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MEASUREMENT, MANAGEMENT AND AVOIDANCE OF EXTREME EVENTS IN THE SPANISH BANKING SECTOR

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The distinction between the typical and the exceptional is ancient, and my stress on discontinuity and concentration has been criticized. Clearly, when faced with rare events, Man finds it difficult to avoid oscillating between overestimation and neglect.

Benoit Mandelbrot

…we should be humble about our ability—and that of bank managers—to predict how losses might be incurred, how a future financial crisis might unfold, and what the effect of a financial crisis might be on the financial system and our broader economy. Greater resilience will guard against the risks that we may not fully appreciate today

*Michael. S. Barr (*Vice Chair for Supervision of the Federal Reserve System), in his analysis on the SVB demise (2023)

…adaptation is not the same as optimization. Adaptation is above all about survival. Survival involves finding not the best solution, but one that is good enough. And for survival, the tails of distributions matter a lot. Especially, we think, in understanding financial crisis.

Kay & King (2019)

Acknowledgements

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Abstract

The principal objective of this research is to understand how to enhance the financial sector's preparedness for low-probability, high-impact extreme events. This study begins by acknowledging the inadequacies of the pre-2008 Global Financial Crisis paradigm, which relied on inadequate risk models to quantify risk and determine capital needed to absorb potential losses.

This research proposes differentiating between measuring, managing and avoiding extreme events, evaluating different theoretical paradigms for each: Extreme Value Theory (EVT) for better measurement, High Reliability Theory (HRT) for management, and Normal Accident Theory (NAT) for avoidance.

Through a survey of 315 specialists in the Spanish financial sector, this research validates a scale for each paradigm, emphasizing prospective measures over historical performance. The findings indicate that a measurement approach, as advocated by EVT, which differentiates general quantitative risk management from advanced modeling capabilities is associated with improved preparedness for extreme events, moderated by a thorough understanding of these models. HRT, operationalized through the five interrelated dimensions of organizational mindfulness, is also associated with enhanced preparedness, although each dimension alone does not correlate with better preparation. Conversely, NAT shows that increased complexity and tighter coupling correlate with decreased preparedness for extreme events.

A gap analysis revealed that both EVT and HRT factors are considered more important than their current application levels in the financial sector. Respondents reported a higher implementation level for EVT variables compared to HRT, but HRT variables were deemed more critical, resulting in a larger gap between perceived importance and current application.

This research highlights the pivotal role of extreme events in the financial sector, revealing that advanced quantitative models and organizational mindfulness significantly improve preparedness. This emphasizes the need for a comprehensive approach to measure, manage, and try to avoid high-impact occurrences effectively.

Resumen

El objetivo principal de esta investigación es comprender cómo mejorar la preparación del sector financiero para eventos extremos de baja probabilidad y alto impacto. Este estudio comienza reconociendo las deficiencias del paradigma anterior a la Crisis Financiera Global de 2008, que se basaba en modelos de riesgo inadecuados para cuantificar el riesgo y determinar las necesidades de capital necesarias para absorber pérdidas potenciales.

Esta investigación propone diferenciar entre medir, gestionar y eludir eventos extremos, evaluando diferentes paradigmas teóricos para cada uno: la Teoría de Valor Extremo (EVT) para una mejor medición, la Teoría de Alta Fiabilidad (HRT) para la gestión, y la Teoría de Accidentes Normales (NAT) para eludirlos.

A través de una encuesta a 315 especialistas del sector financiero español, esta investigación valida una escala para cada paradigma, enfatizando las medidas prospectivas sobre el rendimiento histórico. Los hallazgos indican que un enfoque de medición, como el propuesto por EVT, que diferencia la gestión cuantitativa general del riesgo de las capacidades avanzadas de modelado, está asociado con una mejor preparación para eventos extremos, moderado por una comprensión exhaustiva de estos modelos. HRT, operacionalizada a través de las cinco dimensiones de la atención organizacional, también está asociada con una mejor preparación, aunque cada dimensión por sí sola no correlaciona con una mejor preparación. Por el contrario, NAT muestra que un aumento en la complejidad y el acoplamiento estrecho se correlacionan con una disminución en la preparación para eventos extremos.

Un análisis de brechas reveló que tanto los factores EVT como HRT se consideran más importantes que sus niveles actuales de aplicación en el sector financiero. Los encuestados informaron de un mayor nivel de implementación para las variables EVT en comparación con HRT, pero las variables HRT fueron consideradas más críticas, resultando en una brecha más grande entre la importancia percibida y la aplicación actual.

Esta investigación resalta el papel crucial de los eventos extremos en el sector financiero, revelando que los modelos cuantitativos avanzados y la atención organizacional mejoran significativamente la preparación ante ellos. Como resultado, se enfatiza la necesidad de un enfoque integral para medir, gestionar e intentar evitar eficazmente las situaciones de alto impacto.

Samenvatting

Het belangrijkste doel van dit onderzoek is te begrijpen hoe de paraatheid van de financiële sector voor extreme gebeurtenissen met een lage waarschijnlijkheid en grote impact kan worden verbeterd. Deze studie begint met het erkennen van de tekortkomingen van het paradigma van vóór de mondiale financiële crisis, dat gebaseerd was op ontoereikende risicomodellen om risico's te kwantificeren en de benodigde kapitaalvereisten vast te stellen om potentiële verliezen op te vangen.

Dit onderzoek stelt voor om een onderscheid te maken tussen het meten, beheren en vermijden van extreme gebeurtenissen, waarbij verschillende theoretische paradigma's voor elk worden geëvalueerd: de Extreme Waardetheorie (EVT) voor betere meting, de Hoge Betrouwbaarheidstheorie (HRT) voor beheer en de Theorie van Normale Ongevallen (NAT) voor vermijding.

Door middel van een enquête onder 315 specialisten in de Spaanse financiële sector valideert dit onderzoek een schaal voor elk paradigma, met de nadruk op prospectieve maatregelen boven historische prestaties. De bevindingen geven aan dat een meetbenadering, zoals voorgesteld door EVT, die algemeen kwantitatief risicobeheer onderscheidt van geavanceerde modelleringscapaciteiten, geassocieerd wordt met verbeterde paraatheid voor extreme gebeurtenissen, gemodereerd door een grondig begrip van deze modellen. HRT, geoperationaliseerd door de vijf dimensies van organisatorische mindfulness, wordt ook geassocieerd met verbeterde paraatheid, hoewel elke dimensie afzonderlijk niet correleert met betere paraatheid. Aan de andere kant, NAT toont aan dat toenemende complexiteit en strakkere koppeling correleren met verminderde paraatheid voor extreme gebeurtenissen.

Een kloofanalyse toonde aan dat zowel de EVT- als HRT-factoren belangrijker worden geacht dan hun huidige toepassingsniveaus in de financiële sector. Respondenten meldden een hoger implementatieniveau voor EVT-variabelen vergeleken met HRT, maar HRT-variabelen werden als kritieker beschouwd, wat resulteerde in een grotere kloof tussen de waargenomen belangrijkheid en de huidige toepassing.

Dit onderzoek benadrukt de cruciale rol van extreme gebeurtenissen in de financiële sector, waarbij wordt onthuld dat geavanceerde kwantitatieve modellen en organisatorische mindfulness de paraatheid hiervoor aanzienlijk verbeteren. Dit benadrukt de noodzaak van een integrale aanpak om gebeurtenissen met grote impact effectief te meten, te beheren en te vermijden.

Key Words

Extreme Events, Black Swan, Financial Sector, High Reliability Theory, Organizational Mindfulness, Extreme Value Theory, Normal Accident Theory, Spain

List of Acronyms

AIC = Akaike Information Criterion

AVE = Average Variance Explained

Basel II = Second package of recommendations on banking laws and regulations issued by the Basel Committee on Banking Supervision.

CFA = Confirmatory Factor Analysis

CFI = Bentler comparative fit index

EFA = Exploratory Factor Analysis

EVT = Extreme Value Theory

GFC = Global Financial Crisis

HRT = High Reliabiliy Theory

ML = Maximum Likelihood estimators

NAT = Normal Accident Theory

PCA = Principal Component Analysis

SEM = Structural Equation Modeling

SRMR = Standardized root mean square residual

VaR = Value at Risk

WLSMV = Weighted Least Squares Mean and Variance estimators

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1 Introduction

1.1. Research Background

On the 21st of July 2014, Catalunya Caixa (which is the trade name of the bank officially named Catalunya Banc) was sold in a competitive tender process to its competitor BBVA (De Barrón, 2014). With this sale, one of the largest state-sponsored rescue programs ended, resulting in a total cost to the Spanish state, and by extension its taxpayers, of 12,268 million euros, which represented 4 times the bank's equity in 2007 (Allendesalazar, 2019).

Eight years before, in May 2006, I was recruited by the principal predecessor of Catalunya Banc, called Caixa Catalunya, to help finish the implementation of the Basel II regulation in the bank. The savings bank had been investing heavily in risk modeling capabilities, and was the smallest of 7 banks to be granted authorization to apply internal models for calculating capital requirements according to the Basel II rules.

The implementation of these capital adequacy rules was seen then as the culmination of the enhancements to banks' safety and soundness. This was achieved by aligning capital requirements to the underlying risk profile of banks, by evaluating risk and capital sufficiency by supervisors, and by increasing transparency on risk exposure (Caruana, 2005).

In Caixa Catalunya, this implied development of advanced risk management tools, such as economic and regulatory capital models, rating and scoring models to evaluate credit worthiness of clients, and implementation of stress testing and backtesting exercises. All of these risk management tools had been designed according to the latest standards at that moment and implemented with help from tier 1 management consultants such as Boston Consulting Group, Ernst & Young, and PricewaterhouseCoopers. The models used in Caixa Catalunya calculated worst-case scenarios and one-year losses at the 99.9% level and indicated the bank was sufficiently capitalized to resist any shock that might arise in the next 1,000 years.

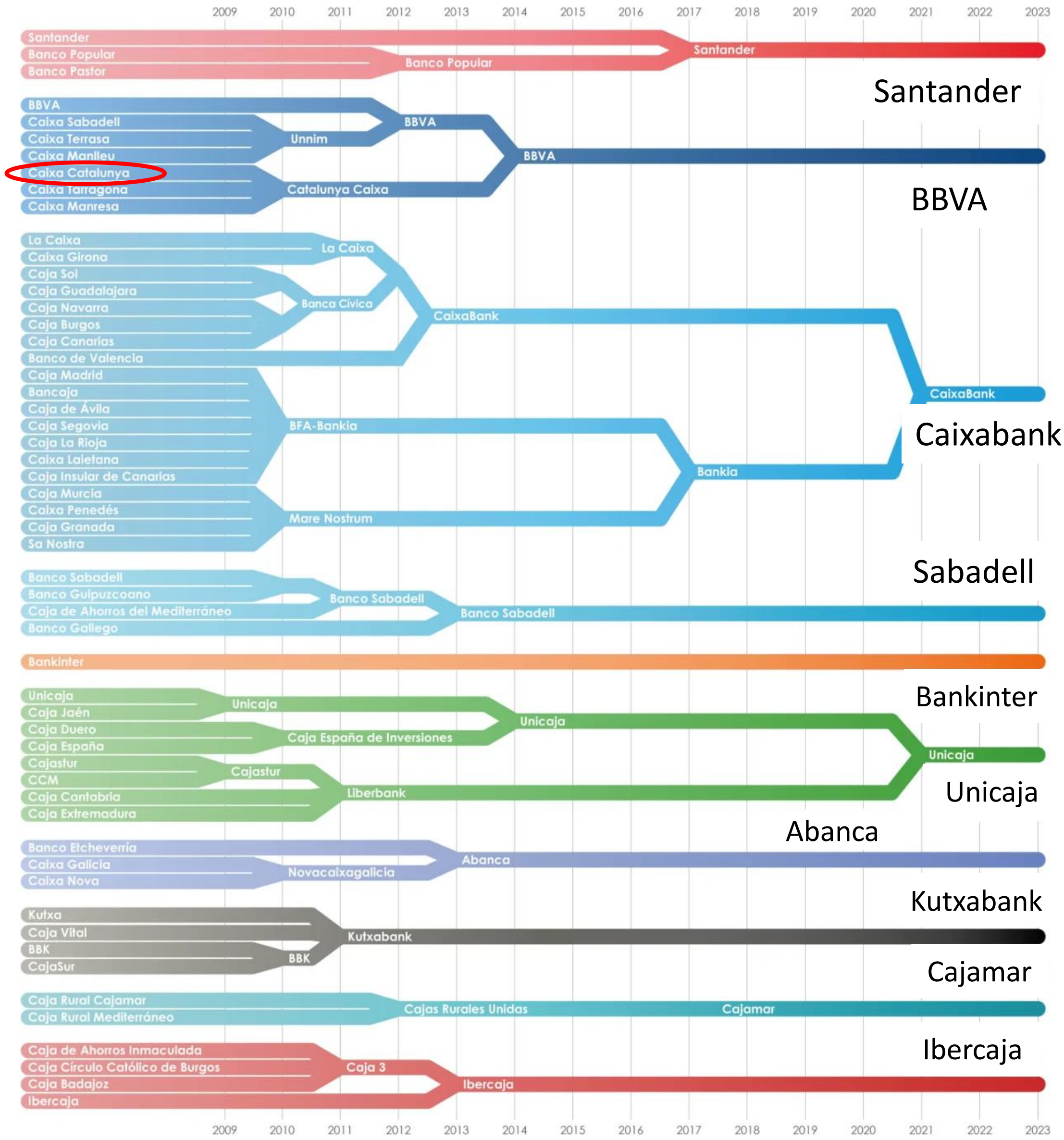
In the summer of 2007, Caixa Catalunya achieved its lowest historical delinquency rate on loans and credits. However, this favorable trend was short-lived as default rates began to rise gradually, before escalating dramatically in 2008, ultimately quadrupling (Trillas, 2008). This increase coincided with the onset of the global financial crisis (GFC), initiated by the bursting of the housing price bubble in the United States. The subsequent implosion of the US subprime mortgage markets had far-reaching consequences, restricting liquidity for wholesale funding for banks worldwide (Tooze, 2018b).

Caixa Catalunya, a non-profit savings bank, was the second largest in the autonomous region of Catalonia and the fifth largest in Spain. Founded in 1926, the bank became particularly vulnerable due to its excessive leverage and high dependence on wholesale funding (European Commission, 2014). As the crisis unfolded, the savings bank was forced to seek government assistance and was pressed to recapitalize and merge with other savings banks, ultimately establishing Catalunya Caixa. This intervention lasted for six years, a period marked by a Eurozone debt crisis that generated a double-dip recession in the European Union which contributed to the impossibility to recover. Caixa Catalunya's substantial exposure to subprime mortgage loans and highly leveraged real estate developers, ultimately culminated in the dissolution of the brand and the end of the savings bank's non-profit status.

All the risk management tools we had at our disposal at the savings bank, did not predict such an event could take place, and came as a complete surprise. However, Caixa Catalunya was not the only financial institution in Spain to disappear. In total, over 60 billion euros were provided by taxpayers for the bail-out of the Spanish Financial Sector (Otero-Iglesias, 2016), and as can be seen in figure 1, the total number of banking groups was reduced from 55 in 2009 to 10 in 2021.[1]

[1]https://www.bde.es/f/webbde/GAP/Secciones/SalaPrensa/InformacionInteres/ReestructuracionSectorFinanciero/Arc/mapa-sector2021.pdf

Figure 1 Evolution of banking entities in Spain (2009-2023)



Source: *https://elordenmundial.com/mapas-y-graficos/fusiones-banca-espanola-tras-crisis-financiera/. Author Álvaro Merino (2023), partiendo de information from Banco de España (2021).*

The financial sector, and outside the Anglo-Saxon world especially the banking sector, is of undeniable importance for the rest of the economy (Prasad, 2021). Banks have since ancient times played an intermediary role taking funds from households with surpluses and making loans to economic agents such as businesses, governments or loans to other households with financing needs (Allen & Santomero, 1997). By providing access to credit and other financial services, banks enable businesses to invest in new technologies and expand their operations, which in turn generates employment opportunities and drives innovation.

Banks also play a central role by processing payments through the national and international payment systems, enabling movements of funds both nationally and internationally in domestic and foreign currencies, and by providing debit and credit card payments services. Any malfunctions in the payments system can cause significant disruptions in trade, which in turn can have a substantial impact on economic growth (Gobat, 2012).

However, despite its importance, as has been shown above, the financial sector faces important risks and both individual banks and the sector as a whole are subject to crises that can have a financial or non-financial origin (Claessens & Kose, 2013; Hull, 2000).

1.2. Research Motivation and Objective

In the light of the events that took place during the global financial crisis, the main motivation for this research is to understand how to be better prepared next time.

To structure this preparedness for extreme events, I propose to differentiate between measuring, managing, and avoiding extreme events. Each of these three possibilities will be addressed with a different theoretical framework.

The risk models that were deployed by financial institutions in accordance with Basel II, failed to predict the financial crisis, let alone prepare for its impact. These models were found to present serious flaws, as indicated by academics such as Danielsson et al. (2001), long before final implementation of the Accord.

These academics recommend use of better models, that are adapted to events that might happen with a very low probability, but with a large impact. The methodology proposed is called “Extreme Value Theory” (EVT), and is a field of statistics that has been applied successfully in areas such as hydrology, but has also found its applications in the Financial Sector (Diebold et al., 2000; Embrechts et al., 1999).

On the other hand, in the aftermath of the financial crisis, many academics and practitioners from the financial sector, given their belief that extreme events cannot be predicted, suggested an entirely different approach to manage the risk of an extreme event

(Taleb et al., 2009; Bookstaber, 2017; Kay & King, 2020). Outside the financial sector, extreme contexts has been addressed in many research streams (Hällgren et al., 2018). Two of these research streams stand out for their applicability to the financial sector and for providing practical tools and methodologies to improve preparedness for extreme events. The first of these frameworks is High Reliability Theory. The applicability of this theory to the financial sector was suggested by Weick and Sutcliffe (2015) in their book "*Managing the unexpected"*. In the third edition of this publication, the largest bank failure in the United States is analyzed, based on the account by Kirsten Grind (2012) on the demise of Washingon Mutual on September 25, 2008. This retail bank had many characteristics in common with the situation that Caixa Catalunya experienced during the global financial crisis. Weick and Sutcliffe (2015, p. 6) offer advise on how this bank might have mitigated some of its problems by following the principles of organizational mindfulness; principles that are the basis of so-called High Reliability Organizations.

High Reliability Theory (HRT) originates from analysis of organizations, such as aircraft carriers, nuclear plants, and air traffic control centers that are able to function almost without errors in an extremely hazardous and unpredictable high-risk environment (Rochlin et al., 1987; Weick et al., 1999).

Hällgren et al. (2018) focus on a second alternative research stream for addressing extreme events, specifically Normal Accident Theory (NAT), introduced by Perrow (1981). Perrow conducted a series of case studies on near misses in organizations such as nuclear plants. He posits that catastrophic accidents in organizations with tightly coupled and highly complex operations are inevitable, since small events might happen that could potentially trigger catastrophic consequences. To avoid exposure to these types of risks, NAT proposes to decouple and simplify operations, and to reduce the size of organizations. The applicability of this theory to the financial sector has been analyzed by various researchers (Mezias, 1994; Palmer & Maher, 2010; Min & Borch, 2022).

Other research streams analyzed by Hällgren et al. (2018), such as contingency theory, organizational learning, and institutional theory, offer valuable insights into organizational behavior and adaptation but are not specifically designed to address extreme events and lack the practical tools and methodologies required for this purpose; consequently, they will not be further examined in this study.

The three selected theories are the basis for understanding how to be better prepared for another extreme event, but each originate from outside the financial sector. To understand their applicability in the financial sector, I conducted a questionnaire among experts from the financial industry to assess their perception regarding preparation for extreme events. In this context, the first research question of this research is the following: **Can each of the frameworks of EVT, NAT, and HRT be identified as separate theoretical constructs in the financial sector?**

Besides delving into the theoretical properties and potential of each of these theories, precisely because the next extreme event has not happened yet, this research will not study historical extreme events to analyze which of these theories might have functioned better. Instead, I pretend to provide a forward-looking perspective, based on the results of the questionnaire among experts from the financial sector. In this light, the second research question is: **As perceived by the expert practitioners in the financial sector, are each of the theoretical frameworks of EVT, NAT, and HRT associated with better preparation of organizations for extreme events?**

In order to evaluate what needs to improve to be better prepared, the third research question is: **As perceived by experts within the financial sector, what are the most important aspects for achieving better preparedness for extreme events?**

Finally, the fourth research question is about factors that may influence the preparedness: **What are the moderator and mediator factors that influence the preparedness for extreme events?**

In order to answer these research questions, I developed a survey targeting specialists within the financial sector who may be exposed to extreme events. Relevant items for the questionnaire were selected from the academic literature on Extreme Value Theory (EVT), High Reliability Theory (HRT), and Normal Accident Theory (NAT). Following pre-testing and beta testing, the final survey was distributed to a sample of 1,524 individuals representing the full spectrum of Spanish banks, yielding 315 valid responses.

The survey results were analyzed applying structural equation modeling (SEM), which consisted of both a measurement model, to assess the statistical relationships between the questionnaire items and the three theoretical paradigms, and a structural model, to examine the linear regression between these paradigms and the concept of preparedness for extreme events as perceived by the respondents. Model fit was evaluated using standard indices, including Chi-square, CFI, RMSEA and SRMR.

The analysis confirmed that EVT, HRT, and NAT are distinct theoretical constructs within the Spanish financial sector. EVT is positively and significantly associated with improved preparedness for extreme events. Notably, the results revealed a differentiation between general quantitative approaches to risk management and the use of advanced modeling capabilities specifically aimed at addressing extreme events. A deeper understanding of these risk models was found to moderate the relationship between EVT and preparedness.

High Reliability Theory (HRT) was also found to be contribute to better preparation for extreme events, through the five dimensions of organizational mindfulness. In contrast, Normal Accident Theory (NAT) suggests that as organizational complexity increases and systems become more tightly coupled, preparedness for extreme events tends to decrease.

The findings indicate that aspects of organizational mindfulness from HRT is highly valued but implemented to a lesser extent, whereas EVT shows a smaller gap between its perceived importance and actual implementation. This research makes several key academic contributions. It addresses the absence of validated scales for Extreme Value Theory (EVT) and Normal Accident Theory (NAT), and provides the first validation of High Reliability Theory (HRT) scales within the financial sector in Spain.

Although the three theoretical frameworks originate outside the financial sector, this research tests their applicability through a comprehensive sector-wide survey of financial specialists, offering new insights into how these paradigms are currently applied and perceived.

The study further contributes by offering an integrated model that links the scales for EVT, HRT, and NAT with perceptions of organizational preparedness for extreme events. By examining both the current application and perceived importance of these frameworks, the research identifies areas where progress may be more effectively pursued.

1.3. Structure of the thesis

This thesis is structured in nine chapters.

After this introductory chapter, in chapter 2, I present the theoretical basis around the development of risk management in the financial sector, the importance of extreme events in banking, and the definitions that are used for extreme events throughout the thesis.

In chapter 3, the three theoretical paradigms for preparation for extreme events are discussed through a literature review of the origin, characteristics, applications, as well as the criticisms of each of these theories. I also present here the main validations of each of the theories that will be used for the survey.

Chapter 4 includes the description of the research method of structural equation modeling that has been used to test each of the theories based on the survey results.

Chapter 5 outlines the detailed research objectives and the 18 hypotheses that have been specified concerning the three theoretical paradigms for management of extreme events.

In chapter 6, the research setup is explained, with information on the questionnaire that was designed and tested, and the strategy used to test its validity.

The research results are presented in chapter 7. First several descriptive statistics, and next the quantitative contrasts of the research hypotheses that have been established.

In chapter 8 the results are discussed, including both their theoretical and managerial implications, and finally chapter 9 includes the answers to the research questions and academic contribution, limitations and areas for further research.

2 Theoretical considerations around risk management and extreme events

2.1. The importance of extreme events in banking

Banks, unlike most industries, create value not only through their assets (in the form of investing and lending), but also through their liabilities, primarily by attracting low-cost deposits (Paul, 2023). The bank's perceived risk significantly influences its ability to issue retail deposits or obtaining financing in wholesale markets. This makes risk management an essential component of a bank's business model, unlike non-financial companies (Stulz, 2015).

