicated that the benefits of diversification were more pronounced in countries with higher country risk, and these benefits decreased over time as country risk improved. This study emphasized the importance of global diversification for investors in both developed and emerging markets and called for further liberalization of international financial markets to enhance diversification opportunities. In addition, Purkayastha, Manolova et al. (2012) synthesized and compared research on diversification and firm performance in developed and emerging economies. They highlighted the diversity of findings within each perspective and suggested that related diversification based on specific resources was preferable in developed economies, while unrelated diversification based on generic resources was more appropriate in emerging economies. This research emphasized the differences in findings between developed and emerging markets and stressed the importance of considering contextual factors in diversification decisions. Considering the findings of Driessen and Laeven (2007) and Purkayastha, Manolova et al. (2012), we can develop hypothesis of diversification benefit depending on level of market development (emerging and developed market).

In conclusion, previous studies support the hypothesis that CAT bonds offer diversification benefits. CAT bonds exhibit unique characteristics that enhance diversification, reduce risk, and provide stable returns. They demonstrate correlation with other financial markets during crises, further highlighting their potential as diversification assets. International portfolio diversification, especially in emerging markets, also yields significant benefits. Understanding these diversification advantages is crucial for effective portfolio management and risk mitigation.

Hypothesis 2: CAT bond acts like diversifier, hedge or safe haven.

2.1 : During non-crisis, CAT bond acts like diversifier rather than hedge

2.2 : During crisis, CAT bond acts like weak safe haven, rather than strong safe haven

The hypothesis that CAT bonds act as diversifiers rather than hedgers and safe havens has gained attention in recent studies. CAT bonds, also known as catastrophe bonds, are financial instruments that provide insurance against natural disasters or other catastrophic events. This hypothesis is supported by several previous studies, including Cummins and Weiss (2009) and Carayannopoulos and Perez (2015), Gürtler, Hibbeln et al. (2016) and Drobetz, Schröder et al. (2020)

Cummins and Weiss (2009) and Carayannopoulos and Perez (2015) examined the behavior of CAT bond returns during the subprime financial crisis and found that the crisis had a significant impact on catastrophe bonds due to weaknesses in their trust account's composition and structure. Despite this impact during crisis periods, CAT bonds were found to offer valuable diversification benefits and act as safe havens, particularly after crises. Gürtler, Hibbeln et al. (2016) investigated the influence of capital market developments, specifically measured by corporate bond spreads, on catastrophe bond premiums. Their study revealed a positive relationship between these factors, which became even stronger after the Lehman Brothers bankruptcy triggered the financial crisis. Although not directly examining the diversifier aspect, this study indirectly supports the notion that CAT bonds can act as diversifiers, as their premiums are influenced by market conditions. Drobetz, Schröder et al. (2020) specifically examines the role of CAT bonds as hedges, diversifiers, and safe havens for various asset classes. The findings suggest that catastrophe bonds are effective diversifiers but not effective hedges. They also act as strong safe havens only during the post-crisis period, particularly against extreme stock market declines. This study provides important insights for institutional investors regarding hedging strategies and portfolio adjustments during market stress.

According to Baur and Lucey (2010), a diversifier is an asset that has a weak positive correlation with another asset. Conversely, a hedge is an asset that is uncorrelated or even negatively correlated with another asset, on average. Lastly, a safe haven is an asset that is uncorrelated or negatively correlated with another asset during times of stress or crisis. In other words, a diversifier provides a mild positive correlation, a hedge shows little to no correlation or negative correlation, and a safe haven exhibits no correlation or negative correlation during challenging market conditions.

In line with the definition proposed by Baur and Lucey (2010), a diversifier is an asset that has a weak positive correlation with another asset. The hypothesis that CAT bonds act as diversifiers aligns with this definition and is supported by previous studies such as Drobetz, Schröder et al. (2020) and Carayannopoulos and Perez (2015), which highlight the diversification benefits provided by CAT bonds and their low correlation with other assets during normal market conditions. Regarding hedging, an asset that is uncorrelated or even negatively correlated with another asset, on average, is considered a weak or strong hedge. While the hypothesis focuses more on CAT bonds acting as diversifiers, the previous study by Drobetz, Schröder et al. (2020) indicates that CAT bonds are not effective hedges, aligning with the definition of a weak hedge. Lastly, a safe haven asset is defined as an asset that is uncorrelated or negatively correlated with another asset during times of stress or crisis. The hypothesis suggests that CAT bonds may act as safe havens. This idea is supported by studies such as Drobetz, Schröder et al. (2020) and Carayannopoulos and Perez (2015), which indicate that CAT bonds offer diversification benefits and act as safe havens, particularly after crises, aligning with the definition of a safe haven asset.

In conclusion, the hypothesis that CAT bonds act as diversifiers is supported by previous studies, and their role as hedges and safe havens is also explored. Understanding the characteristics of CAT bonds in relation to diversification, hedging, and safe haven properties is crucial for effective portfolio management and risk mitigation strategies.

CHAPTER 4: DATA

The dataset includes the Swiss Re Global Hedged CAT Bond Performance Index (SRGLTRR), which serves as the industry's key reference for CAT bonds. This index provides weekly data and is used as a representative measure of CAT bonds. In our analysis, we assess the performance of CAT bonds in comparison to traditional assets i.e. equity and bond. We specifically focus on different levels of market development, including developed market (DM) and emerging markets (EM), within the equity and bond segments. All the data for the indices are denominated in USD and were obtained from Bloomberg and Datastream.

Table 1: Variable description

Index	Type	Region
Swiss Re Global Hedge CAT Bond Performance Index (SRGLTRR)	CAT bond	Global
Morgan Stanley Capital International All Country World (AC WORLD)	Equity	Global
Morgan Stanley Capital International World (WORLD)	Equity	DM
Morgan Stanley Capital International Emerging Market (MSCI EM)	Equity	EM
Bloomberg Global Aggregate Index (LEGATRUU)	Bond	Global
Bloomberg US Aggregate Index (LBUSTRUU)	Bond	DM
Bloomberg EM USD Aggregate Index (EMUSTRUU)	Bond	EM

Our data set includes CAT bond index over the period from 2002-2023 from Datastream. We utilize Swiss Re Global Hedged CAT Bond Performance Index (SRGLTRR) as representative measures of CAT bonds, described in Swiss Re (2014), is designed to capture the returns of CAT Bond markets which has become the industry's key point of reference for CAT bonds. They are unique in that they provide weekly data, unlike other available sources which offer monthly data or have limited observation periods. Although there are some CAT bonds/ILS funds data available such as Aon Benfield's (e.g., Ticker: AONCILS) they are also only available monthly. The limited frequency or duration of these data hampers a robust analysis. Therefore, we rely on the Swiss Re index, which offer a more extensive and reliable dataset.

In analyzing the diversification benefits of CAT bonds compared to traditional asset indices, we consider various asset classes referred to in Table 1. Our objective is to evaluate the overall performance of CAT bonds in relation to traditional assets. For this purpose, we utilize three equity indices that represent different market segments: MSCI AC WORLD Index for the global market, MSCI WORLD Index for developed markets, and MSCI EM Index for emerging markets. Additionally, we consider three bond indices: Bloomberg Global-Aggregate for the global bond market, and Bloomberg EM USD Aggregate Index for emerging market bond, while We adopted the Bloomberg US Aggregate Index as a proxy for the aggregate bond market in developed countries due to the absence of a dedicated index representing the entire developed market. This decision is supported by empirical evidence from the Bank for International Settlements (BIS) as of December 31, 2022. According to the BIS data, the outstanding U.S. bond market size accounted for over 60% of the largest developed market (compared with the G7), while the second-largest market, Japan, accounted for only 14%. Given the significant size and influence of the U.S. bond market, utilizing the Bloomberg US Aggregate Index as a representation of the broader developed market is a reasonable approach. By selecting these indices, we aim to evaluate the diversification benefits of CAT bonds across global capital markets.

Table 2: Sub-period

Period	From	To
Full period	January 1, 2002	May 31, 2023
Pre-financial crisis period	January 1, 2002	November 30, 2007
Financial crisis period	December 1, 2007	May 31, 2009
Pre-Covid-19 period	June 1, 2009	March 10, 2020
Covid-19 period	March 11, 2020	May 31, 2023

This study separated sub-period according to Table 2, The data used for this analysis covers different timeframes. The full period includes data from January 1, 2002, to May 31, 2023. The pre-financial crisis period covers data from January 1, 2002, to November 30, 2007, while the financial crisis period covers data from December 1, 2007, to May 31, 2009. The pre-Covid-19 period includes data from June 1, 2009, to March 10, 2020. The during Covid-19 period covers data from March 11, 2020[1], to May 31, 2023[2]. All the indices used in this analysis are denominated in USD and were obtained from Bloomberg and Datastream.