The organization around risk deals with "*the systems created, the procedures employed, and the accountability relationships that are enacted in and among organizations in order to deal with phenomena that are considered to have the potential to deliver substantial harm*" (Hardy et al., 2020, p. 5).

Risk management in banks has evolved significantly during the previous decades: Advances in finance theory, with applications such as modern portfolio theory, and the capital asset pricing model, culminating in the development of the Black-Scholes model which permitted pricing of financial instruments and derivative products with mathematical rigor (Dionne, 2013).

These developments changed the risk management function from within banks themselves. JP Morgan developed the CreditMetrics and RiskMetrics tools (Crouhy et al., 2000), and promoted the establishment of risk-taking limits applying the Value-at-Risk (VaR) measures (Jorion, 2003). This is a measure of the maximum expected loss for an asset or for a portfolio of assets over a specific time horizon and at a certain level of confidence (say 95% or 99%). This measure, as it is expressed as in monetary units, permits direct comparisons of risks, and is a simple concept that is easy to understand for everybody (Coronado Vaca & Carabias López, 2019). The same idea underlies the concept of economic capital, which represents the amount of losses that a bank may incur in, over a specified time period, and at a given level of comfort for all of its risks (Dev, 2004). The economic capital models that were developed also played an important role in risk-based pricing of assets throughout the financial sector.

Before the global financial crisis, with the implementation of these increasingly sophisticated risk modeling tools, it became widely recognized that the central challenge lay in "*how to quantify risk and thus prize it appropriately*" (Crouhy et al., 2004, p. 3). This emphasis on measurement was further intensified by international regulators, who sought to enhance the soundness and stability of the international banking system (Basel I, 1988). Their primary focus was on capital adequacy, which led to the establishment of minimum capital requirements—initially introduced in 1988 using standard risk weightings. Basel II, officially published in June 2004 (Basel II, 2004), shifted the approach to risk assessment. Under this framework, risk levels are determined through a ratings-based model (Gordy, 2003).

All of the before-mentioned financial models assume some kind of normal or Gaussian distributions. Long before the global financial crisis, numerous academics had already expressed concerns regarding the excessive use of these types of models, emphasizing their inadequacy to capture the fat tails that are prevalent in financial markets (Mandelbrot, 1963; Embrechts et al. 1999; Danielsson et al., 2001).

However, the global financial crisis revealed in real life that these kinds of models were not working properly, and since then, there has been a lot of criticism on the role of models, both from the financial press (Salmon, 2009), from inside the banking sector (Bookstaber, 2017), from banking regulatory authorities (Haldane & Nelson, 2012, Kay & King, 2020) and also from the same academics that had developed the theoretical foundation for these models (Stiglitz, 2018; Embrechts, 2017).

The problem of using Gaussian distributions when modeling the behavior of the price of financial assets, is that they simply disregard the possibility of sharp jumps or discontinuities. For instance, the stock market crash of 1987 when the S&P index dropped by 20.4 percent in one day (Schwert, 1990), was considered to be an event more than 22 standard deviations away from the mean in a Gaussian distribution, which would mean a probability of less than 1 in a Googol (10^{100}) (Mandelbrot & Taleb, 2010).

Intriguingly, the expansion of risk management is frequently driven by incidents that highlight its perceived shortcomings. The evolution of contemporary risk management in banking over the past two decades has been marked by corporate collapses, substantial isolated losses (often linked to fraudulent activities, like those endured by Allied Irish Bank in 2002 and Société Générale in 2008), relatively confined systemic crises (like the

Asian bank crisis of 1996 and the Russian bond crisis of 1998), and, at the systemic level, the global financial crisis of 2007-2008 and the European debt crisis of 2010-2012. Each of these events was portrayed as a failure of risk management, yet the concept of risk management has endured (Mikes, 2011). Moreover, recent events such as the Covid-19 crisis, the invasion of Ukraine (OECD, 2022), and the collapse in 2023 of both the Silicon Valley Bank and Crédit Suisse (Enria, 2023), despite their disparate characteristics and origin, remind us that extreme events should play a much more central role in the risk management strategies of banking organizations.

Since the onset of the global financial crisis, both banking organizations themselves and national and international financial sector regulators and supervisors have come to recognize that ensuring the stability and soundness of the banking system requires more than just risk measurement and capital adequacy, leading to a significant overhaul in financial sector regulation (IMF, 2018).

In addition to enhancing capital adequacy risk measures, regulatory efforts have focused on qualitative aspects. These include improvements to the supervisory role, the issuance of guidelines, and the establishment of principles for sound risk management and risk governance.

This thesis concentrates on the extremes faced by banking organizations, rather than the average, by examining events that are out of the ordinary or are unexpected. I will not focus only on typical financial extreme events but also on non-financial events. Although currently the banking sector is not much affected by natural extreme events such as tsunamis, earthquakes, hurricanes, or wildfires, in the light of climate change risk the impact these kinds of events might have even on a distributed branch banking network should not be underestimated (Sarraf, 2021). There are many more non-financial events that have caused the ruin of banks, such as money laundering scandals, rogue traders, or Libor rate manipulation. Presently, there is a lot of focus on Cybersecurity risks (IMF, 2024), and tomorrow's concerns may very well be different again. It should be taken into account that financial extreme events sometimes have a non-financial origin (for instance, the automated panic sales that many blamed as the cause of the 1987 Black Monday crack) and can affect both the economy as a whole and a banking organization at the individual level. On the other hand, a non-financial event that affects an individual bank can potentially impact the whole financial sector (Schoenmaker, 1996).

While cultural narratives in literature, theater, and cinema often focus on extraordinary and extreme events, the academic field, prioritizing rigorous mathematical concepts and formulas, frequently treats these extreme phenomena as statistical outliers and potential sources of noise in data analysis (Osborne & Overbay, 2004).

To follow Taleb (2020, p. 2), we live in the real world which is full of extreme events, "*a world with a structure of uncertainty that is too complicated for us*". However, we need theory, even if it's not for "*understanding the world, but* [rather for] *getting out of trouble and ensuring survival"*.

2.2. Definitions

Knight (1921) distinguishes between occurrences to which probabilities can be assigned beforehand (risk), in contrast to uncertainty where we don't know in advance what the probabilities are. Feduzi and Runde (2014) on the other hand, differentiate between known-unknowns, which are events where we do not know if they might happen, but we think are plausible to happen, as opposed to unknown-unknowns which are events that we cannot imagine and therefore do not even consider.

Scholars in mathematics, statistics, and finance normally associate extreme price swings with those that are beyond prediction by a Gaussian normal distribution model (Beirland et al., 2004; Embrechts et al., 2013) or with "*tail events, i.e. outliers that lie in the tails of the distribution*" (Chakraborty et al., 2021, p. 2). Sornette (2009) coins the term "*Dragon Kings*" referring to significant outliers, while Taleb (2007) popularized both inside and outside the academic world the term "*Black Swan Event*" referring to low probability events with a large impact that come as a surprise when they occur, but are explained as logical and inevitable afterwards.

Hällgren et al. (2018) provide various definitions of an extreme context offered by scholars of Management and Organization Studies and follow Hannah et al. (2009) to define extreme events in an organizational context as necessarily having to comply with three conditions, (1) having the potential to cause severe consequences, (2) that are unbearable, and (3) that cannot be prevented by the organization.

In this thesis I will follow the differentiation offered by Paté-Cornell (2012) of extreme events or stream of events of low probability and large consequences that may be of two kinds: (1) “perfect storms”, that involve randomness in conjunctions of rare but known events and (2) “black swans” that represent epistemic lack of knowledge where not only the distribution of a parameter is unknown, but the very existence of the phenomenon itself.

3 Research theories for management of extreme events

3.1. Summary of research theories to be tested

As shown in the previous chapter, banks have adopted quantitative risk management methods to protect themselves from the consequences of extreme events. These methods are designed to arrive at estimates of expected and unexpected losses originating from operational, market, and credit risk. With the implementation of the Basel II (2004) regulation, banks are obliged to cover expected losses with provisions (mostly for loan losses), while unexpected losses, as determined with internal risk methods, constitute the regulatory minimum capital requirements to absorb these losses.

Among the prevalent risk measures that were employed, the Value at Risk (VaR) estimates, as mentioned in the previous chapter, stand out. As indicated by Coronado Vaca and Carabias López (2019, p. 31), these VaR estimates, used by financial institutions prior to the 2007-2008 crisis, demonstrated a significant limitation in their predictive capacity. The data used for these estimates came from a period of stability and low volatility leading up to 2007. Consequently, these estimations did not account for potential extreme events. The same authors highly recommend the article by Embrechts (2017) called "*A Darwinian view on internal models*" with very interesting considerations on the future of internal models for risk measurement in insurance and finance. Paul Embrechts is one of the authors of the seminal work "*Modeling Extremal Events for Insurance and Finance*" (1997) and coauthor of a paper written seven years before the global financial crisis (Danielsson et al., 2001) where it is clearly indicated that the statistical models proposed by the Basel Committee for capital requirements of international banking organizations would under-estimate risks in case of extreme events, despite the availability of better risk measures.

In this thesis, I will refer to these better risk measures as Extreme Value Theory (EVT), and this will be the first of the three theoretical paradigms to be assessed for current application and importance to address extreme events in banking. EVT provides an approach to model extreme events with statistical models that originate from the field of hydrology and are more suitable for risks associated with rare and high-impact events, than models based on Gaussian distribution assumptions. This theory symbolizes the efforts to improve measurement of extreme events.

Apart from EVT, the Black Swan Theory, developed by Taleb (2007), is highly cited within the financial sector. This framework emphasizes the profound impact of highly improbable and unforeseeable events. However, its focus is more on the philosophical implications of uncertainty and the limitations of predictive models rather than providing actionable methodologies for measurement and management of extreme events, and will not be further addressed in this research.

To identify practical tools and methodologies for dealing with extreme events, I consequently expanded my research in sectors beyond the financial sector. In the field of Management and Organization Studies, the emphasis lies not so much on measuring or modeling extreme events, but rather on the management of extreme events. Scholars in this domain explore how individuals, organizations, and society can effectively prepare for the impact of such events (Hällgren et al., 2018, p. 1). From the literature review by Hällgren et al. (2018) on extreme events, two major competing approaches stand out, both originating from analysis of some of the largest unexpected man-made disasters of the last fifty years.

The first of these theories came to be known as Normal Accident Theory (NAT). This theory posits that catastrophic accidents are inevitable in tightly coupled and complex operations. Therefore, organizations should aim to decouple and simplify operations to reduce risk exposure. This theoretical construct was developed by sociologists, and was originally applied to high-risk industries such as the nuclear energy sector. It symbolizes the efforts to avoid extreme events.

On the other hand, several case studies were published, describing organizations that operate successfully with near-zero errors in an extremely hazardous and unpredictable high-risk environment. The lessons learnt from these organizations led to the High Reliability Theory (HRT). These organizations achieve this level of safety by maintaining organizational mindfulness, which allows them to anticipate and contain unexpected events. This theoretical construct was developed originally by psychologists and organizational scientists by descriptions of high-risk industries such as nuclear aircraft carriers and symbolizes the efforts to manage extreme events.

Other theoretical frameworks evaluated in Hällgren (2018) include contingency theory, organizational learning, and institutional theory. Contingency theory posits that no single best way exists to manage organizations; effective management depends on aligning structures with specific situational factors such as environment, technology, and size. Organizational learning theory emphasizes that organizations adapt and improve by acquiring, retaining, and transferring knowledge through learning from experience, experimentation, and sharing, thereby enhancing performance and innovation. Institutional theory suggests that organizations are influenced by broader social and cultural norms, values, and expectations, adopting structures and practices to gain legitimacy and conform to institutional pressures, leading to similarities within organizations in the same field. These theories may be applied to extreme contexts, but as they represent broad management theories, they do not provide specialized mechanisms or methodologies tailored specifically for the analysis and management of extreme events; therefore, they will not be addressed further in this research. The three theories that have been selected originate from outside the financial sector, yet they all address concerns commonly expressed within that domain itself. Financial supervisors and regulators in the financial sector consistently advocate for model improvements (e.g., Haldane & Nelson, 2012), systemic risk reduction (e.g., Basel Committee on Banking Supervision, 2022) and enhancements in risk governance (e.g., Enria, 2023).

To the best of my knowledge, these three frameworks have never been tested and compared before in a scholarly manner within the financial sector, and I believe this cross-disciplinary approach may contribute to a richer understanding and be of practical value for the financial sector participants, both for banking organizations themselves, as well as for banking regulators and supervisory bodies.

3.2. Extreme Value Theory

Origin

Risk management is all about measuring adverse circumstances to avoid corporate disasters and failures (Mikes & Kaplan, 2015). Regulatory capital measures have been implemented in all banking institutions in order to be able to resist shocks at the 99.9% confidence level. However, the models used to calculate this percentile, are based on the assumption of a normal probability distribution of returns on financial assets (Gordy, 2003).

A long time before the global financial crisis, many scholars warned about this assumption of normality (for instance Mandelbrot, 1963), and have been developing models to estimate potential losses in the tail of the probability distribution of returns. As indicated by Diebold et al. (2000, p.30) on extreme quantiles and probabilities, "*Extreme quantiles and probabilities are of particular interest because ability to assess them accurately translates into ability to manage extreme financial risks effectively […]*".

In the field of statistics, several ideas emerged that came to be known as "Extreme Value Theory", where a set of data is used that only takes into account the extreme event data, rather than all the data, and thereby fitting the tail and only the tail of a probability distribution.

Gumbel (1958) mentions several endeavors in the study of small probabilities in the beginnings of the twentieth century. Some of these studies used the normal distribution as a starting point, while others set out from the Poisson distribution which provides the number of occurrences of rare events. Extreme value theory on the other hand is not based on the normal distribution and focuses on values rather than frequencies.

The theory and foundations of EVT were established by Maurice Fréchet, Ronald Fisher, Leonard Tippett, Richard von Mises, and Boris Gnedenko (Fisher & Tippett, 1928; Ahmed, 2021) who developed a generalized extreme value theorem that describes different kinds of parametrizations of probability distributions in a converged form as a general distribution function.

One of the original interests regarding extreme values has been in the occurrence of floods "*when water flows where it ought not to flow*" (Gumbel, 1958, p. 4). Also for prediction of earthquakes in the reinsurance industry, extreme value theory has been of great value (Embrechts et al.,1999).

Main Characteristics

Extreme Value Theory (EVT) is a statistical concept that centers on examining severe occurrences, such as events in the tails of a distribution or values that fall outside the typical range of observations. Its main objective is to offer a structured approach for modeling and predicting infrequent events that have a low likelihood of happening but can have substantial consequences.

In its modeling approach, EVT asserts to predicting events that are not present in the historical data base. For instance, Embrechts et al., 2013 cite De Haan (1990) on the quantification of the necessary height of the dikes in the Netherlands after the infamous North Sea flood of 1953, where sea-level reached an elevation of 3,85 meters above the normal sea level (NAP, the New Amsterdam Ordnance Datum by its acronym in Dutch). Applying extreme value theory and associated probability distributions, they calculated that dikes in the Netherlands should at least have a height of 5,14 meters above NAP to be able to resist a one-in-ten-thousand-year surge. This was at least one meter higher than the largest surge recorded in historical accounts.

Even though EVT proclaims to be able to predict beyond the maximum present in historical data bases, most authors belonging to this school of thought, stress the importance of looking at the data, be it earthquakes, floods, war casualties, stock returns, cotton prices or identity theft losses (see for instance Embrechts et al., 2013; Sornette, 2009, Mandelbrot, 1963). Below, the general approach and the assumptions of this modeling technique are described.

There are two main types of models for extreme values, the "*block maxima*" models and the "*peaks-over-threshold*" models. The *block maxima* models, the older type, model the largest observations extracted from large samples of observations. For instance, if we record daily or hourly trading results, the block maxima method can model the quarterly or annual maximum of these values. The approach consists of dividing the observation period into non-overlapping periods (blocks) of equal size and retaining the maximum observation in each block (Ferreira & De Haan, 2016). Then, a parametric statistical method applying an extreme value distribution, such as a Gumbel distribution, a Fréchet distribution or a Weibull distribution is applied to those observations to obtain a loss level at a predefined confidence level (Szubzda & Chlebus, 2019). This method can help define and analyze stress losses but requires a very large data set in order to obtain a sufficient number of blocks (Ahmed, 2021).

The *peaks-over-threshold* (POT) models, the newer type, model all observations above a certain high threshold. Within this kind of models, one has to estimate a shape and a scale parameter to describe a specific generalized Pareto or power law distribution and determine a threshold or location value above which to model the data (Beguería et al., 2011, Gabeix, 2016, Chavez-Demoulin et al., 2016).

The POT models are usually preferred for practical purposes, because they use the data on extreme values more efficiently (McNeil, 1999). However, there are certain mathematical conditions when use of the block maxima models might be justified, for example if only block maxima are available, or when the observations are not independent and identically distributed, for instance in the case of seasonal periodicity in the yearly maxima in storms or floodings (Ferreira & De Haan, 2016; Van den Brink et al., 2005).

Nevertheless, in the context of financial data, the application of block data is not a natural setup. Primarily, POT models describing extreme events in terms of exceedance over a high threshold, prove to be more useful (Nolde & Zhou, 2021).

Application of the theory

EVT as a statistical tool has applications in various fields for prediction of low probability events with large impacts.

As mentioned above, in hydrology, the theory is applied by environmental risk agencies to calculate, for example, the height of sea-walls to prevent flooding, or to evaluate trends in meteorological data (Beirlant et al., 2006; Beguería et al., 2011), or the frequency and magnitude of earthquakes (Sornette, 2009). Similarly, EVT is used to set strength boundaries in engineering for estimation of metal fatigue (Beirlant et al., 2006).

EVT is also used in the field of vehicle and road safety. For instance, it can be used to validate the safety of a vehicle, keeping the validity high and the data requirements low (Åsljung et al., 2017), or for prediction of car crashes "*without the use of crash data, but rather analysing surrogate measures of safety*" (Orsini et al., 2019).

In the field of data science, EVT can be used for establishing thresholds that do not assume the data distribution in order to detect anomalies in the data set (Siffer et al., 2017). The EVT methodology has also been applied in medicine, for detection of signs of a possible epileptic seizure in patients (Karpov et al., 2022).

In the domain of management research, there is a notable emphasis on unusual events and a concern about extremes. However, according to Baum and McKelvey (2006), the statistics of extreme value theory have thus far played a very limited role. They advocate for a more significant incorporation of this theory into a manager’s toolkit. Focus should be on Pareto-like distributions for managers both for identifying blockbuster sales, for identifying market opportunities in the information and communication sector, or for risk management (Andriani and Mckelvey, 2011).

In economics, EVT is used by actuaries to evaluate and price insurance against the probability of rare but financially catastrophic events (McNeil, 1999).

For risk management purposes, the results of the extreme value modeling effort will lead to estimates of a “Value-at-Risk” (VaR) or “Expected Shortfall” (ES) (see for instance McNeil et al., 2015; Rocco, 2014; Longin, 2000; Chavez-Demoulin et al., 2006). With Value-at-Risk, the level of losses at a predetermined threshold is calculated, say at the 97%, 99% or 99.9% of the accumulated losses (Jorion, 2003). Expected Shortfall is calculated as the average expected losses above the predetermined threshold level, and is currently used as the standard for risk management purposes in banking regulation (Nolde and Zhou, 2021).

In the past decades, many papers have been published to demonstrate the non-Gaussian behavior in financial markets where extreme value theory offers a more accurate approach to describe the return performance and sudden price swings (Mandelbrot, 1963; Embrechts et al., 1997, Bensalah, 2000; Ho et al., 2000; Gilli & Kellezi, 2006; Singh et al., 2013; Beirlant et al., 2004, Beirlant et al., 2016, Chakraborty et al., 2021; Alsunbul et al., 2013). The EVT framework does not only model the past but is also a more suitable methodology for predicting future extreme events (Furió & Climent, 2013) and useful for stress testing in financial institutions (Longin, 2000).

Apart from predicting possible extreme events, EVT has also been applied for monitoring financial stress. Dridi et al. (2012) developed an EVT-based control chart to assess fragility of the banking sector and to provide better shift detection properties in order to identify financial stress periods.

Criticism of the Theory

One of the assumptions of Extreme Value Theory is that the data are independent and identically distributed, implying that the variables used in the model are mutually independent and no volatility clustering may occur (McNeil, 1999). For financial data, this is widely assumed not to be true as these data are widely known to present heteroscedasticity (Diebold et al., 2000, p. 35).

Other drawbacks for the use of EVT are mentioned by Rocco (2014) such as: the sensitivity of the parameters to the cut-off selection given that no complete agreement by academics or practitioners has been reached yet; the assumption that the data are not serially correlated, which may not hold in some cases; the complexity and computational cost of multivariate EVT; and the trade-off between the large data requirement and the rarity of extreme events, which makes the data-set choice and preparation very important. However, as indicated by Diebold et al. (2000), if financial managers are aware of both the limitations and strengths of the approach, it offers considerable opportunities to address concerns about tail probabilities.

Another aspect that must be taken into account is the possibility that financial returns with fat tails may have infinite variance (Grabchak & Samorodnitsky, 2010). This implies that standard statistical metrics such as the mean, standard deviation, and variance are not useable (Taleb, 2020, p. 31), enormously complicating standard risk evaluation.

Several years before the global financial crisis, Paul Embrechts (2000), one of the main proponents of use of EVT in a risk management context wrote that Extreme Value Theory provides a framework for understanding the behavior of extreme events in stochastic processes that evolve over time and space and offers a methodological toolkit for dealing with issues such as skewness, fat tails, rare events, and stress scenarios. He also emphasized that while there is always an element of uncertainty as EVT extrapolates into unknown areas, it optimizes the use of available data about extreme phenomena. EVT doesn’t claim to perform miracles, but it is a significant improvement over empirical curve-fitting and guesswork. The key takeaway is that if well-founded methods like EVT are not used, people will resort to less reliable ones (Embrechts, 2000).

Main Validations of the Theory

Some of the most important proponents of advanced modeling approaches to financial risk originate from the Department of Mathematics of the ETH Zürich where the RiskLab was founded in 1994 and whose main proponent is Paul Embrechts and others at the same institution, mostly with a background in mathematics or physics (Embrechts et al., 1999). When writing after the worst part of the global financial crisis had passed, he made several significant remarks on the importance of making explicit the assumptions underlying the models that are being used, and that these are being communicated in a clear manner to all stakeholders involved (Embrechts, 2017). When confronted with the criticism that risk models do not capture tail risk or cannot handle complex interdependencies, he was very clear to indicate that this is "*nonsense to say*", but that these features have to be included in the models, even if this leads to higher capital charges (Embrechts, 2017, p. 16).

Also Andrew Haldane, the former chief economist of the Bank of England, proposes use of more sophisticated models. These models, not based on assumptions of normality, are intended to guide decision-making in the financial sector and take into account potentially fatter tails "*where catastrophe risk may be on the rise*" (Haldane & Nelson, 2012 p. 20).

The characteristics of the models they propose to use include features applied in weather systems such as chaotic dynamics and tipping points. On the other hand, they point out that as a response to the global financial crisis, "*there has been a groundswell of recent interest in modelling economic and financial systems as complex, adaptive networks*" (Haldane & Nelson, 2012 p. 15).

Extreme Value Theory is concerned with complex statistical models to represent tail events. However, in the context of this thesis, the paradigm tested for application in the financial sector, represents a general approach for modeling of extreme events by means of a quantitative approach for risk modeling, symbolizing the efforts to measure extreme events.

In this endeavor, I adopt the approach of Anette Mikes (2011), who conducted an extensive case study among financial institutions and distinguished between two distinct risk cultures. The first is a more holistic culture, "*articulating alternative futures and their implications for the business in order to support wider discussion and debate among* *decision makers*" (Mikes, 2011, p. 237). The second is a more quantitative culture "*that made risk measurement the focus of risk management*" (Mikes, 2011, p. 230).

The latter approach is advocated as more professional by the quantitative risk managers. This risk culture asserts that risk models don't manage risk directly, but provide a starting point for making risk-management decisions based on accurate and high-quality information. If risks are not comprehensively captured and consistently measured, decision-making will be limited, as it will not reflect the true picture, potentially leading to overestimation or underestimation of the actual risk.

The banks in the case study that followed this approach "[..] *were committed to extensive risk modeling and fostered a culture of quantitative enthusiasm in which risk models were regarded as robust and very relevant decision making tools, particularly for planning and performance*" (Mikes, 2011, p. 240).

As an extension to this statement, another banking executive indicated: "[…] *I think if you can't capture all risks pretty comprehensively and measure them consistently, then no matter how skilled or experienced your people are, there's going to be a limit on how good they can make their decisions, because they're not looking at the true picture.*" (Mikes, 2011, p. 239).

Therefore, the characteristics to be evaluated in the application of Extreme Value Theory in banking practices are, on the one hand, based on the mathematical properties of the models in use and sophistication of the banks' modeling capacities. On the other hand, they are based on the correct understanding and use of these models.

Management consultants (see for instance, for a McKinsey report: Gius et al., 2018, for a Deloitte report: Caldwell, 2021) regularly prepare surveys on risk management practices and challenges. However, as far as my knowledge goes, never before has the adoption of Extreme Value Theory or Quantitative Risk Management Tools been subject to a sector-wide empirical test for application and importance within an academic context, and therefore, this survey represents the first validated measurement scale.

3.3. Normal Accident Theory

Origin

Perrow (1981) published a case study of the near meltdown accident at the Three Mile Island nuclear power plant in 1979, and arrived at the conclusion that risk is inherent in technology and accidents will happen no matter what organizations do –often in the absence of any human error. He defines a normal accident as an "*unintended and untoward*" event that "*disrupts the ongoing or future output of the system*" (Perrow, 1999a, p. 65).

Perrow's research on accidents led to a four-level system classification. At the first level lies an individual part, such as a valve. Functionally related combinations of individual parts make up the second level, for instance in an engine. The third level groups units into subsystems like an aircraft's navigation set. The fourth level encompasses all subsystems, forming the entire system like an aircraft carrier or a nuclear power plant (Shrivastava et al., 2009). He differentiated incidents, failures at levels one or two, from accidents, failures at levels three or four. Usually, failures are detected at the lower levels and if they can be anticipated to progress in a comprehensible way to higher levels of the system, engineered safety features (ESFs), such as redundancies and alarms can be designed to avoid accidents. However, on rare occasions, nonlinear, unexpected interactions of even small failures can defeat these safety features. If the system is also tightly coupled, rapidly a cascade of failures may occur that cannot be prevented (Perrow, 2011b).

Main Characteristics

According to Perrow, two factors render technological systems susceptible to normal accidents. The first is "*complex interactions*", which refer to "*unfamiliar sequences, or unplanned and unexpected sequences*" between systems components that are "*either not visible or not immediately comprehensible*" (Shrivastava et al., 2009, p. 1360). The second factor is "*tight coupling*" between components in the system, via which the output of one is the input of the other, with little flexibility. Tight coupling leaves humans insufficient time or little possibility to intervene.

In instances where systems demonstrate both elevated complexity and are tightly coupled, the likelihood of failure significantly increases. However, the incorporation of additional safety devices, often employed as a standard response following a prior failure, could potentially diminish safety margins if it introduces further complexity (Pidgeon, 2011).

Introduction of social redundancies, for instance with double-checking, might inadvertently weaken safety protection, because it might diffuse responsibility and might lead to people overlooking safety checks (Tamuz & Harrison, 2006).

This is a pessimistic view, because it leads to conclusions such as those of Vaughan (1996), cited in Min and Borch (2022) that "*While good management and organizational design may reduce accidents in certain systems, they can never prevent them*".

Nonetheless, Perrow offers several approaches on how to limit the impact of normal accidents turning into a catastrophe. First of all, he points out that "*the larger the organization, the greater the concentration of destructive power*" (Perrow, 2011b, p. 51). However, he also adds realistically, that modern society is not likely to deconcentrate large organizations, and therefore he focuses on system design. Modular systems are less vulnerable and the potential for accidents is more dispersed. At the societal level, we should also reduce our dependencies on few organizations for communication, for power supply, or transportation modes (Perrow, 2007).

The role of regulators is also stressed, especially fostering the creation of independent supervisory bodies, with large scale inspections and the power to enforce the rules and force firms to change its practices (Perrow, 2011b).

Perrow also recommends sharing of information on near misses, errors and system flaws on a sector-wide level by creating shared databases and scorecards (Perrow, 1999b). This disseminating of information among organizations is exemplified by the Aviation Safety Reporting System and a medical reporting system in the United States of America (Tamuz & Harrison, 2006). Within the financial sector, the ORX Consortium is a good example of worldwide recording and dissemination of operational risk loss data among over 100 financial sector participants[2].

[2] https://orx.org/about-us

Applications of the theory

Although Perrow mostly refers to risk with extreme outcomes in an industrial setting, and this theory was tested in various industrial environments (see for instance Wolf, 2001 for an operationalization in the petrochemical industry or Schmidt, 2020 for an application to firefighting operations). He also applies this theory to the occurrence of the financial crisis in the USA in 2008 (Perrow, 2011a), where he indicates that there were many warnings of a housing bubble before it finally burst at the end of the year 2007.

The relevance of the theory was also tested for application to the savings and loans crisis of the 1980s and 1990s in the USA (Mezias, 1994). In this paper, the author cites various sources of an increasing complexity in the savings and loans industry, highlighting the exogenous factor of the interest rate shocks and fluctuations starting in the 1960s and worsening in the early 1980s. He also underscores that the escalating regulatory response exacerbated the overall system complexity. On the other hand, the upsurge of new, more sophisticated financial instruments such as derivatives, large investments in junk bonds and the growth of the repo market contributed to increasingly complex accounting practices, vulnerable to manipulation. The level of tight coupling is illustrated by the globalization of the financial markets with high speed transactions tying up market operators around the globe, but also by changes in the network relationships between state, auditors and firms, with revolving-door patterns for hiring professionals in each of these related sectors (Mezias, 1994, p.190).

The mortgage meltdown in the USA during the global financial crisis was also analyzed from a normal accident theory perspective by Donald Palmer and Michael Maher in 2010. They illustrate the complexity at the firm level and the succession of unexpected turns of events with an email message of an executive at the investment bank Bear Stearns whose sudden collapse in March 2008 as part of the subprime mortgage crisis was a prelude to the global financial crisis. His statement ends with "*you can't make this stuff up*". (Palmer & Maher, 2010, p.85). In their article they also present the tight coupling with statements of individuals directly involved in the rapid demise of Bear Stearns that show there was little each individual "*could do to alter the direction of the chain of events*" (Palmer & Maher, 2010, p.85). Their conclusion is that regulation should focus on decreasing complexity and tight coupling of the financial sector.

More recently, normal accident theory was tested in a case study of an algorithmic trading firm (Min & Borch, 2022). They contend that automated financial markets exhibit both tight coupling and complex interactions, making them susceptible to normal accidents, both at the individual firm level, and triggering a wider market meltdown. As an example they mention the firm Knight Capital, that on August 1, 2012 took only 45 minutes to collapse when a dormant code was unexpectedly triggered, thereby generating millions of erroneous orders. Therefore, measures should be taken to establish links between internal organizational factors and the broader systemic dynamics within modern financial markets.

Criticism of the Theory

One of the major achievements of Normal Accident Theory (NAT) is to shift the focus of accidents away from human error, and towards organizational properties and structure. However, Shrivastava et al. (2009) assert that maybe this shift has gone too far. The human factor is undeniably important and may either trigger an accident or avoid it through timely action (Shrivastava et al., 2009, p. 1362).

Another critique of NAT comes from Leveson et al. (2009). Perrow, in his original work, classifies certain industries as more prone to possibly catastrophic accidents, depending on the level of complex interactions and tight coupling. These are sectors such as nuclear plants, nuclear weapons, space missions, aircraft or chemical plants. According to Leveson and colleagues, if the theory were correct, one would expect that these industries would experience a higher accident rate than in other sectors. This however is not the case (Leveson et al., 2009, p. 229). For this reason, they argue that Perrow's categorizations is "*arbitrary and inconsistent with the actual design of real systems in these industries*" (Leveson et al., 2009, p. 230).

The most important critique of NAT, however, comes from Eugene Rosa (2005) in that the theory is non-falsifiable. Shrivatava et al. (2009, p. 1358) describe this very sharply: "*If a tightly coupled complex system were to succeed in avoiding an accident, NAT proponents would attribute the safe outcome to the system in question being not complicated enough*".

Silvast and Kelman (2013) also assert that Perrow's theory is a truism as no past evidence of the absence of a normal accident excludes the possibility of a future one. However, that doesn't mean we should abandon it, because even if it is just common sense, the perspective should still be used to avoid setting up society for catastrophic failure. Also Perrow himself, in a response to a critique on Normal Accident Theory writes that his theory with its focus on systems should stand along with other theories: "*We need them all*" (Perrow, 2009, p. 1392).

Main Validations of the Theory

The characteristics to be examined for the applicability of Normal Accident Theory in the banking sector in Spain are derived from detailed assessments of the complexity of interactions and variables indicative of tight coupling of processes. Such characteristics are analogous to those studied by Mezias (1994) and Palmer & Maher (2009) within the financial sector. Unlike what happens in an industrial setting, where disaster is mostly internal to an individual organization, in the financial sector, both the complexity and the coupling of operations are not only limited to the individual banking organization, but may propagate to the financial sector as a whole (Haldane & May, 2011). This can also be seen in the case study by Min & Borch (2022) where a failure in one algorithmic trading company was shown to rapidly propagate to the whole of the financial market.

Shrivastava et al. (2009) mentions that the factors that drive complexity of interactions include the presence of components that have multiple functions implying that they can fail in more than one direction, and that the need for specialized personnel involved in the processes limit their awareness of interdependences. This may lead to unplanned or unexpected sequences between components that are "*either not visible or not immediately comprehensible*" (Min & Borch, 2022, p. 281).

On the other hand, tight coupling of operations is manifested when humans have insufficient time or little possibility to intervene. This is also exhibited in the ubiquity of information and communication technology, which increases connectivity within and between organizations and financial markets (Min & Borch, 2022, p. 283).

As a complement to the diagnostic part on the existence of potential for normal accidents to happen in the Spanish Financial Sector, I will also perform a test on the solutions offered. Firstly, by promoting smaller organizations than one or a few very big ones, because the consequences of any failure will be less (Perrow, 2011b, p. 294). And in the second place, in the emphasis that "*improved regulation has a greater chance of success* *than either organizational reforms or the reduction of executive failure*" (Perrow, 2011b, p. 295).

3.4. High Reliability Theory

Origin

In response to the contributions to academic literature by Perrow (1981) and Shrivastava (1987), a group of researchers affiliated with the University of California, Berkeley conducted a series of case studies among organizations such as aircraft carriers, air traffic control (and, more generally, commercial aviation) and nuclear power plants that operate hazardous technologies in a nearly error-free manner under difficult conditions rife with complexity, interdependence, and time pressure. Weick (1987) was the first to use the term High Reliability Organization, focusing on the need to create an organizational culture where decentralized decision-making is fostered, while simultaneously creating a homogeneous set of assumptions and decision premises in a centralized manner to assure compliance without surveillance. On the other hand, Rochlin et al. (1987) highlight the importance of operating with redundancy and flexibility in high reliability organizations such as aircraft carriers. In a similar vein, Roberts (1990) underscores the critical role of ongoing training, accountability, and continuous organizational support in achieving high reliability within these contexts. These measures serve to mitigate the risks identified by Perrow (1981) and Shrivastava (1987).

LaPorte and Consolini (1991) focus on organizations where, unlike most other kinds of organizations, trial and error is not recommended as the preferred method of system improvement, as possible errors in this kind of organizations, even small ones, might have unacceptable or catastrophic consequences. Therefore, they recommend operating in three different modes, depending on the circumstances, first a routine operating mode which is bureaucratic; second a peak demand operating mode, where operators are expected to use considerable discretion in decision making; and third, an emergency mode of operating, which is based on a clear specification of emergency events which is when certain situations that have been simulated and practiced are activated.

Weick and Roberts (1993) integrate insights from high-reliability aircraft carriers with theories of collective mental processes. They emphasize the importance of heedful interrelating among organizational members. Despite the high potential for normal accidents due to tightly coupled technological processes (Perrow, 1981), these organizations remain relatively safe because of the tight coupling of social processes among their members.

The researchers from the University of California, Berkeley were examining organizations "*whose tasks and political setting made errors very costly*" (Rochlin, 2011, p 14). However, some have broadened the scope of organizations where they found that the lessons learned might also apply. For instance, Roberts and Libuser (1993) applied the principles of High Reliability Organizations to a banking organization that managed a turnaround after having nearly faced the prospect of failure. The strategies that were applied take into account factors such as a focus on reliability with redundancy of people in terms of a second set of eyes, implementation of process auditing and training on operations, a migrating of decision making to the lower levels of the organization by individuals that are most qualified to make them, but with the possibility of an outside specialist help for specific issues. At higher organizational levels, key decision makers are able to "see the big picture" through information flows where warning signals are communicated and members are encouraged to surface problems quickly.

Weick et al. (1999, p. 86) argue that in traditional definitions of reliability, the notions of repeatability or reproducibility are fundamental, but this fails to acknowledge that to remain reliable, a system must be able to *"handle unforeseen situations in ways that forestall unintended consequences*". For high reliability functioning, they use the term collective or organizational mindfulness, as an enriched awareness at the organizational level, but where both the quality of attention and the conservation of attention is concerned. For High Reliability Organizations to be effective, this not only translates into a state of mind, but rather translates into a repertoire of actions.

Main Characteristics

Organizational mindfulness consists of 5 interrelated dimensions of behavior: preoccupation with failure, reluctance to simplify interpretations, sensitivity to operations, commitment to resilience, and deference to expertise (Weick & Sutcliffe, 2001, 2007, 2015; Weick et al., 1999).

Preoccupation with failure is a distinctive characteristic of High Reliability Organizations (HROs) as revealed in numerous case studies of Nuclear Submarines (Bierly & Spender, 1995), Aircraft carriers (Roberts, 1990), or Air traffic systems (LaPorte, 1996). These organizations exhibit a chronic suspicion that all is not well, which translates into actively considering and an ongoing wariness of the possibility of failure. They consider any failure or near miss as an indicator of potentially larger problems (LaPorte & Consolini 1991). This also involves a willingness and encouragement towards the reporting of mistakes, and the open discussion of problems. These organizations treat any lapse as a symptom that something is wrong with the system, or that small errors could have severe consequences. This reporting is necessary for safety promotion and assurance (Teske & Adjekum, 2022).

In this context, an anomaly might refer to a cue that something does not fit in, or that accidents happen when evidence that is discrepant from the current assessment is missed, or when something unexpected is normalized (Vaughan, 1997). This focus on potential failure also induces concentration and has the potential for finding deeper insights (Vogus & Sutfcliffe, 2012) and it contradicts the assumption that success demonstrates competence, which makes people drift towards complacency. On the contrary, "*Attending to potential failures implicit in success is equivalent to acting on the assumption that any current success makes future success less probable*" (Weick et al., 1999, p 94).

In the view of the HRO scholars, organizational mindfulness is more than just focusing on failure. It also encompasses a sensitivity to the variety and complexity of the world surrounding us. The dimension of *Reluctance to simplify* refers precisely to this complexity, and the tendency many organizations have to simplify the way situations are handled (Weick et al., 1999). In HRO's the reluctance to simplify reflects a warning against posing general labels to situations that are occurring, as they may neglect specific signs that something unexpected is about to occur (Weick & Sutcliffe, 2015) or that collective "blind spots" to problems are created (Eastburn, 2018). As noted by Aven and Krohn (2014), this also applies in a risk context, as a need to see beyond quantitative expressions in terms of general probability of failures and expected losses, or judgements based on simple rules of thumb.

Instead, a thoughtful, data-driven process should be used to consider the uniqueness of a problem before applying a solution (Hales & Chakravorty, 2016). This usually implies being able to take into account multiple points of view, and fostering healthy skepticism. It requires that organizations need an ability to manage conflict and disagreement (Weick et al., 1999) and have to develop policies to reconcile organizational contradictions to maintain collaboration and cooperation. Usually, this means that redundancy is implemented in the system, with backups and double checks, and it needs high levels of trust among the members of the organization to function, for them to listen to others, to speak out, and not to be afraid of interrupting operations (Weick & Sutcliffe, 2015).

The dimension of *Sensitivity to operations* involves maintaining situational awareness and a vivid sense of details (Ray et al., 2011) and plays a main role in HRO's on the front line, where operations take place. The key lies in being able to capture the big picture, not so much at a strategic level, but through constant updates at the operational level, making continuous adjustments to prevent the build-up of errors (Weick & Sutcliffe, 2001). The way to put this sensitivity to work is to be anchored in the present with all your mind, without distraction (Weick & Sutcliffe, 2015). This concept is closely related to the Eastern or Buddhist perspective of mindfulness, which Vogus and Sutcliffe (2012) describe as a moment-to-moment awareness of present events, characterized by a non-judgmental attitude.

At the organizational level however, this sensitivity extends beyond the actions of individual operators. It also operates at the team level through a process known as heedful interrelating (Weick & Roberts, 1993). In this process, each team member understands how their individual work is connected to the actions of others and is interrelated within the system as a whole. Another element of sensitivity to operations is that personnel is expected to broaden their skill sets beyond their designated job duties and that senior managers undergo cross-training for various roles. This way, access to additional resources is increased in case something unexpected comes up (Teske & Adjekum, 2022).

Another characteristic of the dimension of sensitivity to operations is where honest and transparent communications is promoted, combined with instantaneous dissemination of information throughout the organizational hierarchy. This facilitates the organization in developing a precise representation of its real-time operations and devising innovative solutions to problems by sharing information about obstacles with all stakeholders involved (Vogus & Welbourne, 2003).

It should also be taken into account that the capacity to sense weak signals can enhance adaptability and facilitate early detection of changes that might potentially disrupt its performance quality (Su & Linderman, 2016).

All three previous dimensions of organizational mindfulness address the capacity of an organization to anticipate issues that may arise and develop into an extreme event (Eastburn, 2018). The following dimensions on the other hand, treat containment as it is concerned with resolving issues once they have surfaced.

Containment is described by the *Commitment to resilience* of an organization, which is defined as the "*capacity to cope with unanticipated dangers after they have become manifest, learning to bounce back*" (Weick et al., 1999, p.100). This involves a capability to react quickly and accurately before the events have a chance to escalate and cause more severe harm (Ray et al., 2011). Apart from flexibility, resilience requires elasticity to be able to stretch without breaking, and recovery to return to the previous state (Weick & Sutcliffe, 2015).

One of the characteristics of High Reliability Organizations is that they possess informal networks that facilitate the "*rapid pooling of cognitive knowledge to handle events that were impossible to anticipate*" (Weick et al., 1999). Another element of the commitment to resilience is the capacity to maintain the organization functioning, in times of disruption, while maintaining a positive mindset in the organization (Hillmann & Guenther, 2021). The ability to improvise is also highlighted as a significant element of organizational resilience, as this can create new ways for solving challenges (Herberg & Torgersen, 2021). The commitment to resilience at the organizational level also implies learning from experience with adversity (Williams et al., 2017), although HRO scholars stress the need to simultaneously both believe in your past experience but remain in doubt that this time may be different (Weick & Sutcliffe, 2015). The opportunity, however, lies in not only learning a lesson but also in acting on that information (Buchanan, 2011).

The fifth dimension of High Reliability Organizations, also related to containment, is the *Deference to expertise*. This refers to the migration of decision-making when something unexpected happens, to those persons in the organizations with the greatest expertise on the specific subject, regardless of their hierarchical rank (Roberts et al., 1994). This not only means that critical decisions are pushed down to lower levels of the organization, but also that they are made by the individuals most qualified to make them, which sometimes implies migrating upwards for instance for political decisions, or laterally in case complex issues arise (Roberts & Libuser, 1993).

Care should be taken, that deference to expertise does not stretch into deference to reputation, when individuals remain silent out of deference to the expertise of others (Blatt et al., 2006), thereby ignoring signals of disaster. As Weick and Sutcliffe (2015) relate when quoting a highly experienced firefighter, he has never encountered this specific fire. Therefore, deference to expertise also requires humility as an attitude towards the task, to avoid that an increase in experience makes people less vigilant (Barton & Sutcliffe, 2009).

Another factor of deference to expertise is that more mindful leaders are not afraid to ask for help from senior leaders, from mentors or from coaches (Chesley & Wylson, 2016). Recognizing the limitations of one's knowledge and seeking external assistance is indicative of strength and self-assuredness (Weick & Sutcliffe, 2015). Organizations that defer to expertise exhibit high flexibility and adaptability, ensuring that any issue can swiftly garner the necessary attention across all organizational levels (Weick et al., 1999).

Application of the theory

As mentioned before, High Reliability Theory has been applied mainly to high reliability organizations that use high hazard technologies (Weick, 1999), and where errors may result in catastrophic consequences (Busby & Iszatt-White, 2014).

In hospitals, there is a research stream that proposes applying the principles of High Reliability Theory to improve patient safety (Tamuz & Harrison, 2006; Ausserhofer et al., 2013, Etchegaray et al., 2019). Its main conclusion is that the behaviors implicit in this theory lead to the emergence of a safety culture, which is strongly associated with fewer medication errors and patient falls (Vogus & Sutcliffe, 2007, p. 52). Dwyer et al. (2023), in a scoping review of empirical studies on the application of high reliability organization theory, found that the healthcare industry was represented in three of the five articles they identified in their review. They suggest that this industry may have similar characteristics as the traditional HRO type of organizations, such as clear goals on safety, a management structure that is typically hierarchical, with a strong specialization of staff and a lack of commercial pressure (Dwyer et al., 2023, p. 7).

Applicability outside typical HRO, where there is no imminent danger for human casualties, has been studied for sectors as diverse as water utility (Bradshaw, 2008), a highway construction and maintenance organization (Busby & Iszatt-White, 2014), in business schools (Ray et al., 2011), construction (Enya et al., 2018), oil and gas (Ndubisi & Al-Shuridah, 2019), or information systems research (Dernbecher & Beck, 2017). The main conclusion of this research is that organizational mindfulness may offer a way to reduce vulnerabilities and become more situationally aware (Ray et al., 2011) of the world and its hazards (Weick & Sutcliffe, 2015, p. 19).

Also in the financial sector several studies have been carried out on the application of the principles of the high reliability theory and of organizational mindfulness. Brendan Young (2011) analyzed the banking sector and, taking into account the events during and after the global financial crisis, concluded that the HRT framework may be appropriate for organizations that pose a systemic threat. As cultural norms and ethical considerations play pivotal roles, organizational mindfulness for banks may offer a potential avenue for progress.

In the same year, Eastburn (2011) presented his doctoral thesis on managing the unexpected in banking and, several years later, published an article on the same subject that concludes that although organizational mindfulness may not be able to predict the next financial crisis, "*it does provide an opportunity to reflect on what makes a particular bank remain at ready, and thus, successful, despite adverse economic conditions*" (Eastburn, et al., 2018, p. 141).

Van den Eede, et al. (2006) studied the application of HRT in an IT department of a large financial institution. They mapped aggregated non-financial risks and allocated each of these to the NAT concepts of either complexity or tight coupling, and were able to assign solutions offered by one of the HRT dimensions of sensitivity to operations, preoccupation with failure, and commitment to resilience to almost 80% of the risks they identified, thereby concluding that HRT "*can provide the risk management discipline with a theoretical framework that can help with the decision making process underlying it" (*Van den Eede, et al., 2006, p. 8).

Criticism of the Theory

A longstanding debate persists between proponents of Normal Accident Theory and High Reliability Theory (see Shrivastava et al., 2009; Perrow, 2009b; Leveson et al., 2009; Rijpma, 1997; Tamuz et al., 2006). HRT scholars argue for the feasibility of implementing preventive measures against major accidents. In contrast, NAT proponents, while acknowledging the contributions of HRT, contend that accidents are inevitable due to the inherent complexities of systems (Perrow, 2009).

Just as is the case of NAT, HRT has also been accused of being non falsifiable. For instance, Shrivastava et al. (2009, p. 1375) claim that HRT can justify its inability to forecast error-free operations by attributing faults retrospectively and asserting that accidents occurred due to violations of high-reliability conditions.

Leveson et al. (2009, p. 229) explain the debate very clearly when making reference to Sagan’s (1995) compilation of alarming near-misses in nuclear weapons handling, that could be interpreted in two contrasting ways: either as a testament to our fortunate escapes (NAT) or as evidence of the system’s robustness and effective defenses (HRT).