Table 3: Summary statistic of weekly return for CAT bond and Alternative assets indices

Index Returns	Mean	Stand Div	Skewness	Kurtosis	Unconditional Correlation with CAT bond
Panel A: Full period, January 2002 to May 2023 (1113 observations)					
CAT Bond	0.12	0.751	(9.625)	292.592	1.000
Equity Global	0.09	2.432	(1.173)	12.972	0.070
Equity DM	0.09	2.427	(1.180)	12.986	0.071
Equity EM	0.10	2.938	(0.782)	10.035	0.065
Bond Global	0.06	0.810	(0.144)	4.771	0.012
Bond DM	0.06	0.547	(0.519)	5.663	0.042
Bond EM	0.12	1.045	(3.220)	36.511	0.092
Panel B: Pre-financial crisis, January 2002 to November 2007 (306 observations)					
CAT Bond	0.16	0.351	0.162	57.760	1.000
Equity Global	0.15	1.837	(0.299)	3.703	0.017
Equity DM	0.17	1.853	(0.308)	3.608	0.021
Equity EM	0.43	2.564	(0.719)	4.772	0.053
Bond Global	0.15	0.801	(0.147)	2.722	(0.030)
Bond DM	0.10	0.479	(0.237)	3.608	0.008
Bond EM	0.23	0.917	(1.274)	8.379	0.020
Panel C: Financial crisis, December 2007 to May 2009 (78 observations)					
CAT Bond	0.07	0.411	(4.210)	25.468	1.000
Equity Global	(0.65)	4.766	(1.063)	7.600	0.398
Equity DM	(0.65)	4.829	(1.015)	7.417	0.402
Equity EM	(0.61)	5.996	(0.443)	5.851	0.389
Bond Global	0.07	1.093	0.337	3.741	0.117
Bond DM	0.09	0.696	(0.429)	3.430	0.276
Bond EM	(0.01)	2.381	(2.473)	14.655	0.500
Panel D: Pre-Covid-19, June 2009 to March 2020 (562 observations)					
CAT Bond	0.13	0.895	(8.603)	256.244	1.000
Equity Global	0.14	2.012	(0.846)	6.744	0.023
Equity DM	0.13	2.015	(0.809)	6.603	0.023
Equity EM	0.05	2.481	(0.433)	5.160	0.017
Bond Global	0.06	0.701	(0.249)	3.781	(0.052)
Bond DM	0.08	0.456	(0.537)	4.191	(0.032)
Bond EM	0.15	0.652	(0.531)	5.750	(0.006)
Panel E: Covid-19, March 2020 to May 2023 (168 observations)					
CAT Bond	0.08	0.874	(9.463)	113.925	1.000
Equity Global	0.16	2.988	(0.560)	7.709	0.122
Equity DM	0.14	2.893	(0.629)	7.873	0.124
Equity EM	(0.02)	2.799	(0.702)	5.697	0.104
Bond Global	(0.11)	0.977	(0.142)	6.493	0.158
Bond DM	(0.08)	0.794	(0.231)	4.919	0.165
Bond EM	(0.08)	1.275	(2.631)	18.545	0.214

[1] March 11, 2020, was chosen as the start of Covid-19 period since it marks the declaration of Covid-19 as a global pandemic by the World Health Organization.

[2] May 31, 2023 was chosen as the end of Covid-19 period since the World Health Organization declared end to Covid-19 as a global health emergency in May 2023.

Table 3 presents the descriptive statistics of the daily returns for the CAT bond and alternative assets across five distinct periods, derived from the changes in the natural logarithms of the indices. Throughout the full period, the CAT bond consistently yields a higher average return than the alternative assets. All assets, in general, exhibit negative skewness, suggesting a distribution with longer left tails, which implies a higher likelihood of observing negative returns. This asymmetry in returns becomes particularly prominent during the financial crisis and the Covid-19 pandemic, highlighting the market's volatility during these challenging times.

In the pre-financial crisis phase, the CAT bond's superior average returns become evident, with both assets showcasing negative skewness and heightened kurtosis, hinting at the turbulent nature of the market as it approached the crisis. This turbulence peaks during the financial crisis, with the alternative assets experiencing negative average returns, while the CAT bond manages to remain resilient, still yielding positive returns on average.

Before the onset of the Covid-19 pandemic, the CAT bond maintained its trend of outpacing the alternative assets in terms of average returns. The distributions of all assets during this period continued to lean towards negative skewness, with kurtosis values remaining elevated. The pandemic's impact on the market is evident during the Covid-19 period, as all assets exhibit pronounced negative skewness and heightened kurtosis, emphasizing the market's volatility during these unprecedented times.

One of the striking features of the CAT bond is its pronounced kurtosis in all periods, which suggests a leptokurtic distribution. A leptokurtic distribution implies that the CAT bond's returns are characterized by more frequent extreme values than would be expected in a normal distribution. This is particularly noteworthy, as these extreme values, or "fat tails," indicate a higher risk of substantial price changes in short time intervals.

CHAPTER 5: METHODOLOGY

The aim of this study is to determine the diversification benefits offered by the CAT bond to other asset classes. To achieve this, we adopt the DCC-GARCH model proposed by Engle (2002) In line with previous research conducted by Ratner and Chiu (2013), Bouri, Molnár et al. (2017) and Drobetz, Schröder et al. (2020), our empirical tests are conducted in three stages, following a similar approach. First, we employ the bivariate DCC model, as proposed by Engle (2002), to estimate the DCC coefficients, which capture the dynamic correlation between the return series of the CAT bond and traditional assets. Subsequently, we study the relation between conditional correlations and conditional volatilities by regression following Chong, Miffre et al. (2009) to examine the diversification benefits of CAT bond. Thirdly, in the last stage, we conduct multiple regression analyses to examine the characteristics of the CAT bond as a hedge, diversifier, and safe haven against traditional assets. To initiate the study, we will calculate the index return using the following formula and apply it to our methodology.

$$r_t = ln\frac{Index_t}{Index_{t-1}} \times 100$$

5.1 Dynamic conditional correlations (DCC)

The DCC model, developed by Engle (2002), offers several advantages over traditional multivariate GARCH models, such as the Baba-Engle-Kraft-Kroner (BEKK) - GARCH model and constant conditional correlation (CCC) model. According to Cho and Parhizgari (2009), the DCC-GARCH model is computationally simpler and capable of capturing dynamic and time-varying correlations between return series, addressing issues of unreasonable parameter estimates and convergence that may arise in traditional GARCH models. The DCC model combines the flexibility of a univariate GARCH model with direct parameterization of conditional correlation Engle (2002). In our analysis, we employ the pairwise DCC model to estimate correlations between return series, considering the large number of return series involved. This approach helps avoid potential biases in parameter estimates that can occur when dealing with higher dimensions Hafner and Reznikova (2012).In addition, Conditional correlations are favored for portfolio rebalancing as they offer real-time insights into the dynamic relationships between assets, allowing for adjustments that align with current market conditions and risk levels. They enhance risk management by adapting to market changes and volatility, ensuring that rebalancing decisions are responsive to the latest economic events and trends, rather than relying on historical averages that may not reflect the present market state.

$$r_t = \mu_t + \omega r_{t-1} + \varepsilon_t \tag{1}$$

In the equation, r_t represents the vector of returns for CAT bonds and traditional assets at time t. The conditional mean vector of r_t is denoted by μ_t. The co-efficient of the autoregressive term is represented by ω, and ε_t represents the vector of error terms. The conditional variance equation of the DCC model is formulated as follows:

$$h_t = C + a\varepsilon_{t-1}^2 + bh_{t-1} \tag{2}$$

where h_t represents the term for conditional variance. The constant term is denoted by C, while a represents the parameter that captures the short-run volatility persistence, also known as the ARCH effect. The parameter b represents the GARCH effect, which captures the long-run volatility persistence. Additionally, the normal restrictions that apply to univariate GARCH models, such as nonnegative variance and stationarity, are also imposed in this context.

The time-varying correlation matrix Q_t specifies the DCC (1,1) equation, a square positive-definite matrix such as :

$$Q_t = (1 - \theta_1 - \theta_2)\bar{Q} + \theta_1 \varepsilon_{t-1}\varepsilon'_{t-1} + \theta_2 Q_{t-1} \tag{3}$$

Equation (3) is the correlation matrix, with $Q_t = (q_{ij,t})$ and $Q_t^* = (q_{ii,t}^*) = \sqrt{q_{ii,t}}$ as a diagonal matrix. In this context, Q_t represents a square positive-definite matrix that captures the conditional variance-covariance of residuals ε_t ; The parameter θ_1 captures the effects of previous shocks on the current DCC, while θ_2 represents the effects of previous DCCs on the current DCC. The vector ε_t represents the standardized residuals obtained from the initial step of the GARCH (1,1) estimation process. Furthermore, certain conditions must also be fulfilled in this framework as follows :

$$\theta_1 \geq 0;\ \theta_2 \geq 0;\ \theta_1 + \theta_2 < 1$$

Where θ_1 and θ_2 are nonnegative scalar terms such as $\theta_1 + \theta_2 < 1$, are scalar parameters to measure the effects of previous shocks and previous DCCs on the current DCC.