Another aspect pointed out about HRT literature is that the theory and its characteristics have been developed mainly through case studies of very specific organizations which may not apply to other types of organizations (Leveson et al., 2009).

Sutcliffe (2011) indicated that the choice of terminology of High Reliability Organizations was unfortunate, because it implies that the high reliability is based on an absolute and static standard of performance, while in reality these organizations distinguish themselves by constantly seeking to improve reliability in difficult circumstances.

It ought to be mentioned that in the 2015 third edition of the groundbreaking book ‘Managing the Unexpected’, Weick and Sutcliffe apply the high reliability theory to a plethora of industries, including museums, automobile manufacturing, and banking. This signals that the essence of their theory is well applicable beyond the high-hazardous organizations studied in the last decade of the 20th century.

Main Validations of the Theory

In their 2001 publication, Weick and Sutcliffe included a set of 47 items to assess the degree of implementation of the 5 dimensions of organizational mindfulness. Ray, Baker and Plowman adapted this scale in 2011 into a 43-item scale that was applied to the top managerial level of Business Schools in the United State and demonstrated that the proposed subscales of mindfulness were perceptually distinct, albeit highly related.

Based on the original scale from Weick and Sutcliffe, Eastburn (2018) elaborated a 28-item scale which he applied to top level decision-makers in US community banks.

Vogus and Sutcliffe (2007), based on the mindful organizing and high reliability theory, developed a 9 item scale for hospitals, that was validated with 1685 hospital workers between December 2003 and June 2004. This scale which they called the Safety Organization Scale (later called Mindful Organization Scale, MOS), was also validated in a study among 1630 Swiss hospital workers by Ausserhoven et al. (2013) in translations in German, French and Italian. In 2017, Magnano et al. validated the Safety Organization Scale in Italian among 654 workers, mainly in public administration and in public health organizations. They found 8 of the 9 items of the MOS to load adequately into one factor. In 2020, Renecle et al. translated this 9 item scale into Spanish and applied it to 573 workers in a Spanish nuclear power plant. They argue that "*It is one of the few measures of mindful organizing to show sound psychometric properties in terms of (1) evidence of validity based on relationships with other variables (e.g., discriminant and criterion), (2) sound reliability and (3) evidence justifying the aggregation of individual scores to the group-level*" (Renecle et al. 2020, p. 5). This one-factor mindful organizing construct is a bottom-up construct driven by the employees to improve operational outcomes (Dernbecher & Beck, 2017, p 5).

In this research focusing on extreme events in an environment that do not involve an imminent danger of accidents involving human lives, I am more interested in analyzing the top-down view of an organizational capability to capture discriminatory detail about emerging threats and to create a capability to swiftly act in response to these details (Vogus and Sutcliffe, 2012). For this reason, the characteristics to be tested on the applicability of High Reliability Theory in the banking sector in Spain are based on the original scale developed by Weick and Sutcliffe in 2001 and successfully tested among Business Schools by Ray et al. (2011), employing all 5 previously explained dimensions of the top-down construct of organizational mindfulness.

4 Research Method

The principal research method that is followed in this thesis, is Structural Equation Modeling (SEM).

4.1. Origin

The essence of SEM is to test a theory (Hayduk et al., 2007) and that is precisely what this thesis is all about. In this chapter I will briefly explain the main characteristics and functioning of SEM.

The origin of SEM goes back to the 1920s when Sewall Wright developed path analysis for illustrating the factors leading to coat color in guinea pigs (Wright, 1920; Pearl & Mackenzie, 2018).

The main idea behind his study was that starting from a theory for causes of differences between coat color, the path coefficients (representing the magnitudes of causal effects) may be calculated by means of a study of correlations. This is never a method to discover these causal effects (Pearl and Mackenzie, 2018). As was shown by Bollen and Pearl (2013), still today many academics are confused by this statement and therefore criticize the approach, because they understand that the method purports to be able to establish causation from associations, which is clearly not the case. The correlation only indicates the statistical relationship between the variables; it is the underlying theoretically established mechanisms between the variables that establish causation.

The path analysis for estimating causal effects applying regression techniques was combined in the 1970s with techniques for factor analysis (Rosseel, 2012) by specifying a model that represents testing of theory among theoretical constructs that are being measured with observed variables (Kline, 2023, p.8).

This method allows researchers to analyze complex relationships among variables simultaneously within a unified framework. The methodology has been applied in epidemiology, psychology, education, sociology, and business, amongst others. The availability of dedicated computer programs for calculation of the regressions, correlations and factorials has made this methodology increasingly popular among researchers with thousands of studies being published at an increasing rate (Kline, 2023).

One of the most cited works in this research community is the paper by Jöreskog (1970), who defined a model notation for the equations and built a computer program, called LISREL, to perform all the necessary computations for the SEM. LISREL is currently the program notation on which most of the subsequently developed computer programs have been based (Kline, 2023). These can be commercial packages such as Mplus, SPSS Amos, CALIS in SAS/STAT, or open source software such as lavaan in R, or Semopy in Python.

4.2. Main characteristics

Structural equation models are a type of statistical tool that allows us to understand and estimate the relationships between different variables. These variables can be either observed (indicator variables) or unobserved (latent variables or theoretical constructs). The relationships between these variables are based on specific theories or hypotheses. Graphically, the observed variables are depicted by rectangles, and the unobserved variables by circles.

The model's parameters are estimated in such a way that they minimize the differences between the calculated and actual observed data. These estimations are represented by a matrix that shows the variances (how much each variable varies) and covariances (how much two variables vary together) of the indicator variables.

The degree of similarity between the estimated variance/covariance matrix and the actual data variance/covariance matrix is usually expressed in terms of likelihood. This likelihood represents how likely it is that we would observe the actual data, if the model, with its estimated parameters, perfectly represented the real-world situation from which the data was collected.

In other words, if our model was a "correct" model, the predicted matrix would match the actual data matrix. This is because, in this ideal scenario, our model would perfectly capture the underlying relationships in the population from which the data was obtained. However, in practice, there is usually some degree of difference between the model's predictions and the actual data.

It is possible to obtain multiple models that seem to fit the data well, but are actually incorrect in terms of their underlying causal relationships. These are referred to as "mis-specified” models (Hayduk et al., 2007). Some of these models might be “covariance-equivalent” or “nearly covariance-equivalent”, meaning they predict the same or nearly the same covariances (relationships between variables) as the correct model.

However, just because a model fits the data well in terms of covariance does not mean it is correctly specifying the causal relationships between variables. In other words, a model can appear to fit the data well (i.e., have a small degree of “covariance ill fit”), but still be seriously mis-specified in terms of its causal relationships.

A “saturated model” is a model that includes every possible relationship between the variables. Because of this, a saturated model is guaranteed to fit the data perfectly. However, just because a saturated model fits the data, it does not mean it correctly specifies the causal relationships between the variables. In fact, because a saturated model includes so many relationships, it can often be far from the true causal model (Hayduk et al., 2007).

4.3. Steps for building a SEM

As a high level description of contemporary SEM methodology, in this thesis, the steps indicated by Bollen et al. (2022, p. 4) will be followed. These are the following:

1) Model specification
2) Model implied moments
3) Identification of parameters
4) Estimation
5) Model fit

Model Specification. This requires the representation of the research hypothesis as a path diagram or as a series of equations (Kline, 2023). The notation developed by Jöreskog (1970), lives on to this day in the lavaan for R (Rosseel, 2012) and Semopy for Python (Igolkina and Meshcheryakov, 2020) packages, although in each package there are minor differences in notation.

As in this thesis the open source lavaan package written in R will be used, hereafter I will follow the syntax used in that package for model specification.

The SEM model consists of two parts, the measurement submodel and the structural submodel.

The **measurement submodel** can have a formative or reflective approach. In the case of the reflective approach, the unobserved latent theoretical constructs are the cause of the observed variables. Formative measurement, on the other hand, assumes that the latent construct is caused by the observed variables. As indicated by Kline (2023, p. 225), formative measurement approaches have several drawbacks in SEM and, therefore, only relationships for reflective latent constructs will be tested in this research.

In the case of this thesis, the observed variables are the answers to the questionnaire and the latent theoretical constructs are the EVT, NAT and HRT paradigms that are being tested.

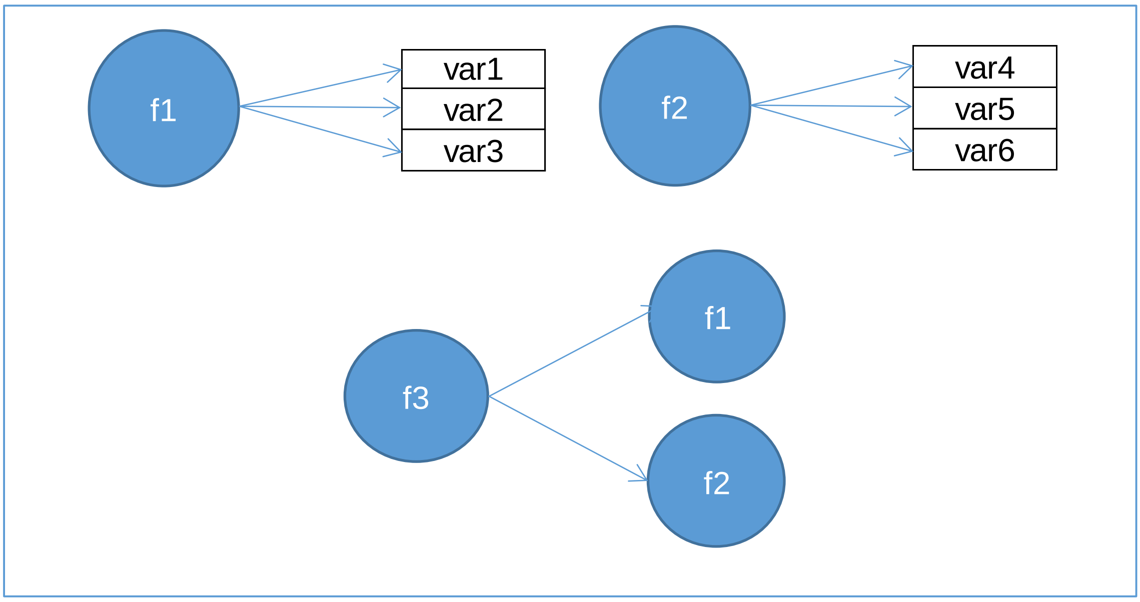
Following Rosseel (2012) the notation in lavaan to be used for the measurement submodel is the following:

```
f1 =~ var1 + var2 + var3

f2 =~ var4 + var5 + var6

f3 =~ f1 + f2
```

Here var1 to var6 are the observed variables from the answers of the questionnaire, and f1 and f2 are the latent theoretical first order constructs. On the other hand, f3 is a second-order latent factor, that is entirely based on latent variables itself. The special operator used in lavaan "=~" can be interpreted as *is manifested by*.

Graphically, this can be viewed as in figure 2.

Figure 2 Graphical representation of the measurement submodel



Source: author's own elaboration, based on Rosseel (2012)

The **structural submodel of the SEM model** is really just a combination of various linear regressions at the same time, where independent (or exogenous) variables in one regression equation can be dependent variables in another. This also permits the integration of mediator factors in a straightforward manner.

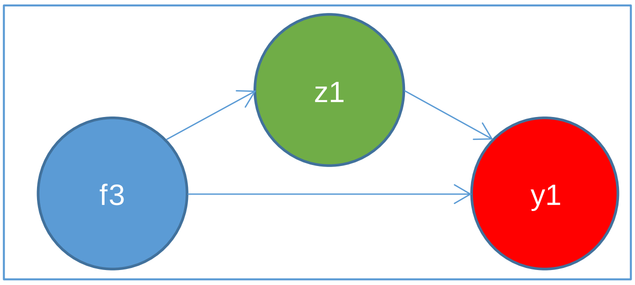
Following Rosseel (2012) the notation in lavaan to be used for the structural part is the following:

y1 ~ f3 + z1

z1 ~ f3

Here, applying lavaan syntax, the factor f3 has a direct causal effect on the dependent variable y1. Additionally, the factor z1 is operating as a mediator factor between the latent factor f3 and the dependent variable y1, which in this example also depends directly on factor f3. The tilde sign (~) act as the regression operator in lavaan. Graphically, this can be shown as in figure 3.

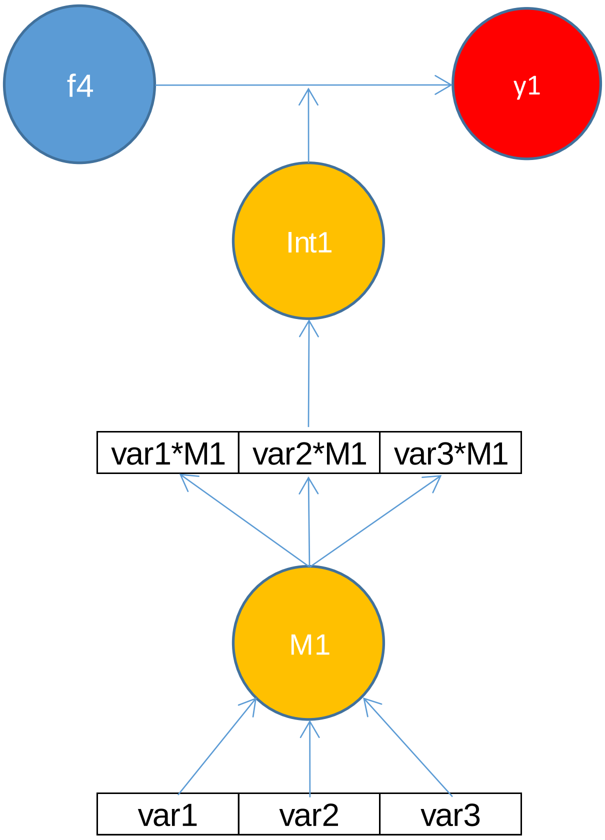
Figure 3 Graphical representation of the structural submodel



Source: author's own elaboration, based on Rosseel (2012)

Moderator effects can also be incorporated in lavaan by first creating an interaction term between the moderator variable and the independent variables, and applying a residuals centering procedure as indicated by Little et al. (2006). This interaction term is then included in the structural submodel as another regression factor. The moderator variables can influence the strength and direction of an independent variable on a dependent variable (Baron & Kenny, 1986). Graphically, this can be represented as in figure 4.

Figure 4 Graphical representation of the moderator interaction effect



Source: author's own elaboration, based on Rosseel (2012) and Little et al. (2006).

Please note that in the lavaan syntax, in the structural submodel, neither residual error terms nor an intercept is explicitly included. However, once the model is fitted, both the intercept and the variance of residual error are estimated, but as these are almost always part of a regression model, there is no need to specify them in the formula (Rosseel, 2012, p.6). In the model output they are indicated by a double tilde sign (~~) for both variance of error terms within each variable and for the covariance between variables. The output for the intercept is only shown when moderator effects with groups are tested and is shown with the following sign: ~+.

Model implied moments. This concept refers to the covariances or correlations between the variables in the model. In the original path diagrams developed by Sewall Wright (1920), the correlations, variances or covariances were decomposed in the model that was specified in the previous step.

The methods that developed in the 1970s such as the one by Jöreskog (1970), used a matrix approach and proposed a general model to derive the implied moments by using matrices. This approach breaks down the observed variables' characteristics into model parameters, making it easier to analyze different factor analysis models. Users can input specific data like factor loadings and covariance matrices into the model to calculate variances and covariances based on the model's parameters.

Identification of parameters. SEM is a group of simultaneous equations whose parameters must be estimated from the available data. A model parameter can either be free, fixed or constrained (Kline, 2023, p- 101). If the parameter is free, it must be estimated by the computer with the data. If the parameter is fixed, then it is specified by the modeler to equal a constant. A constrained parameter is estimated within some restrictions, typically relative to other parameters of the model.

It is necessary that overall system parameters can be expressed as a function of the means, variances, and covariances of the observed variables. If there is more than one way to solve for the same parameters in the equations, then the parameter is said to be overidentified. If there is no unique solution available, the parameter is not identified (Bollen et al., 2022). This concept is important, as it may apply that an equation is true according to theory, but the resulting model is not identified, and therefore adaptions should be made that have to respect the theory (Kline, 2023).

Estimation. Currently, most SEM apply Maximum Likelihood (ML) for parameter estimation. This method was generalized by Karl Jöreskog and made available in the LISREL program that forms the basis for most of the current computer software available for SEM. As indicated by Kline "*Parameters in the ML method are estimated iteratively in nonlinear optimization algorithms that minimize the fit function*" (Kline, 2023, p. 132). These iterations normally imply that the computer derives an initial approximate solution and then tries to improve the initial parameter estimates.

Anderson and Gerbing (1988, p. 412) highlight that when using SEM for theory testing (as is the case in this thesis), full-estimation methods such as Maximum Likelihood (ML) or Generalized Least Square (GLS) are advantageous. These methods are preferred over Partial Least Square estimation approach, especially when the goal is not prediction. On the other hand, Kline (2023, p. 140) point out that the GLS method, which is a member of the larger family of methods known as fully Weighted Least Squares (WLS) estimations, obtains similar results to ML with very large samples. However, in smaller samples, the ML approach is usually more efficient. The advantage of WLS is that it doesn't require any distributional assumptions, such as the normality of the variable responses.

Kline (2023) also mentions the Unweighted Least Squares (ULS) method as a potentially robust method for parameter estimation that could be used for a second analysis of the same model and data after having performed an ML estimation. The ULS method requires the variables to have the same scale, which is the case of the questionnaire that was applied in this thesis and has the advantage that it does not require a positive definite covariance matrix.

The arbitrary distribution estimator (ADF) can also be mentioned as another full estimation method that makes no assumptions of the distributions of the variables. This method however, is generally not recommended when models with a large number of factors are tested, or when the sample size is smaller than 500 (Kline, 2023, p. 141), both of which apply to the questionnaire that was conducted for this thesis.

In case the final variable is categorical, another full WLS estimation may be used, known as Diagonal Weighted Least Squares (DWLS). In this method, the weight matrix consists of just the diagonal of the variances and covariances of the estimated polychloric correlations, constraining the off-diagonal elements to zero (Kline, 2023, p.324). The package lavaan, automatically switches to the option "WLSMV" (Weighted Least Squares Mean and Variance) if categorical data are detected. This method specifies the combination of the DWLS estimator with robust standard errors. This option has been shown to produce accurate parameter estimates and better fit than WLSM, show little bias, and have more accurate standard errors of parameter estimates than those based on WLS (DiStefano & Morgan, 2014).

Model fit. The next step is to evaluate model fit. A long list of fit indices has been developed over the years to evaluate the models, each with its own set of benefits and shortcomings (Hooper & Coughlan, 2008). When fitting a SEM model in lavaan, the computer provides a list of 46 statistics to evaluate goodness of fit (Rosseel, 2018). As indicated by Kline (2023, p. 165), this large number of fit indexes may incite cherry-picking, or the selective reporting of those indexes that support the model. Therefore, he recommends reporting only a minimum fixed set of indexes, which will be described next.

Chi-square. In the original work of Sewall Wright (1920), the only fit index that was used was the likelihood ratio chi-square test (Bollen, et al., 2022). Also Jöreskog only applied as global fit statistics the model chi-square, its degrees of freedom and it *p*-value (Kline, 2023, p. 156). This statistic compares the parameter-implied covariance matrix with the population covariance matrix. If the value of chi-square equals zero, the model fits the data perfectly. Therefore, this test statistic is a badness-of fit statistic, implying that the higher its value, the worse the fit (Kline, 2023).

Unfortunately, as indicated by Hooper and Coughlan (2008), this test assumes multivariate normality and even properly specified models may be rejected if this assumption does not apply. Furthermore, with large samples, the chi-square statistic nearly always rejects the model. Therefore, these authors recommend using the chi-square relative to the degrees of freedom of the model, although Kline (2023, p.161) points out that there is neither statistical, nor logical foundation in using this measure as the degrees of freedom have nothing to do with the sample size, and there are no clear guidelines on the maximum cut-off values.

RMSEA. Root mean square error of approximation. This is an absolute fit index for badness-of-fit where 0 is the best result. The index is sensitive to the number of estimated parameters in the model and favors parsimony. Hooper and Coughlan (2008) recommend values close to 0.06 or a stringent upper limit of 0.07 for this index, while Kyndt and Onghena (2014), recommend values below 0.06 but consider acceptable values lower than 0.08. Normally this index is reported together with its 90% confidence interval (Kline, 2023).

CFI. Bentler comparative fit index. This is an incremental goodness-of-fit statistic, where 1.0 is the best result. This happens whenever the chi-square of the model does not exceed its expected value. If the result of the CFI equals 0.90, this means that the model reduces the raw noncentrality parameter by 90% compared with the baseline model (Kline, 2023, p. 168). Hooper and Coughlan (2008) indicate that originally a cut-off point of >= 0.9 was used, but more recently a value of >0.95 is recognized as good fit (Kyndt & Onghena, 2014).

SRMR. Standardized root mean square residual. This is an absolute badness-of-fit index, where a result of zero means that there are no differences between the observed and predicted correlations. Both Hooper and Coughlan (2008) and Kyndt and Onghena (2014) indicate that well-fitting models reach values of < 0.05, but state that values as high as 0.08 are considered acceptable. Kline (2023) points out that apart from evaluating the SRMR index, also the residuals should be analyzed and reported to obtain a complete picture of the correspondence of the model with the data.

It is strongly suggested to discuss in detail whether to retain or discard a specified model, based on more than only the fit indexes (Kline, 2023). Additionally, Hayduk et al. (2007) recommend reporting on the diagnostics undertaken to investigate any significant model ill-fit as indicated by the chi-square test, its degrees of freedom and its *p*-value.

Model Comparison. Models that are based on the same variables, but using different numbers of free parameters are called nested models (Kline, 2023, p. 182) and can be compared applying a chi-square difference test, where both the change in the value of the chi-square test and the difference in the degrees of freedom are compared. Models that cannot be derived from each other by adding or removing parameters or constraints are called nonnested models. The difference in chi-square between two nonnested models cannot be interpreted as a test statistic (Kline, 2023, p. 190). However, these models can be compared using information criteria such as the Akaike Information Criterion (*AIC*), or the Bayes Information Critierion (*BIC*).

These criteria reflect both model fit and model complexity, and the model with the lowest value on these criteria should be preferred (James et al., 2021). Theoretically, these information criteria can also be used to compare models that are based on different subsets of variables originating from the same sample, but as indicated by Kline (2023, p. 190), the comparisons may become less meaningful.

4.4. Advantages and disadvantages

SEM is a method that is widely used in the social sciences to test theory, especially when dealing with unobservable theoretical constructs.

This method has the advantage of being able to combine factor analysis to detect unobservable theoretical constructs from observed variables originating for instance from a questionnaire, with linear regressions to establish relationships between independent indicators and a dependent variable, all in one framework.

As it has been used very extensively, many model assessment indexes and criteria have been established over the years. Moreover, the complex calculations can nowadays be executed very quickly using advanced specialized computer programs and programming libraries.

The goal of SEM is to establish and test causal relationships, and as these are based on what theory establishes, this goes beyond the simple correlations that may be found in datasets.

However, SEM, because of its complexity, requires good statistical knowledge in all of the areas covered, in addition to theoretical understanding of the subject matter (Kline, 2023).

It also differs from normal linear regression in that the focus of analysis is on the variances and covariances, and not on estimation of means of the parameters (Kline, 2023).

4.5. Main motive for use in this thesis

The different theoretical paradigms for addressing extreme events that may occur in the financial sector are all unobservable latent constructs. The measurement submodel of Structural Equation Modeling is particularly useful to simultaneously assess the relationships between multiple observed variables, such as those obtained from a questionnaire, with latent constructs, while also accounting for measurement error.

On the other hand, each of these theoretical paradigms aims to improve the ability of organizations to measure, avoid, or manage extreme events. This is closely aligned with the structural submodel of SEM, where the input variables have an impact on a dependent variable. Applying SEM, the same integrated syntax can be used for both submodels. This allows for addressing the research questions and evaluating the research hypotheses outlined in the following section.

5 Research Objectives and hypotheses

5.1. Objectives

The global financial crisis demonstrated that an extreme event has the potential to drastically impact and even decimate a significant portion of financial institutions within a specific country. In response to this crisis, substantial efforts have been undertaken to improve the resilience and preparedness of the financial sector. These efforts span multiple dimensions, including improvements at the institutional, supervisory and regulatory level, as well as measures taken at the individual bank-level.

Following the global financial crisis, several other extreme events have unfolded. These events include the Covid-19 pandemic, the Russian invasion of Ukraine, and the recent interest rate hikes prompted by the 2021-2022 inflation surge. Notably, in Spain, financial sector entities have demonstrated heightened resilience during these subsequent challenges.

Presumably the financial sector may not emerge unscathed from a new extreme event that might ensue. The three theoretical frameworks for addressing extreme events that were evaluated in Chapter 3, symbolize efforts to improve strategies for measuring, managing or avoiding extreme events. Each of these frameworks originated outside the financial sector.

- Extreme Value Theory originated as a statistical methodology that provides tools for modeling and assessing the risk of extreme events in a more accurate manner.
- Normal Accident Theory was developed by sociologists and applied to high-risk industries, such as the nuclear energy sector and provides insights into understanding that accidents are inherent outcomes of complex and tightly coupled systems.
- High Reliability Theory was developed by organizational scientists and psychologists also for high risk sectors and provides a framework for organizational mindfulness to empower organizations to effectively anticipate and contain unexpected events.

The first of these approaches was chosen as academia's response for improving the predictive risk models that had been proven not to capture the tail risks that the financial crisis represented. The second approach was chosen as the dominant theoretical approaches to avoid an accident from happening, and the third approach for management of extreme events. Both of these last two approaches are primarily applied in high hazard industries.

As each of these three theories originate from outside the financial sector, I wanted to assess their applicability in the financial sector by means of a questionnaire among experts from the financial industry. In this context, my first research question is the following: **Can each of the frameworks of Extreme Value Theory (EVT), Normal Accident Theory (NAT), and High Reliability Theory (HRT) be identified as separate theoretical constructs in the financial sector?**

As the main objective of this research is to assess how the Financial Sector might be better prepared for the next extreme event, the second research question is: **As perceived by the expert practitioners in the financial sector, are each of the theoretical frameworks of EVT, NAT, and HRT associated with better preparation of organizations for extreme events?**

To be able to evaluate what needs to improve to be better prepared, the third research question is: **As perceived by experts within the financial sector, what are the most important aspects for achieving better preparedness for extreme events?**

And finally, the fourth research question is on factors that may influence the preparedness: **What are the moderator and mediator factors that influence the preparedness for extreme events?**

The following section presents the research hypotheses that have been developed for each of the theories. Given the application of the approach of Structural Equation Modeling, within each theoretical framework, I first address the measurement submodel of the latent theoretical constructs, followed by an examination of the structural component of the relation of these constructs with the perceived preparation for extreme events for each of the three theoretical paradigms.

5.2. Hypotheses

Extreme Value Theory

In the measurement submodel, in the first place, I specify that Extreme Value Theory (EVT) can be identified as a separate theoretical construct in the financial sector (Hypothesis 1), as part of the first research question. Furthermore, this construct can be divided into one separate theoretical construct that revolves around the quantitative management of risks in an organization in a general sense, in line with Mikes (2011), and on the other hand the application of advanced capabilities for modeling of events beyond the normal probability distribution (Hypothesis 2).

In the structural submodel of SEM, in the first place my hypothesis is that EVT is associated with a better preparation of financial institutions for extreme events (Hypothesis 3).

There are certain factors however, that I believe could moderate the effect of EVT on the preparation for extreme events and for this reason I developed several detailed research hypotheses based primarily on over 20 years of experience in the financial sector and taking into account the observations of Embrechts (2000, 2017). In the first place, I hypothesize that the lack of understanding of risk models being used in financial institutions reduces the effectiveness of EVT (Hypothesis 4). Furthermore, the possibility of an extreme event may act as a moderator variable in the relation between extreme value application and the preparation for the management of extreme events (Hypothesis 5). Additionally, my hypothesis is that the size of a financial institution acts as a moderator factor in the application of the EVT construct, with larger institutions having a greater trust in the possibilities of advanced models to improve preparedness for extreme events (Hypothesis 6).

In the structural submodel, I also hypothesize that the tools for management of the different phases of an extreme event have a mediating role in the effectiveness of the extreme value theory construct in the preparation of a financial institution for an extreme event (Hypothesis 7).

Normal Accident Theory

In the measurement submodel, the first hypothesis is that Normal Accident Theory can be identified as a separate theoretical construct (Hypothesis 8). Furthermore, this construct can be divided into one separate theoretical construct that revolves around the complexity of interactions on the one hand, and on tight coupling of operations on the other hand (Hypothesis 9).

In the structural submodel, my hypothesis is that an increased presence or complexity and tight coupling in an organization is associated with a lower level of organizational preparedness for extreme events (Hypothesis 10).

High Reliability Theory

In the measurement submodel, my initial hypothesis posits that High Reliability Theory, expressed as organizational mindfulness, can be identified as a separate theoretical construct in the financial sector (Hypothesis 11).

Furthermore, each of the five dimensions or organizational mindfulness described above can be found as separate theoretical constructs, through the dimensions of preoccupation with failure, reluctance to simplify, sensitivity to operations, commitment to resilience, and deference to expertise (Hypothesis 12).

In the structural submodel, in the first place I posit that organizational mindfulness is associated with a better preparation for extreme events (Hypothesis 13).

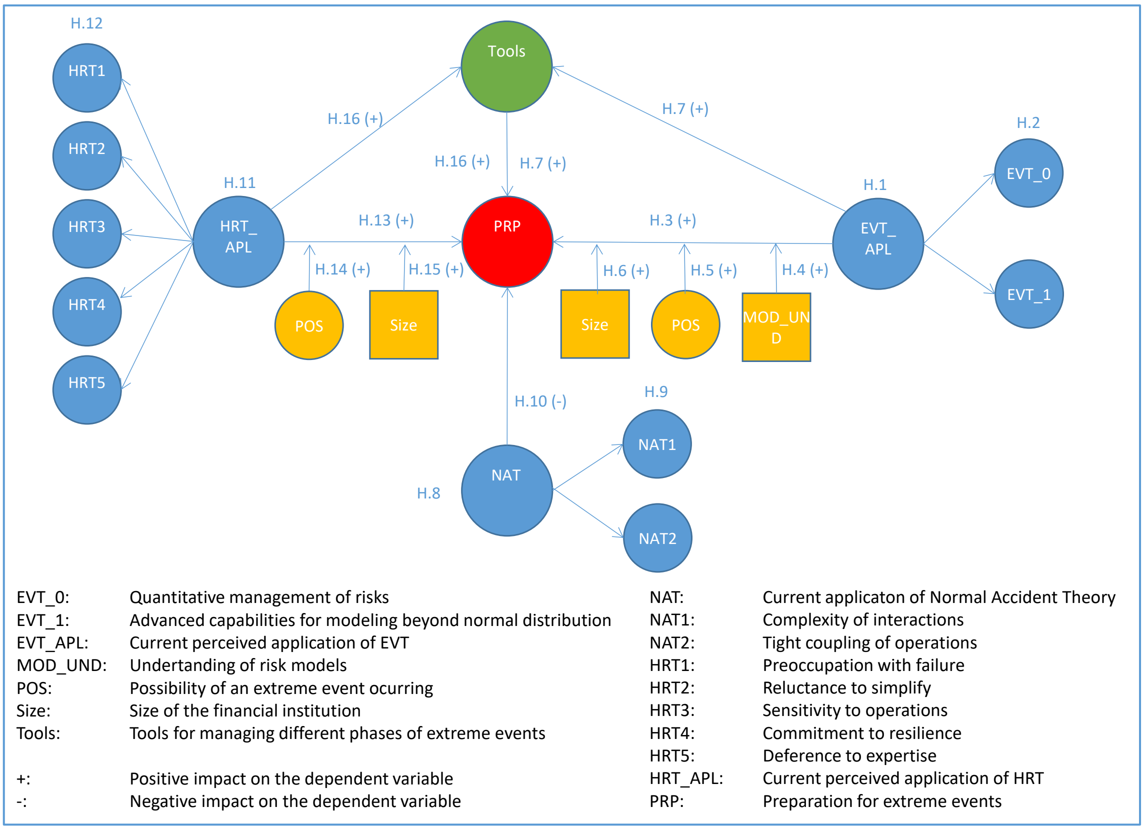
There are certain factors, however, that I believe moderate the effect of HRT on the preparation for extreme events. For this reason, I developed several detailed research hypotheses based primarily on over 20 years of experience in the financial sector and taking into account the observations of Weick & Sutcliffe (2001, 2011, 2015). I hypothesize that the possibility of an extreme event may act as a moderator variable in the relation between the application of HRT and the preparation for the management of extreme events (Hypothesis 14). Additionally, my hypothesis is that the size of a financial institution acts as a moderator factor in the application of the HRT construct, with larger institutions having a greater trust in the possibilities of organizational mindfulness to improve preparedness for extreme events (Hypothesis 15).

In the structural submodel of the evaluation of the HRT construct, I also hypothesize that the tools for management of the different phases of an extreme event have a mediating role in the effectiveness of the high reliability theory construct in the preparation of a financial institution for an extreme event (Hypothesis 16).

Graphical representation of the hypotheses

The entire model that will be tested on the application of Extreme Value Theory, Normal Accident Theory, and High Reliability Theory can be visualized as shown in figure 5.

Figure 5 Complete Hypothesized Model

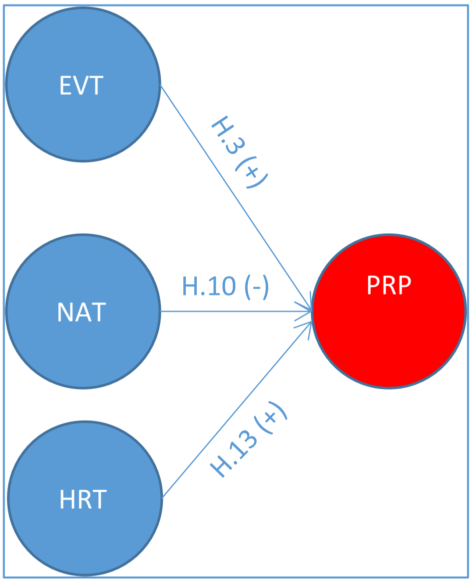


Source: author's own elaboration.

In this figure, the measurement submodel is represented with the blue circles that show the latent theoretical construct that are being tested. The structural submodel is represented with the following colors: in red is the exogenous variable on the preparation of an organization for extreme events, in yellow are the moderator factors on the eventual organizational preparation, and in green is the mediator factor.

In figure 6, a simplified model without the moderation and mediation factors is represented.

Figure 6 Simplified Hypothesized Model



Source: author's own elaboration.

Other Hypotheses

Related to the third research question, I will also posit that there is a gap between the current application of the Extreme Value Theory construct compared to its optimal level of application (Hypothesis 17). On the other hand, I also hypothesize that the current application of organizational mindfulness in the financial sector is lower than the optimal level, as perceived by the financial sector experts (Hypothesis 18).

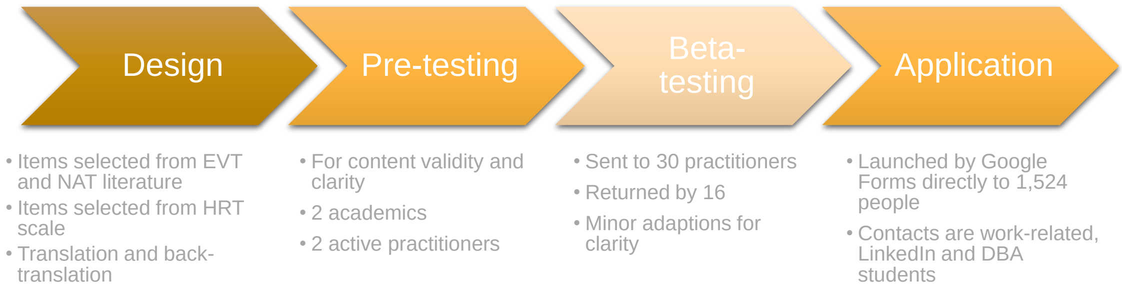
6 Research Setup

To test the application of the different theoretical frameworks for dealing with extreme events, a questionnaire was designed to be presented to experts in the financial sector that may potentially deal with extreme events. Therefore, functional areas that were addressed were departments of risk management, compliance, finance, control, technology and operations, legal, audit, and general management.

6.1. Questionnaire design and measures

The questionnaire items were designed based on the academic literature on each of the theoretical constructs evaluated in chapter 3 and symbolize efforts to measure, manage, or avoid extreme events. The steps taken in the survey development are outlined in figure 7 and are described in detail in this section 6.1 and in section 6.2.

Figure 7 Survey development steps



Source: author's own elaboration.

Current Application in the financial sector

For Extreme Value Theory, relevant items were obtained from the academic literature by the main proponents of EVT in the financial sector, Paul Embrechts, Didier Sornette and Andrew Haldane.

However, since a significant portion of their academic literature comprises intricate technical details that may be difficult to understand for those outside the domain of financial modeling, I chose to incorporate more broadly accessible questions related to the use and comprehension of quantitative methods and models in line with the differentiation made by Mikes (2011) between organizations that have a more holistic approach based on internal control, and others that are more quantitatively based and are more focused on measurement and analytics.

For Normal Accident Theory the items were derived from the studies on the original work by Charles Perrow on tight coupling and complexity of interactions, and from more recent work by Perrow (2011) on the alternatives for coping with the before-mentioned factors. Specific questionnaire items were also based on Min and Borch (2022) on the application of normal accident theory in financial markets, and on the paper by Shrivastava et al. (2009) that compares NAT with HRT. For both of these theories, no previously validated scale has been found in the academic literature.

For High Reliabiliy Theory, the items were adapted from the work by Ray et al. (2011), who in turn adopted it from Weick and Sutcliffe (2001). The original validated scale of 43 items was reduced to 15 items, 3 for each of the 5 dimensions of organizational mindfulness, after a thorough analysis of the potential applicability of these items in the financial sector. I follow Sutcliffe et al. (2016) in the selection of the scale to be used, as I am interested in mindfulness at the collective level (organizational mindfulness), and I am interested in the multiple dimensions of mindfulness. The 9-item Safety Organizing Scale, or MOS, developed and validated by Vogus and Sutcliffe (2009), loaded into one factor, translated into Spanish, and validated in a nuclear power plant in Spain by Renecle et al. (2020) was not used, because this scale applies to mindful organizing as a bottom-up approach to safety on the floor (be it a hospital, or a nuclear power plant), whereas the original scale with multiple dimensions predominantly focuses on the concept of organizational mindfulness. This principle, integral to structuring processes, pervades the organization following a top-down approach (Vogus & Sutcliffe, 2012), and is therefore deemed more useful in the context of a financial institution.

For application in the Spanish financial sector, the questionnaire items on application of the theoretical frameworks were translated by me from the original English language to Spanish. I have a C2-level in English and a near-native level of Spanish after living and working in Spanish-speaking countries for almost 30 years. For contrast of any conceptual errors or inconsistencies, a back-translation was performed by the co-director of this thesis who is a Spanish native with extensive experience living and working in English-speaking countries. This approach addresses both linguistic aspects and industry-specific jargon, ensuring the accuracy and relevance of the questionnaire items.

Perceived importance in the financial sector

One of the key aims in this research is to assess not only the current application of the three different theoretical frameworks, but also the perceived importance of success of each of these frameworks.

Consequently, each item concerning the application of EVT, NAT, and HRT has been complemented with an item requesting the respondent's level of agreement regarding its criticality.

Other survey items

Aside from the strict application of the theoretical frameworks, several items are included in the questionnaire to assess the perceived feasibility of different kinds of extreme events in the coming 10 years, the perceived preparation of the organizations for different kinds of extreme events, and the tools available in the organization to calculate the probability of an extreme event occurring, to prepare for it, to manage it would represent, and to bounce back afterwards.

Several control items are also included to permit analysis on the type of organization, and the role and experience of the respondents.

6.2. Questionnaire content validity testing and application

All the variables used for testing of the research hypothesis used a five-point Likert scale varying from either "Totalmente en desacuerdo" (totally disagree) to "Totalmente de acuerdo" (totally agree), or from "Nunca" (never) to "Siempre" (always), depending on the attribute of the variable. Hinkin (1998) recommends using a five-point scale as it is in line with the original scale developed by Likert and it has been shown that coefficient alpha reliability increases up to the use of five points, but levels off with more item-points. In this research, the theoretical paradigms (EVT, NAT, HRT) are represented as latent factors to be tested in the survey. It is recommended that at least four items per scale are needed to test homogeneity within each latent factor, although adequate internal consistency may be obtained with only three items (Hinkin, 1998). Kline (2023) suggests that for each factor under consideration, a prudent minimum is the employment of three to five indicators. However, he further elucidates that in a scenario where only one out of three potential indicators exhibits satisfactory psychometric properties, it might be better to exclude the two inferior indicators and avoid diluted or contaminated estimations.

To test content validity and clarity of the questionnaire, first a pre-test was executed among 2 academics of whom one is a retired practitioner, and 2 active practitioners in a banking organization. Afterwards, a beta testing of the questionnaire was mailed to 30 people in the financial sector, of whom 16 returned the questionnaire. Based on the results of this beta testing, minor adaptions were implemented before sending out the final version of the questionnaire.

For assessing current application of each theoretical paradigm, the following number of items was included in the final questionnaire version:

- Extreme Value Theory (EVT): 7 items
- High Reliability Theory (HRT): 15 items, 3 for each of the dimensions of organizational mindfulness
- Normal Accident Theory (NAT): 4 items

In Appendix I the final 67 questionnaire items in Spanish are included, together with their origin in English language, academic sources and codifications.

The research survey was conducted using Google Forms for its ease of use and forwarding, and the direct connection to a Google spreadsheet where the respondents' results were recorded.

Contact information was first obtained through the utilization of my work-related email contacts, complemented with personal connections from LinkedIn both in the financial sector and from consultants working for the financial sector in Spain.

The beta testing took place from Monday, September 4 until Friday September 15, 2023, and the massive launch took place between Thursday, October 26 and Thursday, November 16, 2023.

The range of banks that were approached is highly representative of the Spanish financial sector, with respondents belonging to the following banking organizations:

Abanca	Banco Sabadell	Caixabank	ING España
Arquia	Banco Santander	Crédit Suisse España	Kutxabank
Banca March	Bankinter	Deutsche España	Laboral Kutxa
Banco de España	BBVA	EVO Banco	Unicaja
Banco Mediolanum	Caixa Enginyers	Grupo Caja Rural	Wizink

The questionnaire was administered following the Ethical Guidelines (Academy of Management, 1995) regarding informed consent and anonymization. Accordingly, the questionnaire included an introduction explaining the purpose of the study. It emphasized that participation was voluntary and that all data was confidential and only accessible to the researchers who would use it in an aggregate manner. Neither the individual respondent's names nor e-mail addresses were requested. The name of the respondent's organization was requested voluntarily for segmentation purposes only and in case the respondent preferred not to share the name, additional data on type of organization, size and level of activity was requested to allow segmentation.

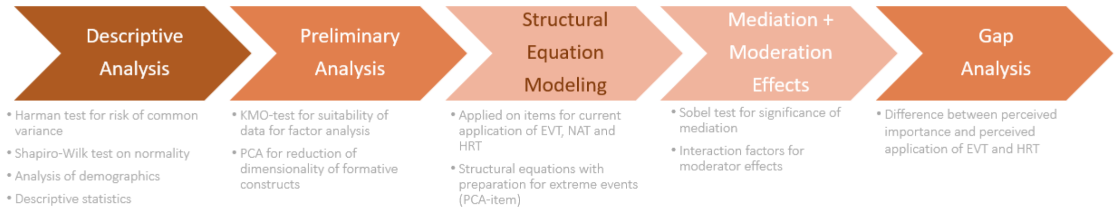
A total of 1.524 people were approached directly through e-mail or LinkedIn messages. The questionnaire was also published on LinkedIn and respondents were encouraged to resend the survey to their contacts within the banking sector. Until November, 16, 2023, a total of 315 valid responses was received, which implies a respondent rate of 20.7% of the directly addressed persons. Apart from the demographic information, all the other questions were mandatory, and therefore the final sample counts with all 315 responses.

Contrary to both Ray et al. (2011), in their survey of organizational mindfulness in business schools and Eastburn (2018), in his survey of organizational mindfulness in US community banks who both limited their scope to top management level respondents, I follow Fowler et al. (2007, p. 93) and address all organizational levels in supporting functions in the banking organizations to avoid bias toward stating that their organization is better prepared than it might really be.

6.3. Steps for building and estimation of the SEM

The steps taken in the survey development are outlined in figure 8 and are described in detail in this section 6.3.

Figure 8 Survey result analysis



Source: author's own elaboration.

Descriptive Analysis

I first performed a Harman test to evaluate if there is risk of common variance in the data. And thereafter a descriptive analysis of each of the variables separately, including a Shapiro-Wilk test on normality of the variables.

Preliminary Analysis

Before proceeding to the SEM model specification, I performed several preliminary analysis.

In these analysis, I performed a Keyser-Meyer-Olkin (KMO) test to assess whether sufficient common variance is shared among the variables of the questionnaire (Howard, 2023, p.3) and to assess if the data is suitable for factor analysis.

In this preliminary stage, I analyzed several related variables that cannot be considered to be the cause of an underlying reflective construct, but rather as part of a formative construct which is caused by the observed variables. Formative constructs cannot be entered into the classical structural equation model (Kline, 2023), neither as dependent nor as independent constructs. For this reason, I performed a principal component analysis (PCA) to reduce the dimensionality of these variables, such as the possibility of different extreme events, the preparation for different extreme events, and the tools that organizations possess to manage different phases of an extreme events. To evaluate the suitability of the constructed one-dimensional principal components, I assessed the explained variance.

Structural Equation Modeling

In chapter 4.3 the steps for building a SEM as indicated by Bollen et al. (2022) were addressed: models specification, implied moments, identification of parameters, model estimation, model fit and model comparison.

Regarding model specification, I followed the recommendation of Kline (2013) to specify hypotheses first (see chapter 5.2), which were fitted to an initial model, and to specify a list of possible modifications to the initial model that may be "*justified according to theory*" (Kline, 2023, p. 33). This way, respecification is done regarding underlying theory, not to obtain a model to fit the data.

These hypotheses were separated into a measurement submodel for the latent constructs for each of the 3 theories of EVT, NAT and HRT, and a structural submodel to assess their relation with preparation for extreme events.

The implied moments for the covariances and parameter identification were obtained using lavaan for R, where a matrix approach was used based on each of the observed variables for current application of the theories in the financial sector. For model estimation, the maximum likelihood method was applied.

For model estimation, in the first place, the measurement submodel was addressed. At this point, as was mentioned above, I utilize a 5-point Likert scale for each variable, ranging from "totally disagree" to "totally agree". When dealing with an ordinal scale that comprises fewer than five categories, treating the data as continuous can introduce biases in parameter estimates, inaccuracies in standard errors, and a potentially misleading chi-square statistic (Xia & Yang, 2019). In this case however, given the use of exactly 5 points in this research, to assess model fit, I exclusively present Maximum Likelihood (ML) estimators which is indicated for continuous variables.

As indicated above, neither Extreme Value Theory nor Normal Accident Theory have been validated before as a theoretical scale and High Reliability Theory was validated with a much large scale. For this reason, I performed an exploratory factor analysis to explore whether the basic factor structure can be replicated for current application of these theoretical paradigms. With this objective in mind, I followed Osborne and Fitzpatrick (2012) to divide the survey randomly into two independent subsamples (n=315; RND0=160; RND1=155) and to assess robustness of the factor loadings exclusively for the variables for current application of each of the theoretical paradigms, without taking into account the other survey items.

After that, a confirmatory factor analysis was performed on the theoretical paradigms, to assess if these paradigms should be represented as unidimensional or multidimensional constructs.

The second stage of the structural equation modeling phase consists of the structural submodel for the current application of the theoretical paradigms based on the retained measurement model, as a joint measurement. Here a linear regression is added to the latent constructs that have been confirmed in the first measurement stage.