Therefore, the DCC between asset i and j at time t is given as :

$$\rho_{ij,t} = \frac{q_{ij,t}}{(\sqrt{q_{ii,t}}\sqrt{q_{jj,t}})} \quad (4)$$

Where, $\rho_{ij,t}$ is the conditional correlation between the assets which obtain from the elements q of matrix Q_t in equation (3)

To ensure the reliability of our DCC-GARCH model, we conduct diagnostic tests to detect any autocorrelation and heteroscedasticity in the asset return series. However, we have omitted the specific details of the DCC modeling and its parameters in this discussion. The model was solely employed to extract the pairwise DCCs, as depicted in equation (4), which are then utilized to evaluate the hedge and safe haven properties of the CAT bond, as outlined in equation (7).

5.2 Diversification Benefits

To further explain the findings obtained from equation (4), this research proceeds by adopting the approach of Chong, Miffre et al. (2009) for the subsequent two equations. Equation (5) involves regressing the conditional correlation on a time trend.

$$\rho_{ij,t} = \alpha_{ij} + \sigma_{ij} t \quad (5)$$

Where t is the time and σ_{ij} coefficient represents the conditional correlation to trends overtime, if it is statistically significant.

In line with Chong, Miffre et al. (2009), the relationship between the conditional correlations and the conditional volatilities is explored using equation (6).

$$\rho_{ij,t} = \alpha_{ij} + \beta_{1,ij}\sqrt{c_{i,t}} + \beta_{2,ij}\sqrt{c_{j,t}} + e_{ij,t} \quad (6)$$

The subscript i and j represent CAT bond and traditional assets respectively, while $\sqrt{c}$ represents the conditional volatility or time-varying risk of its subscripts' market, the β_{ij} coefficient suggests the relationship between CAT bond and traditional assets return conditional correlation and the conditional volatility of the market respectively to the subscripts.

The regression model (6) is used to examine the diversification benefits of CAT bonds compared to traditional assets. The coefficient β_{ij} in the model represents the correlation between CAT bond and traditional assets, considering the volatility of the CAT bond. If the coefficient $\beta_{1,ij}$ is significantly positive, it indicates an increase in the correlation between CAT bond and other assets during periods of high equity market volatility. Conversely, if the coefficient $\beta_{2,ij}$ is significantly negative, it suggests a decrease in the correlation between CAT bonds and traditional assets during times of elevated equity market volatility. In other words, when the volatility of traditional assets is high, the correlation between CAT bonds and those assets is weakened. As stated by Baur and Lucey (2010) A lower value of $\beta_{2,ij}$ implies greater benefits for investors using CAT bond as a diversifier against traditional assets. This model is applied across all periods in the study to support the validity of the first hypothesis.

5.3 Hedge, diversifier, and safe haven

Expanding on the research conducted by Baur and Lucey (2010) and Bouri, Molnár et al. (2017), this study aims to delve deeper into the role of the CAT bond as a diversifier, hedge, or safe haven in relation to the traditional assets. To achieve this, we utilize the DCC-GARCH model, as mentioned earlier, to extract the DCC coefficients in separate time series for all pairwise correlations. Subsequently, we perform multiple regression analyses where these coefficient time series serve as the dependent variables, while the independent variables consist of several dummy variables (D). These dummy variables represent extreme negative movements in the lowest 10th, 5th, and 1st percentiles of the return distribution, respectively, which is related to the tail behavior of financial asset return distributions and extreme price movements. By employing this methodology, we can assess the extent to which the CAT bond acts as a diversifier, hedge, or safe haven against the traditional assets.

$$\rho_{ij,t} = \delta_{0,ij} + \delta_{1,ij}D\left(r_{jt}q_{10}\right) + \delta_{2,ij}D\left(r_{jt}q_{5}\right) + \delta_{3,ij}D\left(r_{jt}q_{1}\right) + v_{ij,t} \quad (7)$$

The $\rho_{ij,t}$ represents the time series of DCC coefficients for each pairwise correlation between CAT bond and traditional assets. The r_{jt} refers to the return of traditional assets which are equity and bond. The $v_{ij,t}$ represents the residual term. Additionally, the constant term ($\delta_{0,ij}$) and the coefficients of the dummy variables (D) at different quantiles, such as $\delta_{1,ij}$ (10%), δ_{2}, ij (5%), and $\delta_{3,ij}$ (1%), indicate the hedge, diversification, and safe haven properties of CAT bond.

The effectiveness of the CAT bond as a diversifier for equities can be determined by the significance of the $\delta_{0,ij}$ coefficient. If $\delta_{0,ij}$ is significantly positive, it indicates that the CAT bond can act as diversifier. On the other hand, the CAT bond can act as a weak or strong hedge depending on the value of $\delta_{0,ij}$. If $\delta_{0,ij}$ is zero, it suggests a weak hedge, while a negative value indicates a strong hedge. It is a weak (strong) safe haven if either $\delta_{1,ij}$, $\delta_{2,ij}$ or $\delta_{3,ij}$ coefficients are zero (negative). This model is applied across all periods in the study to support the validity of the second hypothesis.

CHAPTER 6: EMPIRICAL RESULT

The data presented in Table 4 showcases the estimated outcomes of a bivariate DCC-GARCH model applied to weekly returns of the CAT bond and various traditional asset indices. The conditional mean of daily returns is modeled as a VAR process with optimal lag lengths. Observing the results, we find that for most indices, past returns significantly influence their current returns, emphasizing the importance of their own lagged dynamics in predicting current returns. Specifically, for the CAT bond, it is evident from coefficients that previous weeks' returns have a substantial predictive power over its current returns. However, the influence of traditional assets on the CAT bond's returns seems to be mixed, with some assets having a predictive power and others not.

Turning to the conditional variance, the coefficients ω0, ω1, and ω2 are found to be highly significant, indicating the time-varying nature of the variance and covariance. A closer look at the persistence of shocks to conditional variance reveals that they are highly persistent for both CAT bonds and traditional assets. Specifically, CAT bonds exhibit slightly weaker persistence compared to traditional assets.

Considering the dynamic conditional correlations (DCC), the results provide an insight into the evolving relationship between the CAT bond and traditional assets. A detailed examination would require looking at specific coefficients and their significance levels to determine how the correlation between these assets changes over time, especially during volatile periods.

The DCC-GARCH model effectively captures the time-varying relationships between CAT bonds and traditional assets. The significant influence of past returns on current returns for most indices underscores the importance of historical data in predicting future movements. Moreover, the dynamic nature of the conditional variance highlights the shifting volatility landscape of these assets. The findings lay a foundation for further exploration, especially in understanding the diversification benefits of CAT bonds relative to traditional assets.

Table 4 Results of the DCC-GARCH model estimation

	CAT bond		Equity Global	
CAT bond (-1)	0.213***	(0.0297)	-0.0475	(0.0507)
CAT bond (-2)	0.0899***	(0.0250)	-0.00697	(0.0546)
CAT bond (-3)	0.0529***	(0.0202)	0.00113	(0.0486)
Equity Global (-1)	0.0219***	(0.00173)	-0.0191	(0.0338)
Equity Global (-2)	-0.0133***	(0.00173)	0.0133	(0.0328)
Equity Global (-3)	0.0216***	(0.00185)	-0.0848***	(0.0308)
Arch (ω1)	5.328***	(0.407)	0.252***	(0.0379)
Garch (ω2)	0.0866***	(0.0166)	0.699***	(0.0400)
Cons (ω0)	0.00900***	(0.00146)	0.360***	(0.0951)
Log likelihood	-2713.265			
Θ1	0.00710	(0.0226)		
Θ2	0.894***	(0.295)		

	CAT bond		Equity DM	
CAT bond (-1)	0.190***	(0.0352)	-0.0487	(0.0512)
CAT bond (-2)	0.0868***	(0.0248)	-0.00486	(0.0552)
CAT bond (-3)	0.0364	(0.0233)	0.0162	(0.0493)
Equity DM (-1)	0.0207***	(0.00197)	-0.00956	(0.0339)
Equity DM (-2)	-0.0109***	(0.00278)	0.0145	(0.0329)
Equity DM (-3)	0.0227***	(0.00217)	-0.0804***	(0.0309)
Arch (ω1)	5.253***	(0.418)	0.235***	(0.0363)
Garch (ω2)	0.0981***	(0.0178)	0.719***	(0.0392)
Cons (ω0)	0.00795***	(0.00149)	0.332***	(0.0910)
Log likelihood	-2714.052			
Θ1	0.0156	(0.0475)		
Θ2	0.582	(0.786)		