Model fit was evaluated separately for the CFA model in line with the two-stage procedure recommended by Anderson and Gerbing (1988). In the measurement submodel, the theoretical paradigms of EVT, NAT and HRT were evaluated for unidimensionality using goodness-of fit statistics, specifically chi-square, CFI, RMSEA and SRMR (as discussed in chapter 4). Reliability was assessed using Cronbach's alpha and McDonald's omega. Both of these measures should be greater than 0.7 (Cheung et al., 2023). Convergent validity was evaluated by examining the standardized factor loadings, which should be higher than 0.5 (Fornell & Larcker, 1981), and additionally with average variance extracted (AVE). If AVE is greater than 0.5, than on average more variance is explained by the common factor than by the error terms (Kline, 2023, p. 239). Discriminant validity was assessed by evaluating whether the theoretical paradigms can be identified as unidimensional or multidimensional constructs. In order to do this, I compared nested models for each paradigm with their model fit statistics and performed a chi-square difference test.

Model fit for the structural submodel was evaluated with the significance and the direction of the regression coefficients.

For evaluation of the mediator effects outlined in chapter 5, I follow Baron and Kenny (1986) and calculate significance of mediation with a Sobel test and I determine partial or full mediation according to the change in the significance of the regression coefficients. Furthermore, I follow Little et al. (2006) to determine moderator effects by establishing a residual-centered interaction factor for the different moderator effects outlined in chapter 5, applying the same criteria of significance of the regression coefficients.

The last phase of the analysis of the results consist of a gap analysis on the difference between the perceived importance and the perceived application of both the EVT and the HRT constructs. This was done calculating the average evaluation on a Likert scale for the current application of the theoretical paradigm of EVT and of HRT and comparing those with the average evaluation for the importance of the same variables. See Appendix I for the list of questionnaire items.

7 Research Results

In this chapter, as outlined in section 6.3, I will first present the general descriptive statistics and the Harman's single factor test for possible bias in the questionnaire results. Thereafter, I will detail the preliminary analysis that was performed before applying SEM. Subsequently, the results of the Structural Equation Modeling is presented, first with the measurement submodel, where both a EFA and a CFA analysis were performed, and then with the structural submodel and the analyzed mediation and moderator factors. And as a last phase a gap analysis between current application and perceived importance.

7.1. Descriptive statistics

Harman's single-factor test

The Harman single-factor test applied on all variables indicates that the variance explained by the first factor is 19%, which suggests that we do not have a risk of common variance in the data.

Demographic items

Table 1 Demographics sample population

Organization Type		
Banking organization	292	93%
Consultancy firm	12	4%
Investment fund	2	1%
Insurance firm	3	1%
Other sectors	6	2%
	315	

Organization Size		
Over 500 Billion €	271	86%
50-500 Billion €	5	2%
5-50 Billion €	3	1%
Less than 5 Billion €	5	2%
Unknown	8	3%
Not a bank	23	7%
	315	

Funcional Area Respondents		
General Management	9	3%
Global Risk Management	169	54%
Local Risk Management	36	11%
Technology & Operations	26	8%
Finance	24	8%
Internal Control	14	4%
Compliance	7	2%
Audit	6	2%
Legal	5	2%
Others	19	6%
	315	

Management Level		
Director	63	20%
Manager	134	43%
Analyst	118	37%
	315	

Years of experience		
< 5 years	4	1%
5 - 10 years	9	3%
11 - 20 years	97	31%
> 20 years	205	65%
	315	

As can be seen in table 1, over 90% of the respondents work directly in a banking organization, and 86% of respondents work at one of the top-3 banks in Spain (Santander, BBVA or Caixabank) with assets over 500 Billion Euro. This is in line with the current composition of the banking sector in Spain, where these 3 banks represent 83% of total assets of the top 10 banking organizations (See table 2).

Table 2 Top 10 Banks in Spain (December 2023)

Bank	000 Million €	% top 10
Santander	1986.00	47%
BBVA	857.44	20%
Caixabank	671.27	16%
Sabadell	260.00	6%
Bankinter	114.48	3%
Unicaja	107.41	3%
Abanca	74.83	2%
Kutxabank	63.71	1%
Cajamar	60.16	1%
Ibercaja	54.52	1%
Total Assets of banks in Spain	2878.75	

Source: Public end-year reports of banks.
Ranking: https://campus.credimarket.com/ranking-bancos-espanoles/2023/11/02/.
Total Assets in Spain: https://www.bde.es/webbe/en/estadisticas/compartido/datos/pdf/a0451e.pdf

As can be seen in table 1, 65% of respondents have over 20 years of professional working experience. This is in line with publications on the banking and insurance sector where it is pointed out that over 57% of the workers in these sectors are over 45 years old[3].

Key non-demographic items

In the following tables, I will present the respondents' answers on a Likert scale translated to numerical values from 1 to 5.

[3] See: https://www.randstad.es/nosotros/sala-prensa/empleados-de-la-banca-y-seguros/

Table 3 Descriptive Statistics on possibility, preparation, and tools for extreme events

	Mean	SD	Shapiro-Wilk Test of normality W	p	# Respondents according to Likert scale 1	2	3	4	5
Possibility that one of the following extreme events will affect your organization over the coming 10 years					Very unlikely…				….Very feasible
An event associated with climate change	3.29	1.24	0.91	< .001	29	60	80	84	62
A new financial crisis	4.19	0.88	0.80	< .001	3	12	42	122	136
An event associated with information security or cybersecurity	4.08	0.93	0.83	< .001	2	20	52	117	124
A very significant fine for financial crime or market abuse	2.57	1.13	0.90	< .001	59	105	83	50	18
A very significant loss due to technological disruption	2.84	1.13	0.91	< .001	34	102	85	69	25
Average perceived possibility of 5 different types of extreme events	*3.4*	*0.72*	*0.99*	*0.013*					
To what extent do you think your organization is prepared to withstand any of the following extreme events?					Not at all prepared…				..Very prepared
An event associated with climate change	3.58	1.01	0.88	< .001	13	33	78	141	50
A new financial crisis	4.03	0.71	0.81	< .001	1	6	50	182	76
An event associated with computer security or cybersecurity	3.98	0.74	0.82	< .001	2	7	56	179	71
A very significant fine for financial crime or market abuse	3.92	0.91	0.85	< .001	1	26	60	139	89
A very significant loss due to technological disruption	3.85	0.88	0.84	< .001	5	19	62	161	68
Average of my organization's preparation to face 5 different types of extreme events	*3.9*	*0.61*	*0.97*	*< .001*					
The tools we have are sufficient to be able to:					Totally disagree…				...Totally agree
Calculate the probability of an extreme event occurring	3.19	0.94	0.90	< .001	12	59	121	103	20
Prepare in advance in case it happens	3.46	0.88	0.87	< .001	2	49	93	145	26
Carry out good management of the crisis or extreme event	3.92	0.77	0.83	< .001	2	12	60	177	64
Recover once it has happened	4.01	0.72	0.82	< .001	0	9	54	178	74
Average of the sufficiency of the tools that my organization has to face different phases of an extreme event	*3.6*	*0.63*	*0.98*	*< .001*					

Table 3 shows the respondent's answers to the questionnaire items asking for their perception of the possibility of an extreme event occurring during the coming ten years, the preparedness of their organization in case this extreme event should happen and the tools their organization possesses for dealing with an extreme event.

The respondents clearly perceived the occurrence of extreme events such as a financial crisis or an event associated with cybersecurity, as more plausible than the occurrence of events related to climate risk, fines owing to financial misconduct or market abuse, or a technologically disruptive event. The average Likert value of the first two kinds of events was 4.19 and 4.08 respectively, significantly above the average value of 3.4 for the sample (t-test statistic: 19.879 and 18.072 with 314 degrees of freedom and p-value <0.001).

A larger proportion of respondents perceived their organization to be prepared or very prepared for any of the before-mentioned extreme events compared to those who perceived their organization was not at all prepared or somewhat not prepared. The lowest score was for the preparation for the impact of a climate risk related extreme event (3.58) while the highest perceived score was the preparation for a financial crisis (4.03). This difference is statistically significant (t-test statistic of 8.298, with 314 degrees of freedom and p-value <0.001).

Regarding the tools that organizations possess for effectively addressing extreme events, the lowest score was for calculating the probability of an extreme event occurring (3.19), whereas the highest score was for the tools for recovering from an extreme event once it has happened (4.09). While the majority of respondents agreed that the tools their organization possessed are sufficient either for preparing in advance (54%), for carrying out good management of the crisis (77%), or for recovering from an extreme event once it occurs (80%), only a minority (39%) agreed or totally agreed that their organization possessed the tools for calculating the probability of an extreme event occurring.

Table 4 Descriptive Statistics on the bank's ability to model the occurrence of an extreme event

			Shapiro-Wilk Test of normality		# Respondents according to Likert scale				
	Mean	SD	W	p	1	2	3	4	5
The bank's ability to model the occurrence of an extreme event									
In our organization a more quantified approach to risk assessment is advocated using proper measurement systems	4.10	0.83	0.82	< .001	2	13	42	153	105
In my organization, risk models are considered essential tools for decision making.	4.49	0.74	0.70	< .001	0	7	26	89	193
In our organization we are able to measure all risks consistently to be able to have the true map of our risk exposure	3.96	0.85	0.84	< .001	3	14	60	155	83
The models we use in my organization are understood at all levels	3.30	0.98	0.90	< .001	14	47	112	114	28
The models we use in our organization capture risk in the tails of the distribution	3.61	0.85	0.87	< .001	4	22	109	138	42
In my organization we analyze tipping points in our data to see if phenomena are occurring that can mark the beginning of very significant changes	3.87	0.91	0.86	< .001	5	16	76	137	81
We model economic and financial systems as complex, adaptive networks	3.83	0.95	0.86	< .001	8	18	70	141	78
Average perceived ability of organizations to model extreme events	*3.88*	*0.63*							

Table 4 shows respondent's perception regarding the bank's ability to model the occurrence of an extreme event.

It can be seen in this table that banks currently place significant emphasis on a quantitative assessment of the risks they face. More than 80% of the respondents agreed or strongly agreed that their organizations adopt a more quantified approach, with risk models being regarded as essential tools for decision making, while 75% agreed or strongly agreed that their organization is able to measure all risks in a consistent manner to obtain a map of their risk exposure. These questions, even though they were asked in relation to the capacity to model extreme events, may have been answered taking into account a more general use of models for risk management and measurement.

A smaller majority of respondents expressed agreement or strong agreement with the implementation of advanced modeling techniques in their organizations. These capabilities include the analysis of tipping points, capturing risk in the tails of the distribution, and modeling the financial system as a complex and adaptive network and are more specific for modeling and measurement of extreme events. It should be noted however, that between 22% and 34% of the respondents provided a neutral answer (3 on the 5 point Likert scale) which possibly denotes the unfamiliarity of the respondents with the concepts that are being surveyed.

On the other hand, the respondents demonstrated less agreement on the full comprehension and understanding of risk models, with an average score of 3.30, and fewer than 45% expressing agreement or strong agreement with this statement.

Table 5 Descriptive Statistics on the bank's ability to anticipate issues that may arise and develop into an extreme event

	Mean	SD	Shapiro-Wilk Test of normality		# Respondents according to Likert scale				
			W	p	1	2	3	4	5
The bank's ability to anticipate issues that may arise and develop into an extreme event									
In my organization, we focus more on our failures and mistakes than on our successes	2,98	0,87	0,89	< .001	9	84	136	76	10
In my organization, we regularly update our procedures after experiencing a problem	3,99	0,81	0,84	< .001	2	12	57	159	85
In my organization, people feel free to talk to their superiors about problems	3,82	1,08	0,85	< .001	12	30	53	128	92
In my organization, people are encouraged not to take anything for granted	3,94	0,89	0,86	< .001	1	20	68	134	92
People in my organization generally prolong their analysis to understand the nature of the problems that come up	3,98	0,82	0,84	< .001	1	14	60	156	84
People in my organization listen carefully; it is rare that anyone's view is dismissed	3,55	0,95	0,89	< .001	10	27	104	127	47
The leaders of our organization pay close attention to the day-to-day operations of the company	3,73	1,01	0,88	< .001	5	35	78	118	79
During an average day, people come into enough contact with each other to build a clear picture of the current situation	3,63	0,87	0,88	< .001	5	21	108	134	47
If unexpected surprises arise in my organization, we have access to resources	3,84	0,88	0,85	< .001	4	20	66	157	68
Average perceived ability of organizations to anticipate extreme events	*3,72*	*0,60*							

Table 5 contains the results of the questionnaire items with the respondents' perception regarding the bank's ability to anticipate issues that may arise and develop into an extreme event. These items are part of the HRT scale for the dimensions of preoccupation with failure, reluctance to simplify and sensitivity to operations developed by Weick and Sutcliffe (2001) and validated by Ray et al. (2011).

In this table, it can be seen that, on average banks currently place less emphasis on a managerial approach to anticipate issues that may develop into an extreme event than on the quantitative approach to model the occurrence of such events (3.72 vs 3.88 on a 1 to 5 Likert scale). The items that received the highest level of agreement are the regular updating of procedures after experiencing a problem (77% of respondents agreed or strongly agreed), and the deepening of analysis to understand the nature of the problems that come up (76% of respondents agreed or strongly agreed). On the other hand, respondents perceived that in their organizations attentive listening and frequent inter-personal interactions were less frequently applied with 55% and 57% of respondents expressing agreement or strong agreement with these statements. Taking into account that the survey was addressed to risk, compliance, and other supporting functions, and not to the business development and commercial areas, it seems striking that only 27% of respondents manifested agreement or total agreement with the item of an organizational focus on failures and mistakes, rather than on successes.

Table 6 Descriptive Statistics on the bank's ability to react to an extreme event

			Shapiro-Wilk Test of normality		# Respondents according to Likert scale				
	Mean	SD	W	p	1	2	3	4	5
The bank's ability to react to an extreme event ocurring									
In my organization, resources are continually devoted to training and retraining people in their areas of expertise	4,01	0,87	0,83	< .001	4	14	52	149	96
People in my organization have a number of informal contacts that they sometimes use to solve problems	3,55	0,96	0,89	< .001	8	31	106	119	51
People in my organization generally learn from their mistakes	3,92	0,75	0,81	< .001	1	14	53	188	59
If something out of the ordinary happens, people in my organization know who has the expert knowledge to respond	3,73	0,88	0,86	< .001	3	30	68	161	53
People in my organization value know-how and experience over hierarchical rank	3,41	0,99	0,89	< .001	13	39	104	123	36
It is generally easy to obtain assistance from experts in my organization when something comes up that we don't know how to handle	3,7	0,95	0,88	< .001	4	30	89	126	66
Average perceived ability of organizations to react to extreme events	*3,72*	*0,62*							

Table 6 contains the results of the questionnaire items with the respondents' perception of their organization's ability to contain an extreme event or react in case it happens. These items are part of the HRT scale for the dimensions of commitment to resilience and deference to expertise developed by Weick and Sutcliffe (2001) and validated by Ray et al. (2011).

In this table, it can be seen that the average answers to these items are very similar to the items related to the bank's ability to anticipate an extreme event. The highest score is for the items of organizational commitment to training and the capacity to learn from mistakes (78% of respondents either agreed or strongly agreed with both statements). On the other hand, the lowest score is for valuing experience over rank and for use of informal contacts to solve problems (50% and 54% respectively either agreed or strongly agreed with both statements. Unsurprisingly, the respondents at the Director level had the highest evaluation of both of these items (3.98 vs an average of 3.55 for the informal contacts and 3.67 vs an average of 3.44 for valuing experience over rank).

Table 7 Descriptive Statistics on the bank's complexity and tight coupling of operations

			Shapiro-Wilk Test of normality		# Respondents according to Likert scale				
ɜs	Mean	SD	W	p	1	2	3	4	5
The bank's complexity and tight coupling of operations									
A succession of unexpected turns of events can occur in my organization that not even a person with intimate knowledge of the situation can foresee	3.4	1.08	0.91	< .001	3	57	70	123	62
I think that there is great complexity in the processes of financial sector entities that increase the risk that something may go wrong	3.58	1.03	0.88	< .001	11	58	94	98	54
In my organization, when things start to go wrong, we have little room to maneuver to alter the chain of events	2.75	0.98	0.90	< .001	28	107	103	69	8
I think that in financial sector entities there are many interdependencies that may cause errors in one part to spread to the entire system	3.45	1.02	0.90	< .001	7	56	86	119	47
I think that the size of the organizations influences to increase the possible impact of an extreme event, in case it occurs	3.87	1.02	0.85	< .001	6	33	51	130	95
I think that regulation plays an important role in reducing the possible consequences of the occurrence of an extreme event	4.12	0.90	0.80	< .001	3	20	32	140	120
Average perceived complexity and tight coupling of operations	3.53	0.63							

Table 7 contains the results of the questionnaire items with the respondent's perception regarding the level of complexity and tight coupling of operations in the financial sector, with items extracted from characteristics of the Normal Accident Theory.

This table presents the lowest levels of average agreement to the items presented of any of the three previous sections. Especially in the aspect of tight coupling, in the item where respondents assess if there is little room to maneuver in case things start going wrong, only 24% agree or strongly agree, while fully 43% disagree or strongly disagree with this statement. It should be taken into account that the survey was distributed mainly among people active in retail and commercial banking operations, unlike the case study carried out by Min & Borch (2022), who studied complexity and interconnectedness in firms operating directly on the international financial markets. On the other hand, respondents favor regulation, with 83% agreeing or strongly agreeing that it plays an important role in reducing the consequences of a possible extreme event. A large majority of respondents (71%) also ascribed to the thesis that the size of an organization may increase the impact of an extreme event.

Table 8 Descriptive Statistics on the perceived importance for banks to model, to anticipate and contain extreme events

	Mean	SD	Shapiro-Wilk Test of normality		# Respondents according to Likert scale				
			W	p	1	2	3	4	5
I think it is essential that organizations actively promote the quantitative assessment of risks using appropriate measurement systems.	4,64	0,58	0,62	< .001	0	2	11	84	218
I think that risk models are essential tools for decision-making in financial sector entities.	4,7	0,56	0,57	< .001	0	1	13	64	237
I think it is essential that organizations have the ability to measure all risks consistently in order to make appropriate decisions.	4,72	0,56	0,54	< .001	1	1	8	66	239
I think it is essential that the models used in financial sector entities are understood at all levels.	4,36	0,86	0,73	< .001	2	12	32	94	175
I think it is essential that the models used in financial sector entities include the risk in the tails of the distribution.	4,17	0,81	0,82	< .001	0	8	57	123	127
I think it is essential for financial sector entities to analyze turning points in the data to see if phenomena are occurring that can mark the beginning of very significant changes.	4,48	0,71	0,71	< .001	0	5	25	100	185
I think it is essential that financial sector entities model economic and financial systems as complex and adaptive networks.	4,37	0,74	0,76	< .001	0	3	39	110	163
Average perceived importance of the capability to model extreme events	4,49	0,45							
I think it is essential that organizations focus more on their failures and errors than on their successes.	3,33	1,04	0,91	< .001	17	43	117	96	42
I think it is essential that organizations regularly update their procedures after experiencing a problem.	4,67	0,57	0,60	< .001	0	1	14	72	228
I think it is essential that organizations can talk openly about problems, errors or failures.	4,8	0,49	0,44	< .001	0	4	1	48	262
I think it is essential that organizations be encouraged not to take anything for granted.	4,65	0,55	0,63	< .001	0	1	8	91	215
I think it is essential that organizations deepen the analysis to understand the nature of the problems that arise.	4,69	0,52	0,60	< .001	0	1	5	85	224
I think it is essential for people in organizations to listen carefully and not dismiss anyone's opinions.	4,66	0,58	0,60	< .001	0	3	9	79	224
I think it is essential to have a good "map" of the capabilities and competencies of each person in organizations.	4,31	0,79	0,77	< .001	1	8	35	119	152
I think it is essential that people come into sufficient contact with each other to form a clear picture of the current situation.	4,29	0,72	0,78	< .001	1	2	37	139	136
I think it is essential that organizations have flexibility to obtain resources if unexpected surprises arise.	4,59	0,57	0,67	< .001	0	0	13	104	198
Average perceived importance of the capability to anticipate extreme events	4,44	0,39							
I think it is essential that organizations continually dedicate resources to training and retraining people in their areas of specialization.	4,68	0,54	0,61	< .001	0	0	11	80	224
I think it is essential that organizations have networks of informal contacts to solve problems.	3,77	1,11	0,86	< .001	14	22	88	89	102
I think it is essential that in organizations people learn from their mistakes.	4,74	0,53	0,53	< .001	1	1	5	66	242
I think it is essential that organizations know who has the expert knowledge to respond if something out of the ordinary happens.	4,66	0,56	0,62	< .001	0	1	10	84	220
I think it is essential that organizations value knowledge and experience above the hierarchical rank.	4,54	0,58	0,70	< .001	0	0	14	118	183
I think it is essential that it is easy to get expert assistance when something comes up that you don't know how to handle.	4,59	0,60	0,66	< .001	0	2	13	96	204
Average perceived importance of the capability to react to extreme events	4,50	0,43							

Table 8 contains the average evaluations of respondents on the perceived importance of the aforementioned items related to the capacity to model an extreme event, anticipate or prepare for such an event, and contain or react should such an extreme event occur. As can be seen, in each of these items, the average level of agreement is higher than the perceived current application, indicating there is room for improvement in all of the financial sector organizations. In 20 out of 22 items, less than 5% of the respondents expressed disagreement or strong disagreement regarding the importance of the specific item. Only two items — the importance of informal contacts to solve problems, and the importance in organizations to focus on errors and failures— were evaluated as not important by 11% and 19% of respondents, respectively, which is notably higher than the evaluations of the other items. Without taking these two items into account, the average evaluation of the items related to anticipation and containment is considered more important than the average importance of modeling extreme events. 66% of respondents strongly agree on its importance, while 61% strongly agree on the importance of modeling capabilities.

Table 9 Descriptive Statistics on the perceived improvements in banks after the global financial crisis

			Shapiro-Wilk Test of normality		# Respondents according to Likert scale				
	Mean	SD	W	p	1	2	3	4	5
Perceived improvements after the financial crisis									
As a result of the financial crisis, the models used in my organization have improved to account for the possibility of another extreme event	4,26	0,79	0,78	< .001	3	3	41	131	137
As a consequence of the financial crisis, the culture of attention and anticipation has improved to be more prepared for an extreme event	4,31	0,71	0,78	< .001	0	6	28	144	137
As a consequence of the financial crisis, the culture of resilience and reaction has improved to be more prepared for an extreme event	4,28	0,72	0,78	< .001	1	4	30	150	129
As a consequence of the financial crisis, the complexity and interconnection of processes in the financial sector has decreased and thus the possible impacts of another extreme event have been reduced.	3,22	1,13	0,91	< .001	26	59	86	107	37
Average perceived improvements after the global financial crisis	4,01	0,61							

Table 9 contains the average evaluations of respondents on the perceived improvements in the financial sector after the global financial crisis. A large majority perceived improvements in the modeling capacities, the culture of attention and anticipation, and the culture of resilience (85%, 89%, and 89% respectively expressed agreement or strong agreement on these issues). On the other hand, only 46% of the respondents expressed agreement or strong agreement on the reduction of the complexity and interconnectedness of operations.

In each of the previous tables, I have included the results of the Shapiro-Wikins test of normality, showing that none of the variables are normally distributed. However, this lack of normality is not severe, as can be seen from the skewness and kurtosis measures. With the exception of three variables related to the importance of the capability to model or manage extreme events —where both skewness exceeds 2 and kurtosis exceeds 7 (represented in table 8 with Shapiro Wilk test values below 0.55), indicative of severe non-normality (Curran et al., 1996) —the remaining variables show values lower than this range and may be considered to present moderate non-normality. Kline (2023, p. 137) gives some indications on the implications of severe non-normality for structural equation modeling applying the maximum likelihood estimation method. He indicates that parameter estimates are generally robust, but values of standard errors may be distorted.

7.2. Preliminary analysis

Suitability for Factor Analysis

The first step is to assess the suitability of the dataset created with the questionnaire results for factor analysis, applying Bartlett's test of sphericity for testing if the correlation matrix is significantly different from zeros on the off-diagonals and applying a Keyser-Meyer-Olkin (KMO) test to assess whether sufficient common variance is shared among the variables of the questionnaire (Howard, 2023, p.3). As can be seen in table 10, the data is suitable for factor analysis with an overall Measure of Sampling Adequacy (MSA) of 0.86.

Table 10 KMO and Bartlett's sphericity test for suitability for factor analysis

Bartlett test of sphericity		KMO's test	
χ^2	9219	Overall MSA	0.86
p-value	< .001	Current Application Variables MSA	0.91
df	2016		

Principal Component Analysis for formative constructs

To reduce dimensionality of the formative constructs of the observed variables from the survey, the following items were converted into PCA items:

- Perceived possibility during the next ten years of different kinds of extreme events.
- Preparation of the organization for different kinds of extreme events.
- Tools available in the organization for dealing with extreme events during the different phases (before, during, after).

In table 11, the main statistics for the components are displayed. It can be shown that the correlation between the components and the simple average valuation for the individual variables is higher than 99%.

Table 11 Principal Component Analysis and Reliability Analysis for formative constructs

	Bartlett test of sphericity			KMO's test	% of Variance in 1 component	Correlation vs AVG of variables
	χ^2	p-value	df	Overall MSA		
Possibility of an extreme event	281	< .001	10	0.718	46.1%	99.3%
Preparation for an extreme event	364	< .001	10	0.781	51.6%	99.4%
Tools for dealing with extreme events	378	< .001	6	0.657	58.2%	99.6%

7.3. Structural Equation Modeling

In this section, I present the results of the two-stage procedure recommended by Anderson and Gerbing (1988) for structural equation modeling, where I first present the measurement submodel, and subsequently the structural submodel.

Measurement submodel

Internal Replication in EFA

After randomly dividing the survey results into two independent subsamples (n=315; RND0=160; RND1=155) an Exploratory Factor Analysis (EFA) was performed on each of the subsamples to evaluate the scales for the theoretical constructs that were not validated.

According to the Kaiser criterion of Eigen values of the created factors greater than one, the parallel analysis suggests the use of 3 factors in the first subsample, and 4 factors for the second subsample. As I am testing for the application of 3 different theories dealing with extreme events, I applied an exploratory factor analysis with 3 factors.

As can be seen in table 12, establishing 3 factors, applying oblique (oblimin) rotation, and applying a cut-off point of 0.3, in both samples the items predominantly load into each of the 3 theoretical paradigms. As indicated by Osborne and Fitzpatrick (2012, p.4), the initial step in evaluating structural replicability between the two subsamples is to identify the strongest loading for each variable in both samples and confirm congruence by determining which factor each variable primarily loads onto. In the case of this research, this test failed for one item of the HRT paradigm ("*People in my organization have a number of informal contacts that they sometimes use to solve problems", coded as HRTCON_8_8APL*) and for one item of the EVT paradigm ("*The models we use in my organization are understood at all levels", coded as EVT1.1APL*) because these variables do not load into the same factor in each subsample. This implies that 93% of the variables load to the same factor in each subsample. The second test is to assess whether the factor loadings are roughly equivalent in both subsamples. For this test, Osborne and Fitzpatrick (2012) recommend calculating the square difference between the standardized loadings to facilitate comparison of both positive and negative differences and for highlighting the larger differences. They indicate that once a squared difference is larger than 0.04, the factor loading may be considered volatile. In the case of this study this occurs in one variable for HRT (“*The leaders of our organization pay close attention to the day-to-day operations of the company”, coded as HRTANT_7_1APL*) and in one variable for EVT (“*In my organization, risk models are considered essential tools for decision making”, coded as EVT0.2APL*). Overall, 22 of the 26 variables (85%) concerned with the current application of the theories are loaded in each subsample onto the same factor and with equivalent loadings.

Table 12 EFA Factor loadings for current application

Questionnaire Group	Variable (see Appendix I)	Sample (RND0) Comm-unality	ML1	ML3	ML2	Sample (RND1) Comm-unality	ML1	ML3	ML2	Squared difference
HRT: Ability to anticipate extreme events	HRTANT_5_1APL	0.11	0.23	0.14	0.13	0.13	0.37	-0.01	0.10	0.0196
	HRTANT_5_4APL	0.11	0.21	0.17	-0.04	0.11	0.20	0.20	0.01	0.0001
	HRTANT_5_8APL	0.60	0.78	-0.07	-0.17	0.51	0.72	-0.06	-0.09	0.0036
	HRTANT_6_1APL	0.47	0.67	0.02	-0.03	0.48	0.62	0.10	-0.09	0.0025
	HRTANT_6_5APL	0.49	0.54	0.20	-0.15	0.45	0.53	0.19	-0.09	0.0001
	HRTANT_6_7APL	0.56	0.74	-0.02	-0.11	0.55	0.71	0.01	-0.10	0.0009
	HRTANT_7_1APL	0.50	0.70	0.00	-0.08	0.42	0.49	0.28	0.16	0.0441
	HRTANT_7_4_APL	0.41	0.53	0.18	0.12	0.43	0.65	0.01	0.03	0.0144
	HRTANT_7_8APL	0.36	0.44	0.24	0.08	0.37	0.52	0.18	0.11	0.0064
HRT: Ability to react to extreme events	HRTCON_8_2APL	0.42	0.48	0.25	0.01	0.21	0.31	0.23	0.05	0.0289
	HRTCON_8_8APL	0.27	0.38	0.00	0.39	0.20	0.43	-0.08	0.29	failed
	HRTCON_8_9APL	0.42	0.57	0.13	0.06	0.42	0.61	0.08	0.00	0.0016
	HRTCON_9_3APL	0.47	0.68	0.02	0.03	0.49	0.73	-0.07	-0.01	0.0025
	HRTCON_9_4APL	0.52	0.77	-0.09	0.03	0.43	0.68	-0.03	0.13	0.0081
	HRTCON_9_8APL	0.69	0.78	0.08	0.20	0.39	0.66	-0.13	-0.05	0.0144
EVT: Ability to model extreme events	EVT0.1APL	0.47	0.13	0.59	-0.09	0.37	0.26	0.39	-0.12	0.0400
	EVT0.2APL	0.48	-0.07	0.73	-0.01	0.42	0.30	0.42	-0.09	0.0961
	EVT0.3APL	0.52	0.10	0.65	-0.06	0.46	0.27	0.48	-0.10	0.0289
	EVT1.1APL	0.39	0.24	0.43	-0.12	0.28	0.40	0.18	-0.07	failed
	EVT1.3APL	0.57	0.05	0.73	0.01	0.40	0.14	0.54	-0.07	0.0361
	EVT3.3APL	0.62	0.30	0.58	0.01	0.60	-0.03	0.78	-0.05	0.0400
	EVT3.5APL	0.59	-0.14	0.83	0.00	0.57	-0.08	0.80	0.06	0.0009
NAT: Existence of tight coupling and complexity of operations	NAT1.2APL	0.49	0.04	-0.09	0.68	0.55	0.03	-0.06	0.73	0.0025
	NAT1.4APL	0.48	0.00	-0.01	0.69	0.34	0.00	0.05	0.59	0.0100
	NAT2.4APL	0.33	-0.10	-0.03	0.55	0.27	-0.05	-0.04	0.50	0.0025
	NAT2.6APL	0.39	-0.08	-0.01	0.61	0.50	-0.05	0.03	0.70	0.0081

Legend:
- Loadings below 0.3
- Loadings above the 0.3 cut-off point
- Loadings above the 0.4 cut-off point

See Appendix I for the meanings of the codifications

Confirmatory Factor Analysis

As can be seen from the internal replication in EFA, the observed variables for current application of the paradigms of Extreme Value Theory (EVT), Normal Accident Theory (NAT), and High Reliability Theory (HRT), load into separate factors.

Here, I present the results for the confirmatory factor analysis (CFA) performed on the variables for current application in banking organizations of the theoretical paradigms of EVT, NAT and HRT.

As can be seen from table 13, the 3 factor model, separating EVT from NAT and from HRT has a significantly better fit than a CFA model where all variables load into the same factor, thereby confirming hypotheses 1, 8, and 11. However, it can also be seen in this table that the 9 factor model is confirmed as the best performing model. In this model the Extreme Value Theory construct is separated into 2 different constructs, one for a general quantitative approach towards risk management, and the other for more advanced capabilities to model extreme risk (hypothesis 2). On the other hand, the Normal Accident Theory construct is separated into 2 different dimensions, one for complexity of interactions, and another for tight coupling of operations (hypothesis 9). And finally, the High Reliability Theory construct is separated into the 5 different dimensions of organizational mindfulness: preoccupation with failure, reluctance to simplify, sensitivity to operations, commitment to resilience, and deference to expertise (hypothesis 12).

Even though the chi-square statistic was significant for this model, the chi-square difference test shows a significant improvement, and the values of CFI (0.954), RMSEA (0.042) and SRMR (0.049) are all within the limits for a good model fit as discussed in section 4.3.

Table 13 Nested Model Fit

Fit Statistics		Maximum Likelihood (ML) Estimation				
		1 Factor Model	3 factor Model (EVT, HRT, NAT)	5 factor Model (2 EVT, 2 HRT, 1 NAT)	8 factor Model (2 EVT, 5 HRT, 1 NAT)	9 factor Model (2 EVT, 5 HRT, 2 NAT)
Chi-square	Statistic	1,038.0	526.3	473.1	398.1	370.5
	df	275	272	265	247	239
	p-value	0.0000	0.0000	0.0000	0.0000	0.0000
	Chi-square/ df	3.7744	1.9348	1.7853	1.6117	1.5502
RMSEA	Statistic	0.0938	0.0545	0.0499	0.0441	0.0418
90% confidence interval	lower	0.0878	0.0475	0.0426	0.0359	0.0333
	higher	0.1000	0.0614	0.0572	0.0519	0.0499
CFI (Bentler Comparative Fit Index)		0.7329	0.9110	0.9272	0.9471	0.9540
SRMR (Standardized root mean square residual)		0.0890	0.0578	0.0553	0.0517	0.0494
Chi-square difference test	Dif Chi^2	667.5	155.8	102.6	27.6	reference for comparison
	Dif df	36	33	26	8	
	p-value	0.0000	0.0000	0.0000	0.0006	

One factor Model: Contains all variables on measurement (EVT), managing (HRT) and avoidance (NAT) together in one CFA model

Three factor Model: One factor for variables on measurement (EVT), a second factor on managing (HRT) and a third factor on avoidance (NAT)

Three factor Model: One factor for variables on anticipating extreme events, and another factor for variables for the ability to react to extreme events.

Five factor Model: Two factors for variables on measuring extreme events, EVT (general quantitative management and advanced modeling capabilities), and two factors for management, HRT (anticipating and reacting to extreme events) and one factor for avoidance, NAT.

Eight factor CFA Model: Two factors for variables on measuring extreme events, EVT (general quantitative management and advanced modeling capabilities), Five factors for management, HRT differentiating each of the five dimensions or organizational mindfulness: preoccupation with failure, reluctance to simplify, sensitivity to operations, commitment to resilience, and deference to expertise, and one factor for avoidance, NAT.

Nine factor CFA Model: Two factors for variables on measuring extreme events, EVT (general quantitative management and advanced modeling capabilities), Five factors for management, HRT differentiating each of the five dimensions or organizational mindfulness: preoccupation with failure, reluctance to simplify, sensitivity to operations, commitment to resilience, and deference to expertise, and two factor for avoidance, NAT (complexity and tight couplling).

As can be seen from table 14, the standardized factor loadings were all significant (*p*-value <0.001), and all but 3 variables present standardized factor loadings above 0.5, confirming the convergent validity of the scales. However, as can be seen in table 15, the average variance extracted (AVE) is not above 0.5 for all constructs, implying that in some of the constructs more variance is explained by the error terms than by the common factor.

Table 14 CFA Factor Loadings

Theoretical Paradigm	Factor	Variable	Standardized Factor Loading	P-value	Standardized Error	Non standardized factor loading
Extreme Value Theory	General quantitative approach	EVT0.1APL	0.7089	0.0000	0.4974	1.0000
		EVT0.2APL	0.6906	0.0000	0.5231	0.8752
		EVT0.3APL	0.7406	0.0000	0.4514	1.0723
	Advanced modeling capabilities	EVT1.3APL	0.7169	0.0000	0.4860	1.0000
		EVT3.3APL	0.7853	0.0000	0.3832	1.1733
		EVT3.5APL	0.7054	0.0000	0.5024	1.0994
Normal Accident Theory	Complexity of interactions	NAT1.2APL	0.7911	0.0000	0.3741	1.0000
		NAT1.4APL	0.6467	0.0000	0.5817	0.8572
	Tight coupling of operations	NAT2.4APL	0.6273	0.0000	0.6065	1.0000
		NAT2.6APL	0.7403	0.0000	0.4519	1.2290
High Reliability Theory	Preoccupation with failure	HRTANT_5_1APL	0.3119	0.0000	0.9027	1.0000
		HRTANT_5_4APL	0.2857	0.0000	0.9184	0.8602
		HRTANT_5_8APL	0.7813	0.0000	0.3896	3.1063
	Reluctance to simplify	HRTANT_6_1APL	0.7268	0.0000	0.4718	1.0000
		HRTANT_6_5APL	0.6983	0.0000	0.5123	0.8820
		HRTANT_6_7APL	0.7463	0.0000	0.4430	1.1028
	Sensitivity to operations	HRTANT_7_1APL	0.6674	0.0000	0.5546	1.0000
		HRTANT_7_4_APL	0.6642	0.0000	0.5589	0.8620
		HRTANT_7_8APL	0.6392	0.0000	0.5914	0.8335
	Commitment to resilience	HRTCON_8_2APL	0.6040	0.0000	0.6351	1.0000
		HRTCON_8_8APL	0.3755	0.0000	0.8590	0.6832
		HRTCON_8_9APL	0.6524	0.0000	0.5744	0.9224
	Deference to expertise	HRTCON_9_3APL	0.7332	0.0000	0.4624	1.0000
		HRTCON_9_4APL	0.6964	0.0000	0.5151	1.0573
		HRTCON_9_8APL	0.7788	0.0000	0.3935	1.1389

In terms of reliability, it can be seen from table 15 that 4 out of 9 of the first order factors for EVT, NAT, and HRT reach acceptable levels with Cronbach's alpha and McDonalds omega above 0.7, but the remainder are below this threshold. This changes however for the second order constructs for EVT, NAT and HRT that reach levels of 0.78, 0.69 and 0.88 respectively for McDonald's omega.

Table 15 CFA Reliability

	Extreme Value Theory		Normal Accident Theory		High Reliability Theory				
	General quantitative approach EVT_1	Advanced modeling capabilities EVT_2	Complexity of interactions NAT_1	Tight coupling of operations NAT_2	Preoccupa-tion with failure HRT_1	Reluctance to simplify HRT_2	Sensitivity to operations HRT_3	Commit-ment to resilience HRT_4	Deference to expertise HRT_5
Cronbach's alpha	0.7562	0.7790	0.6764	0.6339	0.4512	0.7664	0.6923	0.5342	0.7747
McDonald's omega	0.7578	0.7800	0.6805	0.6406	0.5093	0.7689	0.6948	0.5422	0.7795
Average Variance Extracted (AVE)	0.5123	0.5427	0.5172	0.4739	0.3240	0.5279	0.4330	0.2879	0.5417
McDonald's omega for the second order factor	0.7906		0.6896		0.8766				

Structural submodel

After the measurement submodel, I present the results of the second stage of the procedure for theory testing, consisting of the structural submodel, where a linear regression is added to the latent constructs that have been confirmed in the first stage. When estimating a joint structural model for all of the 9 dimensions (2 for EVT, 2 for NAT and 5 for HRT) none of these reach significant *p*-value levels and it is therefore discarded that each of the dimensions separately can explain better preparation for extreme events.

However, as could be seen from the EFA, the latent factors within each paradigm are clearly interrelated, while remaining distinct from the constructs of the other theoretical paradigms. Based on this distinction, I follow Koufteros et al. (2009) and develop a second-order model to hierarchically group the EVT constructs into one second-order construct, the NAT constructs in another second-order construct and finally the 5 dimensions of HRT into another second order construct.

In this case all three paradigms have to be assumed to be independent of each other, which is a reasonable assumption, taking into account that each of these paradigms is associated with a different possibility to address extreme events (measurement, management, avoidance) that can and has been implemented independently. The model reaches an acceptable model fit (Chi^2=626.7; Chi^2/df=2.30; RMSEA=0.06; CFI=0.875; SRMR=0.085).

In table 16 the path regression coefficients are shown, and it can be seen that all are significant with *p*-values below 0.05 for HRT, for NAT it is less than 0.01 and for EVT it is less than 0.001.

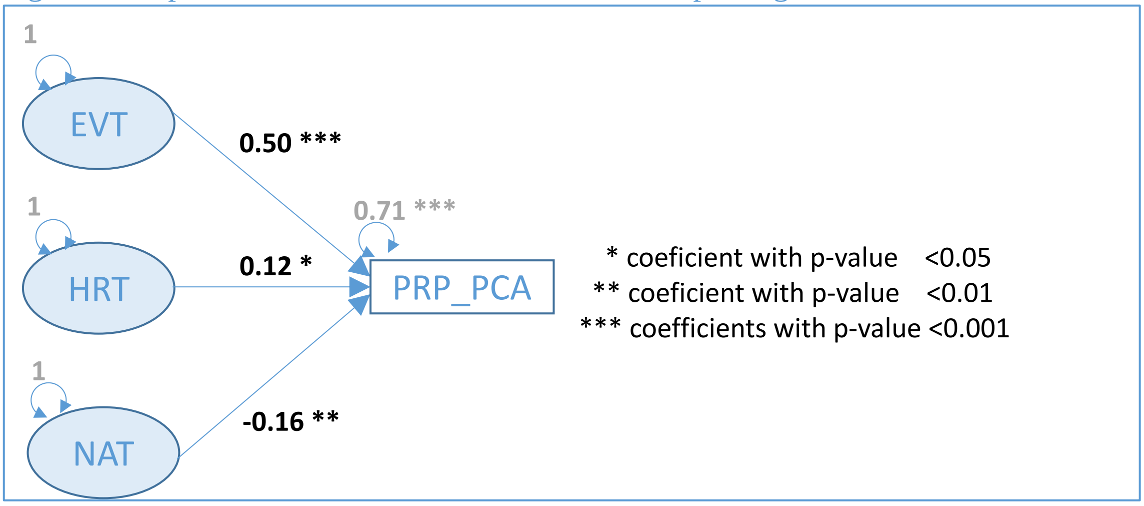
Table 16 SEM path coefficients for all three theoretical paradigms

Factor	Standardized regression coefficient	P-value	Non standardized regression coefficient
EVT 2nd order factor	0.4968	0.0000	0.8001
NAT 2nd order factor	-0.1589	0.0079	-0.1747
HRT 2nd order factor	0.1234	0.0169	0.4146

These numbers confirm hypotheses 3 and 13 where it was indicated that EVT and HRT are associated with better preparation for extreme events. The negative path coefficient in NAT also confirms hypothesis 10 where it was indicated that a higher level of complexity and tight coupling is associated with less preparation for extreme events.

From this analysis it can be seen that EVT, which symbolizes the focus on measurement, has the largest standardized regression coefficient. This indicates that the EVT framework is currently the dominant approach for addressing extreme events in the financial sector. Graphically, this is represented in figure 9.

Figure 9 Simplified SEM Plot for all three theoretical paradigms



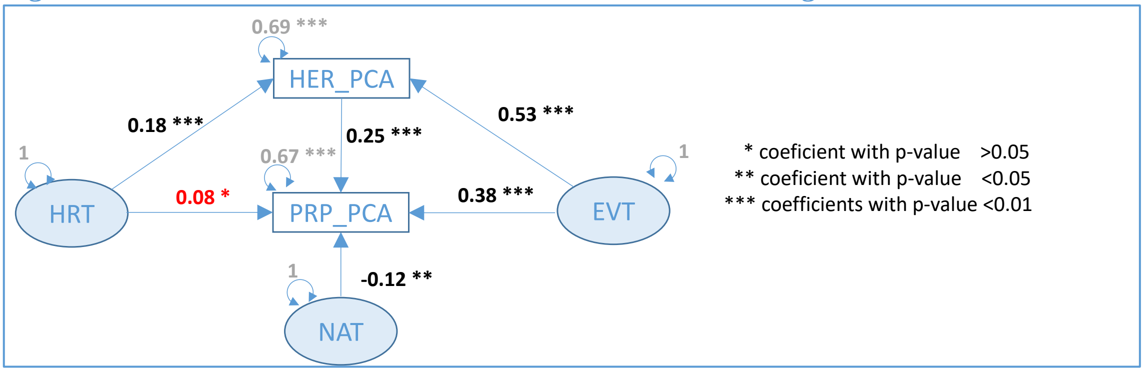
Source: author's own elaboration.

7.4. Mediation and moderation effects

In line with hypothesis 7 and 16, I also test a model that includes the principal component factor of tools for different phases of an extreme event, as a mediator factor between the

EVT and the HRT paradigm. I performed a Sobel test on the significance of the mediation effects (EVT: Z-value 3.93 with *p*-value <0.001 and HRT: Z-value 2.69 with *p*-value <0.01). As can be seen in figure 10, there is a significant path between the tools and the preparation for extreme events. The standardized path coefficient between EVT and preparation for extreme events maintains significant, but 23% lower than in the non-mediated model, implying there is partial mediation. On the other hand, the direct path from HRT to preparation for extreme events ceases to be significant at a level below 0.05, implying full mediation for the tools for different phases of extreme events (Baron & Kenny, 1986).

Figure 10 SEM Plot for the mediator effect for tools for dealing with extreme events



Source: author's own elaboration.

It is important to note, however, that this finding seems self-evident. This is due to the fact that the application of EVT requires the use of specialized tools designed to measure extreme events. Similarly, the application of HRT requires the use of tools tailored to different phases of an extreme event to ensure its effective management.

In hypothesis 4 it was stated that the understanding of risk models (MOD_UND) moderates the effectiveness of the EVT paradigm. This was operationalized with an interaction factor between the EVT variables and the understanding of risk models (coded as EVT*MOD_UND). As can be seen from table 17, this moderation effect is significant (with a *p*-value <0.05), implying that higher understanding of risk models is associated with better preparation for extreme events using the EVT paradigm.

In line with hypothesis 5 and 14, I also evaluated moderation of the possibility of an extreme event (POS_PCA) by creating interaction factors on both the EVT and the HRT paradigm (coded as EVT*POS_PCA and HRT*POS_PCA respectively) but these factors did not reach acceptable *p*-value levels, and therefore these hypotheses are not accepted. In line with hypothesis 6 and 15, I also evaluated moderation of the size of a financial institution (SIZE) by creating interaction factors on both the EVT and the HRT paradigm (coded as EVT*SIZE and HRT*SIZE respectively)[4]. Also in this case these factors did not reach acceptable *p*-value levels, and therefore these hypotheses are not accepted. The coefficients and *p*-values can be seen in table 17 and in figure 11 the complete SEM model plot with its standardized regression coefficients and *p*-values is shown.

Table 17 SEM path coefficients for the moderation factors

Factor	Standardized regression coefficient	P-value	Non standardized regression coefficient
EVT 2nd order factor	0.4855	0.0000	0.7543
NAT 2nd order factor	-0.1917	0.0019	-0.2356
HRT 2nd order factor	0.1519	0.0049	0.5162
EVT*MOD_UND	0.1253	0.0256	0.2498
EVT*POS_PCA	0.0383	0.7050	0.0664
EVT*SIZE	-0.1786	0.0553	-0.5800
HRT*POS_PCA	0.0214	0.8109	0.2397
HRT*SIZE	0.1500	0.0709	0.9523

EVT*MOD_UND: Residuals-centered interaction factor between the current understanding of risk models, coded as EVT_1.1APL with each of the variables for current application of Extreme Value Theory.

EVT*POS_PCA: Residuals-centered interaction factor between the principal component factor of the possibility of an extreme event, coded as POS_PCA with each of the variables for current application of Extreme Value Theory.