	CAT bond		Equity EM	
CAT bond (-1)	0.0489*	(0.0294)	-0.0559	(0.0822)
CAT bond (-2)	-0.113***	(0.0389)	0.0155	(0.0869)
CAT bond (-3)	-0.0844**	(0.0349)	0.129	(0.0825)
Equity EM (-1)	0.00174	(0.00126)	0.0323	(0.0333)
Equity EM (-2)	0.00626***	(0.00133)	0.0499	(0.0328)
Equity EM (-3)	0.0104***	(0.00131)	-0.0150	(0.0316)
Arch (ω1)	4.007***	(0.278)	0.138***	(0.0237)
Garch (ω2)	0.260***	(0.0272)	0.787***	(0.0338)
Cons (ω0)	0.00115*	(0.000670)	0.593***	(0.155)
Log likelihood	-3020.481			
Θ1	0.0394	(0.0665)		
Θ2	0.477	(0.356)		

	CAT bond		Bond Global	
CAT bond (-1)	0.861***	(0.0349)	0.0475	(0.0318)
CAT bond (-2)	0.100***	(0.0286)	0.0693**	(0.0350)
CAT bond (-3)	0.130***	(0.0245)	0.0505*	(0.0280)
Bond Global (-1)	-0.0309***	(0.00487)	-0.0175	(0.0312)
Bond Global (-2)	-0.0250***	(0.00918)	0.0350	(0.0320)
Bond Global (-3)	-0.0419***	(0.00633)	0.00285	(0.0320)
Arch (ω1)	4.563***	(0.337)	0.101***	(0.0185)
Garch (ω2)	0.0326***	(0.0107)	0.865***	(0.0249)
Cons (ω0)	0.0172***	(0.00167)	0.0237***	(0.00872)
Log likelihood	-1602.01			
Θ1	0.0127	(0.0108)		
Θ2	0.941***	(0.0437)		

	CAT bond		Bond DM	
CAT bond (-1)	0.170***	(0.0378)	0.0203	(0.0178)
CAT bond (-2)	0.00950	(0.0399)	0.0220	(0.0192)
CAT bond (-3)	0.0823**	(0.0374)	0.0289*	(0.0176)
Bond DM (-1)	0.0709***	(0.0121)	-0.0685**	(0.0320)
Bond DM (-2)	0.0449***	(0.00542)	0.0611*	(0.0323)
Bond DM (-3)	0.0570***	(0.00742)	0.0339	(0.0316)
Arch (ω1)	4.142***	(0.333)	0.104***	(0.0196)
Garch (ω2)	0.239***	(0.0262)	0.849***	(0.0303)
Cons (ω0)	0.00196***	(0.000706)	0.0134***	(0.00468)
Log likelihood	-1085.921			
Θ1	0.00190	(0.00986)		
Θ2	0.965***	(0.0727)		

	CAT bond		Bond EM	
CAT bond (-1)	0.0873***	(0.0314)	0.0104	(0.0195)
CAT bond (-2)	-0.0591*	(0.0325)	0.0153	(0.0211)
CAT bond (-3)	-0.0113	(0.0327)	0.0142	(0.0194)
Bond EM (-1)	0.0280***	(0.00668)	0.235***	(0.0359)
Bond EM (-2)	0.0124**	(0.00514)	0.0326	(0.0352)
Bond EM (-3)	0.0419***	(0.00423)	0.0194	(0.0332)
Arch (ω1)	4.141***	(0.323)	0.366***	(0.0422)
Garch (ω2)	0.254***	(0.0451)	0.608***	(0.0349)
Cons (ω0)	0.00128	(0.00124)	0.0649***	(0.0121)
Log likelihood	-1584.496			
Θ1	0.0112	(0.0167)		
Θ2	0.925***	(0.107)		

Notes: ***, ** and * denote statistical significance at the 1%, 5% and 10%, respectively.

Figures 1 through 6 present a comprehensive visual representation of the relationship between CAT bond returns and various traditional asset classes across time. The charts highlight two distinct periods of deviation: one in 2017 and another in 2020.

The anomaly of 2017 is deeply intertwined with the catastrophic events of that year, most notably the profound impact of Hurricane Irma, coupled with other significant hurricanes like Harvey and Maria. These events posed considerable challenges to the CAT bond market. Given the design of CAT bonds to provide relief during catastrophic events, the damages from Hurricane Irma might have triggered specific clauses, leading to potential non-payment of bond principals to investors. This period was also marked by a shift in the CAT bond market dynamics, with a possible increase in issuances and a repricing of risk as investors became acutely aware of the tangible risks associated with catastrophic events.

Figures 1 to 3, which map out the relationship between CAT bonds and equities, and Figures 4 through 6, focusing on the bond spectrum, consistently showcase these two periods of anomaly. Although CAT bonds typically exhibit a degree of detachment from broader financial market movements, global events like Hurricane Irma and the Covid-19 pandemic underscore their susceptibility to broader economic forces and investor sentiments.

In summation, Figures 1 through 6 offer an insightful narrative into the CAT bond market's evolving dynamics in relation to other asset classes. The events of 2017, Hurricanes Harvey, Irma and Maria had made their landfalls in late September 2017, and the unprecedented challenges of Hurricane Ian struck Florida in September 2022 and by late October, as we reported, it had become clear that holders of this tranche of catastrophe bond notes were likely at-risk of suffering a total loss. These visual representations, in tandem with detailed data tables, provide a holistic understanding of CAT bonds' multifaceted relationships in the complex tapestry of global finance.

Figure 1: CAT and Equity Global Conditional Volatility CAT– Equity Global Conditional Correlation

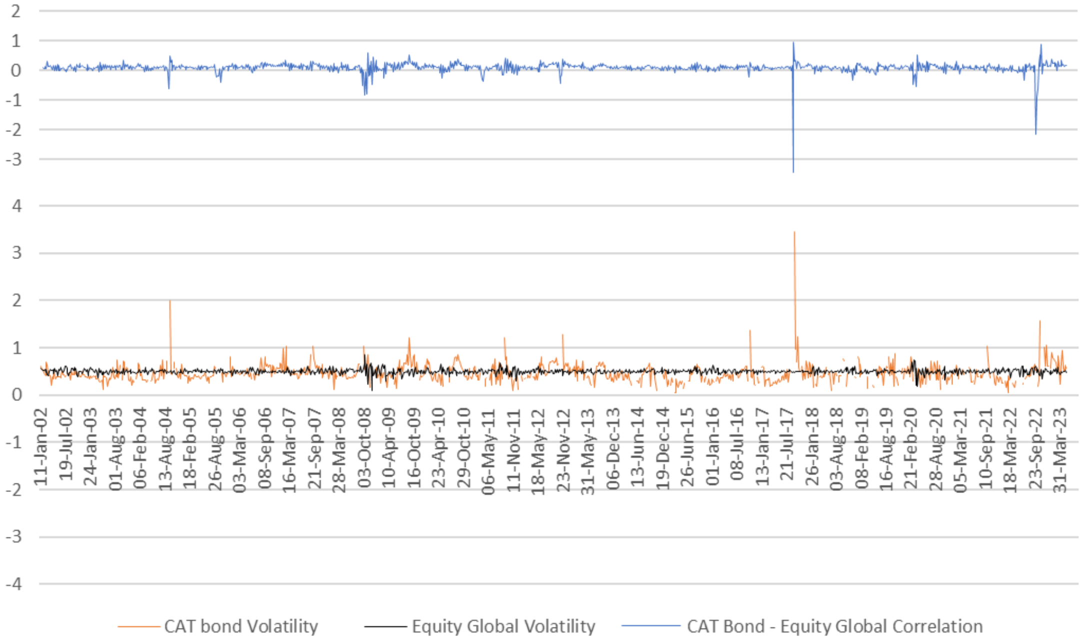


Figure 2: CAT and Equity DM Conditional Volatility CAT– Equity DM Conditional Correlation

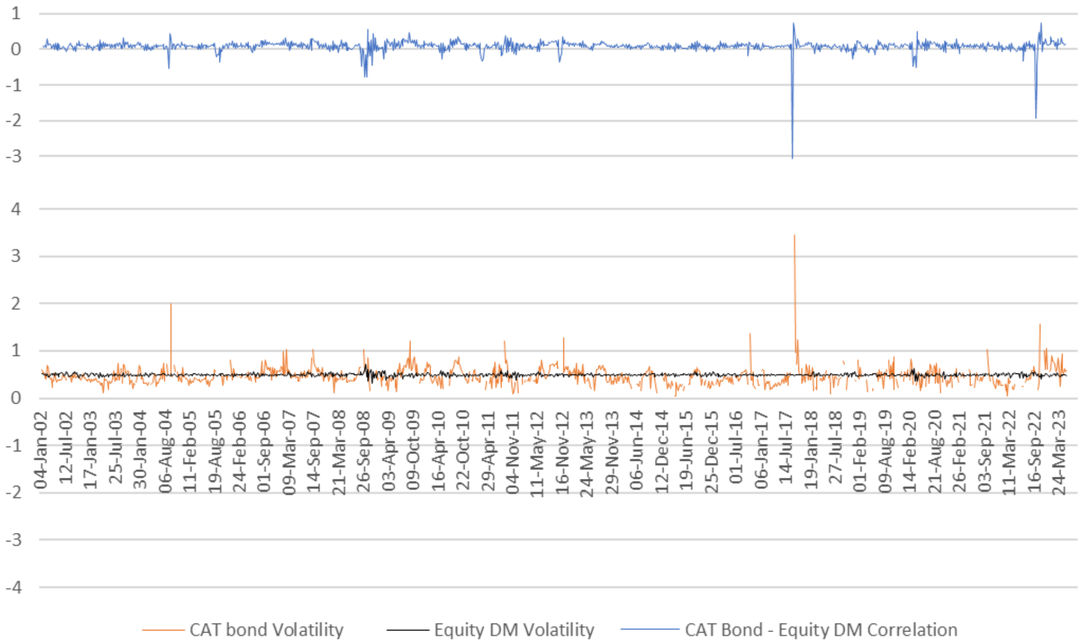


Figure 3: CAT and Equity EM Conditional Volatility CAT– Equity EM Conditional Correlation

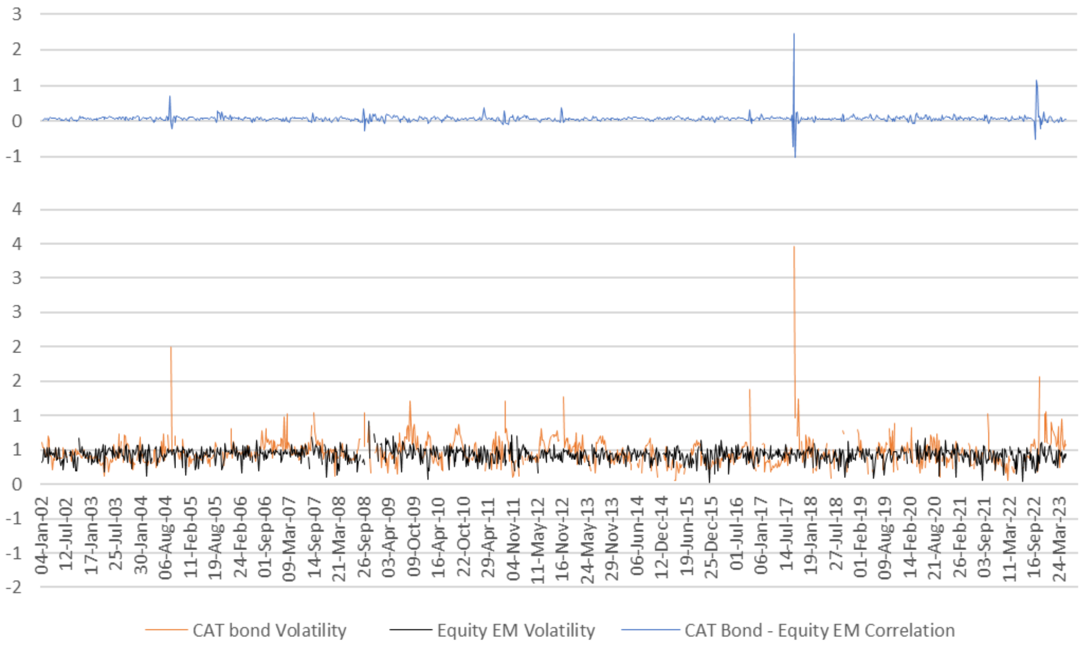


Figure 4: CAT and Bond Global Conditional Volatility CAT– Bond Global Conditional Correlation

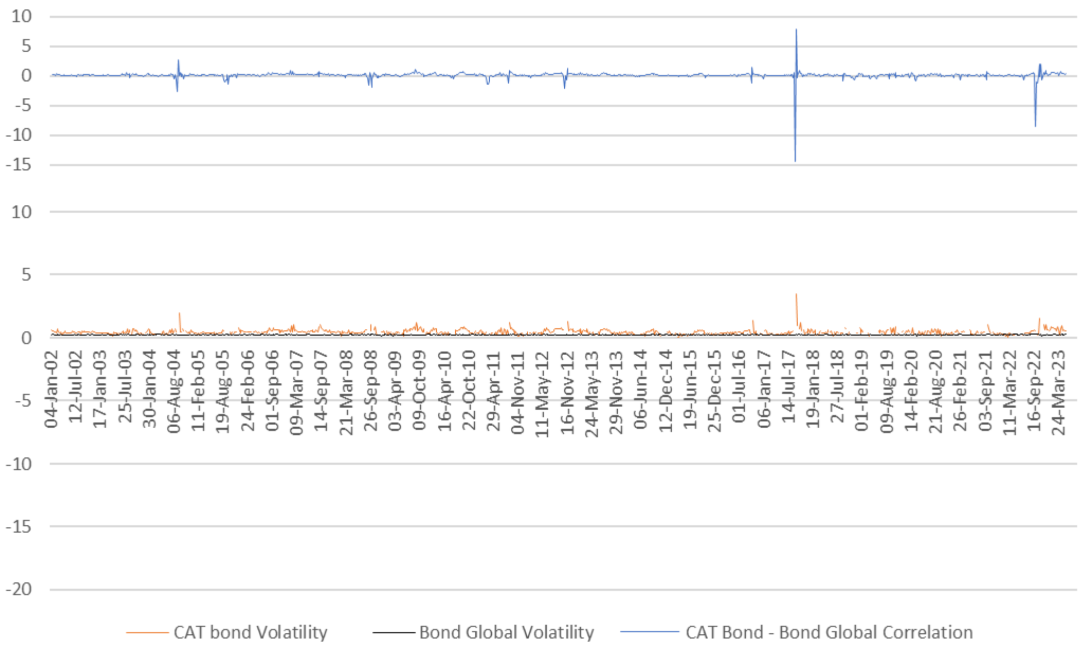


Figure 5: CAT and Bond DM Conditional Volatility CAT–Bond DM Conditional Correlation

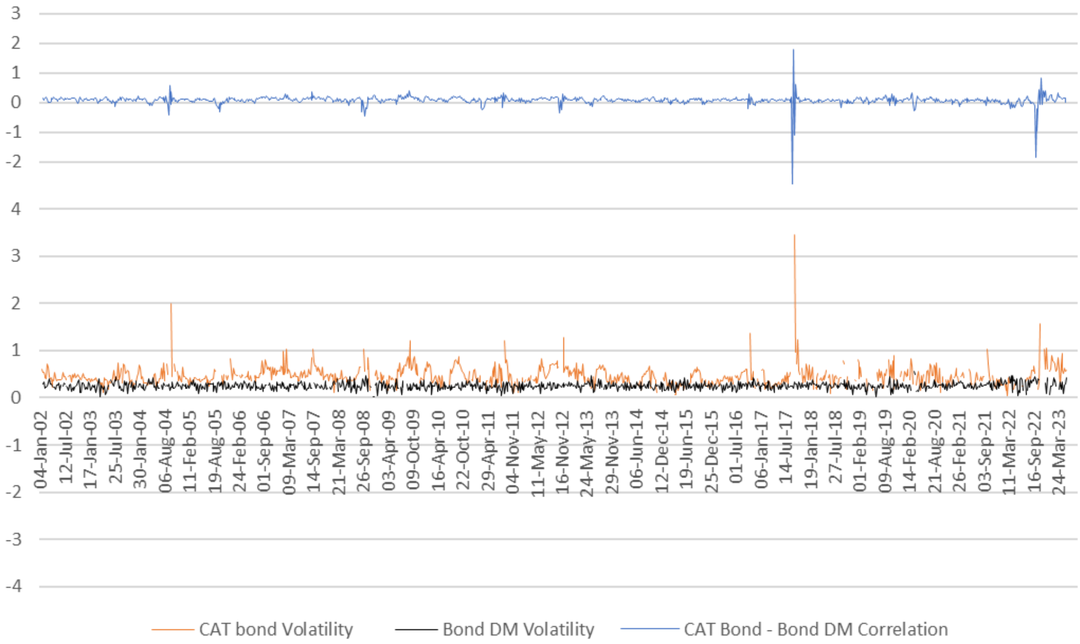
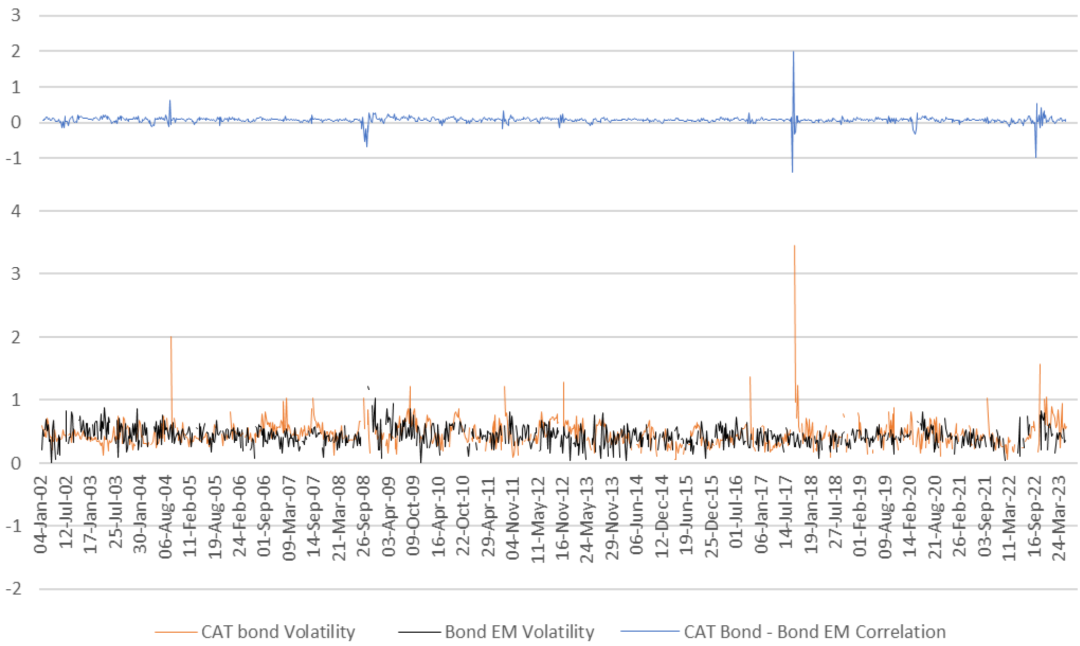


Figure 6: CAT and Bond EM Conditional Volatility CAT– Bond EM Conditional Correlation



Therefore, Table 5 offers insights and the summarization from above figures into the conditional correlation between CAT bond returns and various traditional asset returns, as gleaned from the bivariate DCC-GARCH model. A striking observation is the statistical significance across all average conditional correlations, underlining a robust relationship between CAT bond returns and traditional asset indices. Among the correlations, the Global Bond index stands out with the highest average conditional correlation with CAT bonds, while the Emerging Market Equity index records the least. The variability in these correlations is also noteworthy, as captured by the standard deviation. The Global Bond index exhibits the most pronounced volatility in its relationship with CAT bonds, as evidenced by its high standard deviation value. In contrast, the Emerging Market Equity index seems to maintain a more stable correlation, reflected in its lower standard deviation. Importantly, the absence of a perfect correlation of 1 between any of the asset indices and CAT bond returns suggests inherent diversification benefits. This aligns with the prevalent hypothesis that traditional assets can be diversified effectively using CAT bonds, a sentiment echoed in numerous studies emphasizing the diversification prowess of varied asset classes.

Table 5: Summary statistic of the conditional correlation

Index Returns	Average Conditional Correlation	Std. Dev.
CAT Bond - Equity Global	0.106***	0.18113
CAT Bond - Equity DM	0.102***	0.16487
CAT Bond - Equity EM	0.0653***	0.11041
CAT Bond - Bond Global	0.174***	0.63174
CAT Bond - Bond DM	0.110***	0.15391
CAT Bond - Bond EM	0.0878***	0.10773

Notes: ***, ** and * denote statistical significance at the 1%, 5% and 10%, respectively.

Shifting focus to Table 6, it elucidates the temporal dynamics, painting a picture of the evolving relationship between conditional correlations and time from equation (5) for CAT bond returns vis-à-vis other asset returns. The coefficient $\sigma \times 1000$ is particularly enlightening, revealing the trend in conditional correlation over time. A discernible pattern is the diminishing correlation over time between most indices and CAT bonds, with the notable exception of the Emerging Market Equity index. This diminishing trend bolsters the argument for diversification benefits, suggesting an enhanced diversification potential of CAT bonds relative to traditional assets as time progresses. The accompanying t-statistic values further enrich the analysis by providing a measure of the statistical significance of these trends. While a majority are statistically significant, the nuances in magnitude and direction across indices warrant careful consideration. The adjusted R^2 values, although relatively low, are pivotal in highlighting the model's explanatory power. They signal that while time is a contributing factor, other variables also significantly influence the conditional correlation, underscoring the multifaceted nature of these relationships.

Table 6: The Relation between Conditional Correlation and Time Trend

Index Returns	σ(x1000)	t-Stat	Adjusted R^2
CAT Bond - Equity Global	-0.0274	-1.62	0.0015
CAT Bond - Equity DM	-0.0248	-1.61	0.0014
CAT Bond - Equity EM	0.00607	0.59	-0.0006
CAT Bond - Bond Global	-0.0713	-1.21	0.0004
CAT Bond - Bond DM	-0.044***	-3.07	0.0075
CAT Bond - Bond EM	-0.0235**	-2.34	0.004

Notes: ***, ** and * denote statistical significance at the 1%, 5% and 10%, respectively.

Spanning various significant sub-periods, Tables 8 through 11 provide a deep dive into the nuanced relationship between CAT bond returns and equity indices according to equation (6). Table 8 captures the essence of the "Pre-financial crisis" era, a time often viewed with the lens of nostalgic economic stability. The CAT bond, in its nascent stages, was navigating its place in the financial ecosystem. Its correlations with equity indices during this period were foundational, establishing patterns that hinted at its potential role in future portfolios. The insights from this era are pivotal, as they offer a glimpse of the CAT bond's intrinsic behavior when global markets were relatively unperturbed by exogenous shocks.

Transitioning to Table 9, the backdrop changes dramatically to the "Financial crisis" period. A time of unparalleled economic turmoil, this era tested the resilience and adaptability of all financial instruments. The CAT bond's evolving relationship with equity indices during this tumult signals its sensitivity to macroeconomic disruptions. The shifts in correlation dynamics, more pronounced during this period, reflect the CAT bond's reactive nature and its potential as a stabilizing force in portfolios during financial upheavals.

Table 10 chronicles the "Pre-Covid-19" phase, a period marked by global recovery and a semblance of stability post the financial crisis. Here, the CAT bond's interactions with equity indices suggest its recalibration in a world adjusting to new economic realities. The correlations during this phase, while echoing past patterns, also hint at emerging trends, underscoring the CAT bond's potential diversification benefits in the face of looming uncertainties.

In Table 11, we delve into the "Covid-19" era, a period that reshaped global paradigms. Amidst the pandemic's upheavals, the CAT bond's intricate dance with equity indices stands out. The pronounced correlations and nuanced dynamics during this global health crisis reiterate the CAT bond's adaptability and its significance in portfolios during periods of unprecedented global disruptions.

Building on these insights, Table 7 offers a panoramic view, encapsulating the entire timeline. This holistic perspective underscores the CAT bond's journey, from its foundational correlations to its evolved interactions across diverse market conditions. The table stands testament to the CAT bond's multifaceted role, highlighting its significance as a dynamic tool for diversification. In conclusion, this comprehensive exploration underscores the CAT bond's adaptability, resilience, and evolving significance in the ever-changing global financial landscape.

Table 7: The Relation between Conditional Correlation and Conditional Volatility (Full Period)

	Intercept		CAT Volatility		Alternatives Volatility		Adjusted
	α	t	β	t	β	t	R^2
CAT Bond - Equity Global	0.885***	17.37	0.378***	20.45	-1.449***	-21.07	0.4886
CAT Bond - Equity DM	1.743***	20.11	0.326***	18.88	-2.638***	-21.76	0.4807
CAT Bond - Equity EM	-0.0509*	-1.82	0.183***	7.75	0.00427	0.11	0.0593
CAT Bond - Bond Global	-1.665***	-8.33	1.736***	32.79	1.490***	3.75	0.5268
CAT Bond - Bond DM	0.0571**	2.54	0.391***	19.13	-0.440***	-12.23	0.3536
CAT Bond - Bond EM	-0.167***	-8.79	0.274***	13.79	0.120***	5.59	0.2169

Notes: ***, ** and * denote statistical significance at the 1%, 5% and 10%, respectively.

Table 8: The Relation between Conditional Correlation and Conditional Volatility (Pre-financial crisis)

	Intercept		CAT Volatility		Alternatives Volatility		Adjusted
	α	t	β	t	β	t	R^2
CAT Bond - Equity Global	0.878***	10.59	0.400***	13.17	-1.457***	-12.97	0.5563
CAT Bond - Equity DM	1.582***	11.6	0.355***	12	-2.436***	-12.76	0.5317
CAT Bond - Equity EM	-0.0362	-1.07	0.166***	5.15	-0.00450	-0.1	0.083
CAT Bond - Bond Global	-1.552***	-8.72	1.641***	26.46	1.343***	3.77	0.7172
CAT Bond - Bond DM	0.0560**	2.02	0.380***	13.1	-0.417***	-9.96	0.4845
CAT Bond - Bond EM	-0.165***	-5.84	0.203***	6.63	0.187***	7.17	0.2606

Notes: ***, ** and * denote statistical significance at the 1%, 5% and 10%, respectively.

Table 9: The Relation between Conditional Correlation and Conditional Volatility (Financial crisis)

	Intercept		CAT Volatility		Alternatives Volatility		Adjusted
	α	t	β	t	β	t	R^2
CAT Bond - Equity Global	0.994***	5.44	-0.118	-0.72	-1.179***	-5.39	0.3027
CAT Bond - Equity DM	1.987***	6.3	-0.120	-0.77	-2.599***	-5.95	0.3495
CAT Bond - Equity EM	0.0157	0.19	0.0568	0.64	0.0247	0.31	-0.0283
CAT Bond - Bond Global	-1.243***	-6.13	0.852***	8.28	1.761***	4.39	0.5836
CAT Bond - Bond DM	0.124	1.57	0.0811	0.92	-0.189*	-1.78	0.0324
CAT Bond - Bond EM	0.108	1.28	-0.0578	-0.48	0.0328	0.51	-0.0287

Notes: ***, ** and * denote statistical significance at the 1%, 5% and 10%, respectively.

Table 10: The Relation between Conditional Correlation and Conditional Volatility (Pre-Covid-19)

	Intercept		CAT Volatility		Alternatives Volatility		Adjusted
	α	t	β	t	β	t	R^2
CAT Bond - Equity Global	0.945***	12.74	0.374***	18.57	-1.526***	-15.09	0.5687
CAT Bond - Equity DM	1.641***	13.55	0.325***	16.66	-2.490***	-14.68	0.5335
CAT Bond - Equity EM	-0.124***	-2.63	0.275***	7.48	0.0238	0.36	0.1073
CAT Bond - Bond Global	-2.503***	-6.05	1.865***	21.55	3.052***	3.68	0.4933
CAT Bond - Bond DM	0.0247	0.71	0.407***	14.09	-0.385***	-6.52	0.3355
CAT Bond - Bond EM	-0.184***	-5.86	0.333***	11.09	0.0876**	2.26	0.236

Notes: ***, ** and * denote statistical significance at the 1%, 5% and 10%, respectively.

Table 11: The Relation between Conditional Correlation and Conditional Volatility (Covid-19)

	Intercept		CAT Volatility		Alternatives Volatility		Adjusted
	α	t	β	t	β	t	R^2
CAT Bond - Equity Global	1.011***	6.13	0.451***	7.69	-1.694***	-7.69	0.497
CAT Bond - Equity DM	2.035***	7.3	0.388***	7.56	-3.108***	-7.99	0.5012
CAT Bond - Equity EM	0.196***	3.04	-0.0735	-1.42	-0.110	-1.34	0.0121
CAT Bond - Bond Global	0.177	0.45	1.517***	15.08	-1.937**	-2.57	0.6717
CAT Bond - Bond DM	0.159**	2.38	0.407***	6.6	-0.688***	-6.87	0.4177
CAT Bond - Bond EM	-0.163***	-5.68	0.190***	6.03	0.200***	5.19	0.4458

Notes: ***, ** and * denote statistical significance at the 1%, 5% and 10%, respectively.

Analyzing the results of equation (7) from Table 12 Panels A to E, we delve into the dynamic interaction between CAT bonds and traditional assets across different periods, assessing their roles as potential hedges, diversifiers, or safe havens.

Panel A, representing the full period, offers a holistic view of the CAT bond market's behavior against traditional assets. The consistent significance of the $\delta_{0,ij}$ coefficient suggests a predominant role of CAT bonds as diversifiers throughout this extended timeframe. This overarching diversification trait implies that the CAT bond market remains resilient and relatively uncorrelated with traditional asset movements, providing investors with a potential buffer against systemic shocks.

Turning to Panel B, which captures the Pre-Financial Crisis era, the data echoes a time of relative financial stability. Here, the CAT bond's attributes lean more towards diversification, reflecting its inherent structure to respond primarily to natural catastrophes rather than financial market oscillations.

In Panel C, during the Financial Crisis, we witness a slight deviation in behavior. While the CAT bond still predominantly acts as a diversifier, there are nuances suggesting its potential as a weak hedge. This period's financial tumult might have influenced investor sentiments, leading to shifts in CAT bond valuations and correlations with traditional assets.

Panel D, representing the Pre-Covid19 era, underscores a return to normalcy, with CAT bonds predominantly serving as diversifiers. The absence of any significant financial disruptions during this period supports the CAT bond market's detachment from broader financial market movements.

Lastly, Panel E, encapsulating the Covid19 period, presents intriguing findings. The unprecedented nature of the pandemic and its cascading effects on global economies might have influenced CAT bond dynamics. While the primary role as a diversifier persists, there are subtle hints towards its capacity as a weak safe haven, especially during extreme market downturns.

In conclusion, across these panels, the CAT bond consistently emerges as a robust diversifier, showcasing its potential to provide portfolio stability amidst volatile market conditions. However, during acute financial disruptions, its role can subtly shift, reflecting the complexities and interdependencies of global financial markets.

Table 12: Hedge and safe haven properties of CAT bond returns

	10% quantile ($\delta_{1,ij}$)	**5% quantile ($\delta_{2,ij}$)**	**1% quantile ($\delta_{3,ij}$)**	**Diversifier ($\delta_{0,ij}$)**
Panel A: Full period, January 2002 to May 2023 (1113 observations)				
○ CAT Bond - Equity Global	○ -0.00511	○ 0.00125	○ -0.0414	■ 0.0912***
○ CAT Bond - Equity DM	○ -0.0230	○ 0.0260	○ -0.0543	■ 0.0894***
○ CAT Bond - Equity EM	○ 0.0131	○ -0.0236	○ 0.0119	■ 0.0684***
● CAT Bond - Bond Global	● -0.204**	○ 0.179	○ 0.0304	■ 0.145***
○ CAT Bond - Bond DM	○ -0.0200	○ -0.0244	○ 0.00768	■ 0.0882***
● CAT Bond - Bond EM	○ -0.0227	○ 0.0148	● -0.146***	■ 0.0778***
Panel B: Pre-financial crisis, January 2002 to November 2007 (306 observations)				
○ CAT Bond - Equity Global	○ 0.00655	○ -0.0270	○ -0.0278	■ 0.105***
○ CAT Bond - Equity DM	○ -0.00925	○ -0.0170	○ 0.0104	■ 0.102***
○ CAT Bond - Equity EM	○ 0.000562	○ -0.0101	○ -0.0420	■ 0.0712***
○ CAT Bond - Bond Global	○ 0.0229	○ -0.143	○ 0.133	■ 0.163***
● CAT Bond - Bond DM	● -0.0696***	○ 0.0249	○ -0.0156	■ 0.105***
● CAT Bond - Bond EM	○ -0.0224	○ 0.00907	● -0.0663*	■ 0.0865***
Panel C: Financial crisis, December 2007 to May 2009 (78 observations)				
○ CAT Bond - Equity Global	○ -0.107	○ 0.0943	○ -0.115	■ 0.0570**
○ CAT Bond - Equity DM	○ -0.106	○ 0.0768	○ -0.0735	■ 0.0554**
○ CAT Bond - Equity EM	○ -0.0177	○ 0.158***	○ -0.101	■ 0.0561***
○ CAT Bond - Bond Global	○ 0.00253	○ 0.316	○ -0.249	□ 0.0647
● CAT Bond - Bond DM	○ -0.0600	○ 0.0626	● -0.221*	■ 0.0820***
● CAT Bond - Bond EM	○ -0.0176	● -0.282***	○ 0.0442	■ 0.0776***
Panel D: Pre-Covid-19, June 2009 to March 2020 (562 observations)				
○ CAT Bond - Equity Global	○ -0.0214	○ 0.0278	○ 0.0236	■ 0.0931***
○ CAT Bond - Equity DM	○ -0.0124	○ 0.0278	○ 0.0134	■ 0.0898***
○ CAT Bond - Equity EM	○ 0.0106	○ -0.0192	○ -0.00416	■ 0.0681***
● CAT Bond - Bond Global	● -0.575***	○ 0.612***	○ -0.0882	■ 0.164***
○ CAT Bond - Bond DM	○ 0.0140	○ 0.00480	○ -0.00624	■ 0.0861***
○ CAT Bond - Bond EM	○ 4.05e-05	○ -0.0106	○ -0.0155	■ 0.0772***
Panel E: Covid-19, March 2020 to May 2023 (168 observations)				
○ CAT Bond - Equity Global	○ 0.00122	○ -0.00755	○ -0.187	■ 0.0804***
○ CAT Bond - Equity DM	○ 0.0381	○ -0.0335	○ -0.210	■ 0.0768***
● CAT Bond - Equity EM	○ 0.144***	● -0.125*	○ -0.151	■ 0.0653***
○ CAT Bond - Bond Global	○ -0.0730	○ 0.219	○ -0.209	□ 0.102
● CAT Bond - Bond DM	● -0.139*	○ 0.177	○ 0.0628	■ 0.0588***
● CAT Bond - Bond EM	○ 0.0711	● -0.112*	○ -0.0856	■ 0.0578***

Notes: ***, ** and * denote statistical significance at the 1%, 5% and 10%, respectively.

● : Demonstrated strong safe haven property

○ : Exhibited weak safe haven property

■ : Demonstrated strong diversifier property

□ : Demonstrated weak diversifier property

CHAPTER 7: CONCLUSION

The dynamics of financial markets and the quest for optimal diversification have led to the exploration of various asset classes, among which CAT bonds stand as a beacon of promise. This study was architected with the objective of demystifying the relationship between CAT bonds and traditional assets. As we unravel the layers of data and analysis, certain fundamental truths emerge, shaping our understanding and answering the hypotheses we set forth.

Our first hypothesis delved into the existence of diversification benefits between CAT bonds and traditional assets. The analyses confirmed the hypothesis, revealing that these benefits are not only evident but are also modulated by market conditions. During periods of relative economic stability, CAT bonds exhibited a consistent relationship with assets, both from emerging and developed markets. However, in the face of financial turmoil, like during the financial crisis or the unprecedented Covid-19 pandemic, this relationship fluctuated, emphasizing the importance of market conditions in shaping the diversification potential of CAT bonds.

In addition, the empirical results shows that CAT bonds may offer enhanced diversification in developed markets over emerging markets due to the lower volatility and greater stability of the former, where the intrinsic value of CAT bonds' lack of correlation with market movements is more pronounced. Additionally, the higher efficiency of developed markets ensures that CAT bonds' diversification benefits are clearer and more reliable, as price formation in these markets is less distorted by information asymmetry compared to the often less efficient emerging markets. Moreover, the trigger conditions of the selected CAT bonds are predominantly related to catastrophes in developed markets, with a particular focus on the U.S.

Venturing into our second hypothesis, the multifaceted role of CAT bonds within portfolios became clear. Their behavior was largely dictated by the prevailing market environment. In placid economic landscapes, CAT bonds predominantly acted as diversifiers, reducing portfolio volatility and enhancing returns. This was corroborated by the $\delta_{0,ij}$ coefficients derived from our analysis. However, as storm clouds gathered and financial crises loomed, CAT bonds subtly transformed, taking on the mantle of a weak safe haven. While they didn't consistently act as buffers against declining markets, their reduced correlations with traditional assets painted a picture of resilience, a semblance of stability amidst chaos.

Furthermore, During the COVID-19 period, CAT bonds exhibited safe haven properties possibly due to their low correlation with market stress, as they are linked to physical disasters rather than economic fluctuations, providing stability while traditional assets faltered. The inelastic demand for the insurance protection underlying CAT bonds ensured steady performance despite economic turmoil. Investors' heightened risk aversion led them to seek out alternatives like CAT bonds, which offered a refuge with their stable return profile. Additionally, policy measures that dampened traditional asset returns made CAT bonds relatively more appealing, bolstering their safe haven status.

Recapitulating the objective of this study, we aimed to illuminate the intricate dance between CAT bonds and traditional assets. Through rigorous analytical rigor, we've underlined the dual nature of CAT bonds: their potential as diversifiers and their capability to act as weak safe havens. This duality underscores their invaluable role in modern investment portfolios, highlighting their potential in risk mitigation and return enhancement.

Looking to the future, the vast landscape of CAT bonds offers ample avenues for extended research. A geographically nuanced exploration, delving into specific markets such as the US, Europe, and emerging economies, could provide intricate insights into the behavior of CAT bonds and their relationship with local traditional assets. Expanding the comparative framework to encompass a broader spectrum of alternative assets might further enrich our understanding of CAT bonds' positioning in global portfolios. Extending the comparative framework to include a broader spectrum of alternative assets could provide richer insights. A behavioral lens, examining investor sentiment and reactions towards CAT bonds, especially during crises, could add another dimension to our understanding. Lastly, a deep dive into the market mechanisms, such as liquidity and the role of institutional investors, could further elucidate the nuances of CAT bond price movements and returns.

In conclusion, CAT bonds, with their unique characteristics and behavior, offer a promising avenue for investors seeking diversification and resilience. Their role in modern portfolios is only set to grow, and understanding their dynamics will be pivotal for future financial success.

REFERENCES

Swiss Re (2014). Swiss Re Cat bond indices methodology. https://www.swissre.com/Library/swiss-re-cat-bond-indices-methodology.html

Basher, S. A. and P. Sadorsky (2016). "Hedging emerging market stock prices with oil, gold, VIX, and bonds: A comparison between DCC, ADCC and GO-GARCH." Energy Economics **54**: 235-247.

Baur, D. G. and B. M. Lucey (2010). "Is gold a hedge or a safe haven? An analysis of stocks, bonds and gold." Financial review **45**(2): 217-229.

Baur, D. G. and T. K. McDermott (2010). "Is gold a safe haven? International evidence." Journal of Banking & Finance **34**(8): 1886-1898.

Bekiros, S., et al. (2017). "Black swan events and safe havens: The role of gold in globally integrated emerging markets." Journal of International Money and Finance **73**: 317-334.

Bouri, E., et al. (2017). "On the hedge and safe haven properties of Bitcoin: Is it really more than a diversifier?" Finance Research Letters **20**: 192-198.

Braun, A. (2016). "Pricing in the primary market for cat bonds: new empirical evidence." Journal of Risk and Insurance **83**(4): 811-847.

Carayannopoulos, P. and M. F. Perez (2015). "Diversification through catastrophe bonds: lessons from the subprime financial crisis." The Geneva Papers on Risk and Insurance-Issues and Practice **40**: 1-28.

Cho, J. H. and A. M. Parhizgari (2009). "East Asian financial contagion under DCC-GARCH." International Journal of Banking and Finance **6**(1): 17-30.

Chong, J., et al. (2009). "Conditional correlations and real estate investment trusts." Journal of Real Estate Portfolio Management **15**(2): 173-184.

Clark, S. P., et al. (2016). "Portfolio diversification effects of catastrophe bonds." Available at SSRN 2806432.

Cummins, J. D. and M. A. Weiss (2009). "Convergence of insurance and financial markets: Hybrid and securitized risk-transfer solutions." Journal of Risk and Insurance **76**(3): 493-545.

Demers-Bélanger, K. and V. S. Lai (2020). "Diversification benefits of cat bonds: An in-depth examination." Financial Markets, Institutions & Instruments **29**(5): 165-228.

Driessen, J. and L. Laeven (2007). "International portfolio diversification benefits: Cross-country evidence from a local perspective." Journal of Banking & Finance **31**(6): 1693-1712.

Drobetz, W., et al. (2020). "The role of catastrophe bonds in an international multi-asset portfolio: Diversifier, hedge, or safe haven?" Finance Research Letters **33**: 101198.

Engle, R. (2002). "Dynamic conditional correlation: A simple class of multivariate generalized autoregressive conditional heteroskedasticity models." Journal of Business & Economic Statistics **20**(3): 339-350.

Gürtler, M., et al. (2016). "The impact of the financial crisis and natural catastrophes on CAT bonds." Journal of Risk and Insurance **83**(3): 579-612.

Hafner, C. M. and O. Reznikova (2012). "On the estimation of dynamic conditional correlation models." Computational Statistics & Data Analysis **56**(11): 3533-3545.

Hoyt, R. E. and K. A. McCullough (1999). "Catastrophe insurance options: Are they zero-beta assets?" Journal of Insurance Issues: 147-163.

Kish, R. J. (2016). "Catastrophe (CAT) bonds: risk offsets with diversification and high returns." Financial Services Review **25**(3).

Kiymaz, H. and K. D. Simsek (2017). "The performance of US-based emerging market mutual funds." Journal of Capital Markets Studies.

Litzenberger, R. H., et al. (1996). "Assessing catastrophe reinsurance-linked securities as a new asset class." Journal of Portfolio Management: 76.

Mariani, M. and P. Amoruso (2016). "The effectiveness of catastrophe bonds in portfolio diversification." International Journal of Economics and Financial Issues **6**(4): 1760-1767.

Purkayastha, S., et al. (2012). "Diversification and performance in developed and emerging market contexts: A review of the literature." International journal of management reviews **14**(1): 18-38.

Ratner, M. and C.-C. J. Chiu (2013). "Hedging stock sector risk with credit default swaps." International Review of Financial Analysis **30**: 18-25.

Sterge, A. J. and B. van der Stichele (2016). "Understanding cat bonds." The Journal of Alternative Investments **19**(1): 27-40.

VITA

NAME	Treepatchara Tasnavijitvong
DATE OF BIRTH	12 October 1993
PLACE OF BIRTH	Bangkok
INSTITUTIONS ATTENDED	Chulalongkorn University
HOME ADDRESS	49 Soi Ngamwongwan 23 Yaek15/1 Tambon Bangkrasor Amphur Muang Nonthaburi 11000