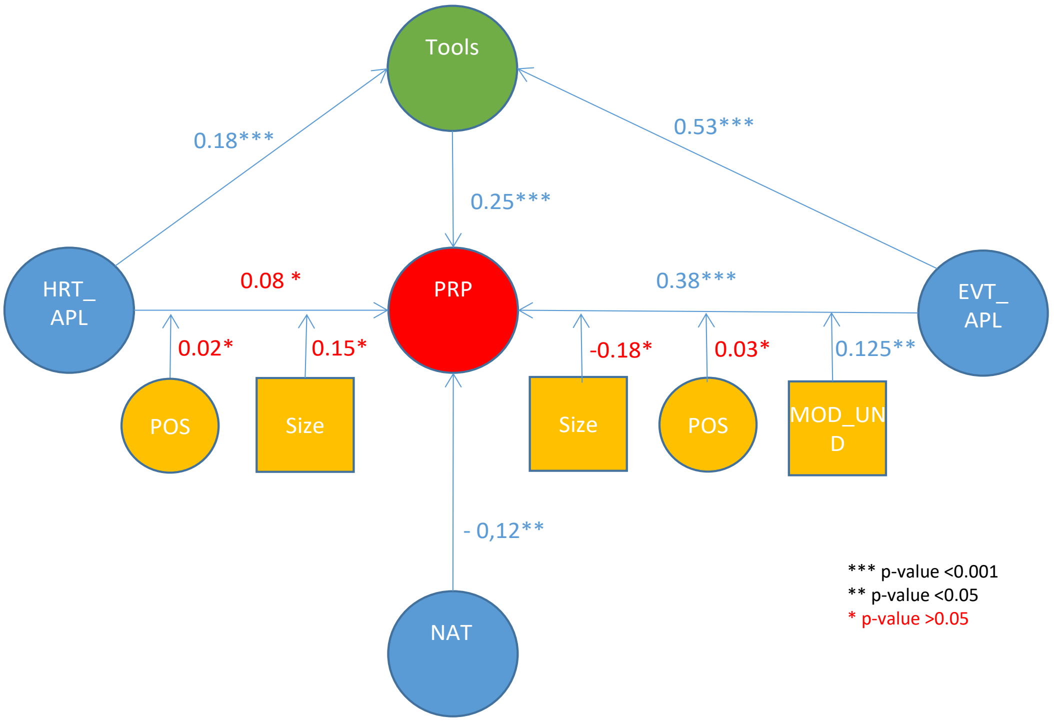
EVT*SIZE: Residuals-centered interaction factor between the size of the bank (assigning the value 1 to banks with total assets of over 500 billion and 0 for those with total assets under 500 billion) with each of the variables for current application of Extreme Value Theory.

HRT*POS_PCA: Residuals-centered interaction factor between the principal component factor of the possibility of an extreme event, coded as POS_PCA with each of the variables for current application of High Reliability Theory.

HRT*SIZE: Residuals-centered interaction factor between the size of the bank (assigning the value 1 to banks with total assets of over 500 billion and 0 for those with total assets under 500 billion) with each of the variables for current application of High Reliability Theory.

[4] It should also be taken into account that the Spanish financial sector is highly concentrated and this is reflected in the profile of the sampled population, where 86% work for institutions that are larger than 500 billion€.

Figure 11 Complete SEM Plot



EVT_APL:	Current perceived application of EVT	NAT:	Current applicaton of Normal Accident Theory
MOD_UND:	Undertanding of risk models	HRT_APL:	Current perceived application of HRT
Size:	Size of the financial institution	POS:	Possibility of an extreme event ocurring
Tools:	Tools for managing different phases of extr. events	PRP:	Preparation for extreme events

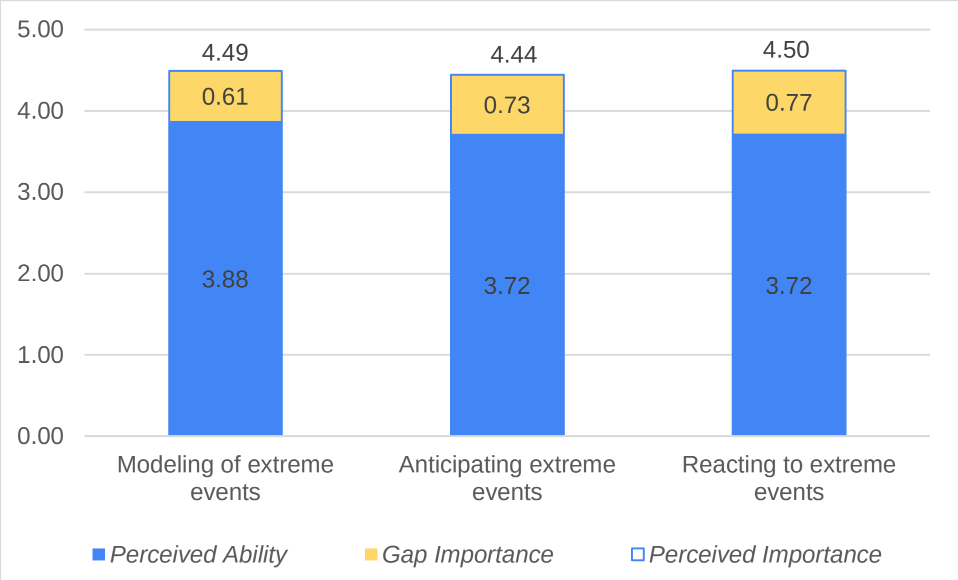
Source: author's own elaboration.

7.5. Gap Analysis

Given that I have asked financial sector participants for their perception of the importance of each of the variables on the current application of EVT, NAT and HRT, a gap analysis can be performed to explore the difference between perceived importance and perceived application.

In figure 12, the average perceived ability of the capability to model extreme events is matched with the average perceived importance of this ability, and this gap is compared with the gap between the perceived ability to anticipate extreme events vis-à-vis its importance and the gap between the perceived ability to react to extreme events in relation to its importance.

Figure 12 Gap between importance and ability for EVT and HRT



First of all, this analysis confirms Hypothesis 17 that states that there is a gap between the current application of the Extreme Value Theory construct, compared to its optimal level of application (t test result=14.031 with *p*-value <0.001). Hypothesis 18, that states that the current application of organizational mindfulness in the financial sector is lower than the optimal level, as expressed in the items for anticipating and reacting to extreme events is also confirmed (t test result=19.460 with *p*-value <0.001).

Furthermore, it can also be seen that the gap in the items of HRT (anticipating extreme events and reacting to extreme events) is significantly larger than the average gap for the items concerning EVT for modeling of extreme events (gap for HRT=0.745 and gap for EVT=0.614 with t test result for difference=3.435 with *p*-value <0.01), implying more should be done to implement organizational mindfulness in the financial sector.

While 48% of respondents do not perceive a gap between actual application and importance of modeling capabilities, and 4% perceive its importance to be below actual application, in the items of HRT for anticipating and reacting to extreme events, a majority (54% and 56% respectively) perceive that these factors are more important than implied by their current application in the financial sector.

8 Discussion

The main goal of this research was to assess whether three alternative theories for managing extreme events are perceived as applicable in the financial sector, and if their implementation is associated with improved preparation for such events. These three theories symbolize efforts to effectively measure, manage, or avoid extreme events.

In this section, I will first discuss the theoretical implications of the empirical research findings on each of the three theories of Extreme Value Theory, Normal Accident Theory and High Reliability Theory. Subsequently, I will discuss the research findings in terms of the lessons these theories can offer for business management, both within the banking sector and beyond.

8.1. Theoretical Implications

Recent academic literature has devoted considerable attention to crises, unexpected and extreme events, and uncertainty. The global financial crisis marked a turning point for the financial sector. Since then, many proposed measures to enhance financial stability and resilience have been implemented, driven largely by supervisory actions and regulatory reforms, but also by an increased awareness among banking institutions of their vulnerabilities. This can be seen in the survey responses of this research, where a majority notes improvements in the financial sector, both in models in use and in the capacity of banks to anticipate and react adequately to extreme events.

There is also a generalized view among the respondents that in the medium term, new extreme events will unfold. However, no generalized consensus can be found on the kind of event that can have an impact on the financial sector institutions, with a large majority viewing the plausibility of a new financial crisis or a major cybersecurity related event occurring, but many respondents also focused on climate change related events, or an impact due to a technological innovation. Over 12% of respondents state other kinds of extreme events that might happen, and predominantly mention pandemics, and geopolitical events.

Extreme Value Theory

Academic research on the first of these theories, Extreme Value Theory, has centered on developing statistical tools for better measurement of extreme events on the one hand, and on ex-post applications of these models to historical databases (both financial and non-financial data), where it was demonstrated that use of EVT methodology would have led to better prediction and pricing of extreme events, compared to use of other types of models (for instance Beirlant et al., 2016; Szubzda & Chlebus, 2019; Alsunbul, 2024).

In this research, I have not examined empirically the effect of EVT on financial outcomes, unlike in previous studies. Instead, I adopted a prospective approach based on the sector-wide perception of preparedness for extreme events.

To be able to effectively measure, manage, or avoid extreme events, highly specialized functions are required. The survey that was performed was specifically targeted towards individuals with these specialized skills in domains such as risk management, compliance, auditing, technology, and finance. Despite the level of specialization of the surveyed population, there was no possibility to survey on even more specialized characteristics of the elements of Extreme Value Theory. Only very general aspects of EVT were surveyed, such as use of tipping points (Sornette, 2009), or modeling complex adaptive networks (Haldane, 2012), or capturing tail risk (Rocco, 2014). Nevertheless, even on these general characteristics, between 22% and 34% of respondents provided a neutral answer, potentially indicating their unfamiliarity with the subject to be able to form an opinion. Therefore, it was not feasible to survey on more specific methodological aspects regarding the characteristics and use of EVT.

For this reason, the focus of this research has been more on a general approach to measuring risks as symbolized by the Extreme Value Theory. As evidenced by the survey results, quantitative risk management methods remain the most commonly used approach for addressing extreme events in the financial sector, and models are perceived to be essential tools for decision making, although these tools may not be able to calculate the probability of an extreme event occurring, and a large proportion of respondents indicated that the models that are being used in their bank are not adequately understood at all levels.

Despite all the regulatory changes that have taken place in the financial sector since the onset of the global financial crisis, the methodology for calculation of capital requirements that are designed to cover unexpected losses has not changed, and still relies on the same normal distribution model (Gordy, 2003). Many additional buffers have been implemented to increase the capital requirements of banks (this can be appreciated for instance at the European level, where the average CET1-level has increased almost a quarter from 12.77% in Q3 2015, to 15.73% in Q4, 2023[5]), but the foundation is still a model that has proven faulty. At the level of Central Banks, many studies have been published on the virtues and advantages of extreme value modeling for specific purposes (see for instance, Rocco, 2014 or Heinz & Rusinova, 2015), but these models have not been incorporated in the official measurements of capital requirements of financial institutions.

The surveyed financial sector experts emphasized the critical significance of risk models and quantitative tools capable of capturing tail risks, deeming their importance even greater than what is reflected by their current implementation. This strongly advocates for the wider implementation of extreme value theory tools for modeling the tail, and only the tail, of probability distributions being used for the quantification of risks in financial sector entities.

In this survey, the understanding of risk models was found to be a significant moderator factor for application of Extreme Value Theory, with a lower understanding associated with a lower level of preparation for extreme events. This kind of warning is not typically found in more technical academic research. However, a more generalist paper stresses the importance that an internal model "[…] *has to be* ***fully understood****; there is no room for black box magic*" (Embrechts, 2017, p. 8. Emphasis from the original paper).

Normal Accident Theory

Normal Accident theory (NAT) was developed with tightly coupled and highly complex industrial processes in mind. In these environments, according to the theory, accidents may happen with fatal consequences that cannot be prevented. As was shown in the survey, to a certain level, this also applies to the financial sector as perceived by the surveyed experts. However, the factor of time does not seem to play such a large role, and the experts largely disagree with the statement that there is no room to maneuver once an

[5] https://data.ecb.europa.eu/main-figures/supervisory-banking-data/capital-adequacy-and-leverage, consulted the 5th of June, 2024. The Common Equity Tier 1 ratio expresses the measure for the banks' highest quality own funds compared to their risk weighted assets in the Euro Area Banks.

extreme event commences. They also do not show a great level of agreement on the possibility that errors in one bank might spread to the entire sector. These findings contradict those of Min and Borch (2022), but it should be taken into account that the sector these authors analyzed was a very specific part of the financial sector focused on algorithmic trading, while my research focused on the Spanish banking sector as a whole, which largely consists of organizations dedicated to traditional retail and commercial banking activities.

To avoid fatal accidents from happening, Normal Accident Theory focuses on limiting the size of organizations and improving regulation. Palmer and Maher (2010), in their analysis of the global financial crisis, also emphasize the role regulation should play to avoid the impacts of extreme events. In this survey, there is large agreement on the importance of regulation, even though since the publication of the article by Palmer and Maher (2010), fourteen years have passed, and in these years, the level of regulation has not ceased to increase. Another interesting finding of this research is that respondents perceive that ever larger banks may suffer more if an extreme event occurs. This is in line with NAT, but contrary to the trend of banking consolidation during the years following the financial crisis. Banks are increasingly compelled to expand their income base in order to be able to fund the necessary technology investments and to manage the expenses of compliance with the rising regulatory burden (Eichengreen, 2023). This trend calls for heightened vigilance on the potential impact of any future extreme events.

High Reliability Theory

Some of the characteristics of High Reliability Organizations, which are able to consistently operate in complex, high-hazard environments while maintaining a high level of safety, may perfectly apply to a banking organization. One of the most interesting recommendations of HRT and the broader academic literature on crisis management (see for instance Hällgren et al., 2018) is that organizations are capable of operating in various modes depending on their surrounding conditions. During the global financial crisis in the bank where I was working, this was very noticeable: while before the crisis, decisions were taken in a highly bureaucratic and hierarchical manner, once the crisis hit, a large amount of discretion was granted to lower-level employees, for instance, to negotiate refinancing and restructuring deals with troubled clients. However, nobody had ever practiced working in such a situation, and no predefined emergency plans existed.

Weick and Sutcliffe (2001, 2007, 2015) argue that organizational mindfulness enables high reliability organizations to operate in a nearly error-free manner, enhancing their ability to anticipate and address potential issues swiftly. Organizational mindfulness consists of 5 dimensions: preoccupation with failure, reluctance to simplify interpretations, sensitivity to operations, commitment to resilience, and deference to expertise. For the survey, a scale that had been validated in business schools was employed (Ray et al., 2011), but reduced from the original 43 items to 15 items, three for each of the dimensions of organizational mindfulness. The results of the survey show that each of these dimensions can be observed, but that they are clearly interrelated within the overall organizational mindfulness construct.

Surprisingly, the aspect of preoccupation with potential failure came out as the least significant of these dimensions in the financial sector, both in terms of current application as well as perceived importance (it should be noted that no model was tested on the perceived importance of each of these dimensions). This might indicate a tendency towards complacency in the financial sector, and is an issue that should be addressed.

The survey assessed the dimension of reluctance to simplify by including items that measured the extent to which issues are analyzed in depth or are taken for granted. The results indicated that a majority of respondents currently perceive analytical rigor and critical thinking to be prevalent at their organizations. Moreover, an even larger majority emphasized the critical importance of fostering such behavior in banks.

For banking organizations, the cultivation of internal skepticism and a rigorous scrutiny of the decisions that are being made, is of paramount importance. Regulators and banking supervisors are aware of the relevance of promoting checks and balances within the organization itself, and guidelines such as those published by the Basel Committee (BIS, 2015) prove this by expecting banks to officially implement organizational structures such as the three lines of defense, each independent from each other, to be able to challenge risk decisions.

The dimension of sensitivity to operations was considered less important in a banking organization compared to the findings from the case studies on high-reliability organizations. This may be attributed to absence of immediate peril for loss of human life in a banking organization. Additionally, as was previously discussed in relation to Normal Accident Theory, time is not deemed critically important in this context. A retail or commercial banking organization does not operate in an environment where crucial decisions have to be made in a split second. Probably a survey focused exclusively on risk, compliance and audit officers working for the areas of financial markets within large banking organizations would have drawn more attention to close surveillance of daily operations. However, it is important that both top management and the support functions maintain close contact with the front line that is in direct contact with clients in order to know what is going on and to be able to define solutions to problems brought up by the front line operators. It is also important to highlight the importance for both individual and collective awareness on what is happening, and to promote adherence to the established procedures and norms in a critical and constructive way.

The fourth dimension of HRT is the commitment to resilience. One of the key elements of this commitment in the HRT literature is the existence of informal contacts that facilitate the rapid pooling of talents to find solutions to problems as they arise (Weick et al., 1999, p.101). In this survey, respondents recognized the value of informal contacts not only for their benefits, but they also acknowledged the potential drawbacks of these informal contacts. Specifically, this suggests that respondents emphasized the view that entrenched and exclusive networks, often characterized by longstanding personal relationships, may stifle innovation and suppress dissenting voices. In contrast, the informal networks that are promoted in the academic literature on organizational mindfulness, are of a different kind, promoting cross-functional collaboration, learning, and knowledge sharing.

Within this same dimension of resilience, the importance of training, and of learning from mistakes was acknowledged for preparation for extreme events. This is in line with HRT theory and should be put in practice to enable timely reaction to emerging situations.

The fifth dimension of deference to experience was perceived as having one of the lowest levels of current application. This contrasts with the high importance that respondents place on the ability to identify the relevant expertise in unexpected situations, as well as the prioritization of knowledge and expertise over hierarchical considerations within the organization. This discrepancy implies there is an opportunity for development on the aspect of deference to expertise in banking organizations.

While Ray, et al. (2011) found evidence of the existence of the five dimensions of organizational mindfulness in business schools, Eastburn (2018) found evidence for organizational mindfulness as a 2-dimension construct in US community banks, differentiating a construct for anticipating extreme events on the one hand, and containing extreme events on the other. In this research, the best model fit was found in a model that differentiates each of the five dimensions of organizational mindfulness into the broader organizational mindfulness construct as a second order model.

The Mindful Organizing Scale (MOS) developed by Vogus and Sutcliffe (2007) is a one-dimensional scale for a bottom-up approach to safety that has been widely used and applied in various empirical settings. The 5-dimension scale that was found in this research is a top-down approach towards implementing a culture of reliability in an organization. While the applications for the bottom-up approach have resulted most useful in high-hazard industries and areas such as healthcare, where serious hazards for human lives exist, the top-down approach, in line with the research by Ray et al. (2011) on business schools and this research on the financial sector, may be more useful for other kinds of sectors where risk of human casualties is not the main concern, but where unexpected or extreme events may occur that can put in danger the survival of the organization itself.

8.2. Managerial Implications

Risk management has always been vital for the functioning of the financial sector, and the quantitative risk management capabilities of banks have shown to be of great value in assessing risks, communicating internally and externally, and for making capital allocation decisions based on both risk and profitability. This has not changed after the financial crisis.

To use the terms that Nassim Taleb has made popular, models that describe the domain of "*Mediocristan*" —where phenomena obey to regular Gaussian probability distributions characterized by thin tails—serve as the foundation for the majority of the models employed by financial institutions. These models are appropriately suited for situations where no single observation can really modify the statistical properties when large samples are being used. On the other hand, in "*Extremistan*", where there is potential for a catastrophe or an extreme event, the tails play a disproportionately large role. Therefore, distinct statistical approaches and models should be used (Taleb, 2020, p. 22).

This is where Extreme Value Theory can and should play a more vital role, as was shown in this research to be the perception of the financial sector experts. During the last couple of years, we have gotten used to extreme and unexpected events such as the Covid-19 epidemic, or the invasion of Ukraine and its impact on energy prices,[6] or the sudden surge in inflation up to levels that had not be seen in rich world countries since at least three decades.[7] This may imply that this kind of extreme events enter regular "*Mediocristan"* models, but other kinds of extreme events that have taken place longer ago, such as the financial crisis that took place already 15 years ago, might not be considered in these models. Consequently, advanced quantitative models that focus on extreme events— the very kind for which preparedness is crucial —should assume a more vital role in the risk management tools of every financial institution. However, ever more complex models have their own model risk, and this research has clearly demonstrated the need for better understanding of the models that are being used. It is not enough for a quantitative specialist to master highly advanced statistical and mathematical models. An effort should be made to explain this kind of models, both to top managers who may make the ultimate decisions based on the results of these models, but also to middle managers, who may ask the right kind of questions on the hypotheses these models are built on and the practical implications of the assumptions that are being made. Just as it may be possible to construct advanced risk models and apply statistical methods that take into account extreme behavior, these models are still crude simplifications of reality. As indicated by Kay and King (2020), if the users of these models take them too literally, plug in invented numbers and base important decisions purely on the model outcome, these models "*become misleading, even dangerous"* (Kay & King, 2020, p. 309).

The use of quantitative risk management functions and advanced risk modeling capabilities is crucial for gaining insight into possible future outcomes. The importance lies not in the numerical output of these tools, such as a price, a probability, or a calculated loss. These outputs, even though they are derived from rigorous methodologies and based on large data sets, should not be the ultimate goal. Instead, they should serve as a source of inspiration, providing insight into how significant losses could come to occur, or how

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[6] https://www.ecb.europa.eu/press/economic-bulletin/focus/2022/html/ecb.ebbox202204_01~68ef3c3dc6.en.html
[7] https://www.economist.com/finance-and-economics/2022/04/22/does-high-inflation-matter

different scenarios might unfold. This enables us to identify which outcomes should be avoided at all cost.

But apart from a quantitative risk management function, in this research it was shown that a managerial approach for anticipating and containing extreme events is a very necessary element of the toolkit of every financial institution. Both the academic and professional literature have extensively focused on the concept of resilience. The High Reliability approach for organizational mindfulness includes this concept, and it is considered important. Nonetheless, the other dimensions of organizational mindfulness are equally important, particularly the dimensions of reluctance to simplify, and sensitivity to operations. Additionally, the dimensions of deference to experience and, to a lesser degree, preoccupation with failure are also significant.

This last dimension, preoccupation with failure, was demonstrated in the research to be perceived as the least important dimension. It has been shown by some scholars, notably Rerup (2005), that several of the aspects of this dimension might come at a cost, such as for instance undermining the bold optimism needed for thinking big, entering new markets or developing new products. It is here that each organization should develop its own compensating forces, creating tension and fostering skepticism, while at the same time driving innovation and encouraging growth. It is important for organizations to exhibit a positive mindset and optimism; however, it is equally important to maintain a level of suspicion, and consider all that may not go well, even though not exclusively.

As shown in this research, there is a larger perceived gap between current implementation of HRT related aspects and their perceived importance, than the gap between current implementation of EVT related aspects and their perceived importance. Therefore, specific organizational programs should be put in place to promote aspects of organizational mindfulness in the organization. At each level of the organization (operating level, middle management, top management, and board of directors) there should be compensating forces: on the one hand “growth driven”, and on the other “mindfulness driven”.

After the global financial crisis, a lot of effort was put into improving the role of the board of directors and the role of risk management within financial institutions. For instance, in 2013 the reviewed Capital Requirements Directive was approved at the European level (2013/36/EU), where article 76 indicates that “*Institutions shall have robust governance* *arrangements, which include a clear organisational structure with well defined, transparent and consistent lines of responsibility, effective processes to identify, manage, monitor and report the risks they are or might be exposed to*".

In the light of the results of this research, these governance principles focusing on structures and processes, should be complemented with the principles of HRT on the *mindset* of the people working in the organization, and with the *mindfulness* at the organizational level itself. Several of the items that were seen as very important, such as "*I think it is essential for people in organizations to listen carefully and not dismiss anyone's opinions*" (coded as HRTANT_6_7IMP), and "*I think it is essential that organizations value knowledge and experience above the hierarchical rank*" (coded as HRTCON_9_4IMP), cannot be improved with the implementation of new external regulation, or internal norms and procedures. For these items to improve, changes in the corporate culture and values are required.

In 2015, the Basel Committee on Banking Supervision published the Corporate Governance principles for banks (BIS, 2015), where a model of three lines of defense was presented, consisting of the business line as the first line of defense, an independent risk management and compliance function as the second line of defense, and a third line of defense comprising the internal audit function that is independent of the first and second lines of defense.

Based on the finding of this thesis, each of these lines of defense should be complemented with specific HRT characteristics, of which the following points should be emphasized.

First, preoccupation with failure should be stimulated, promoting openness and alertness towards small mistakes or close calls.

Secondly, encouraging a reluctance to simplify at all levels, which implies urging people to listen carefully to different points of view, and promoting the performance of thorough analysis not only in the risk and compliance functions, but also in the business lines.

Thirdly, this implies improving the institution's sensitivity to operations, which primarily concerns the business line, but also implies that the second and third lines of defense should strive to approach the operational areas delving into the details of daily operations and being around when consulted, but all the while maintaining their independence.

In the fourth place, improving resilience entails recycling people at all levels and encourage assignments for employees outside their typical domain of expertise, in order to enhance the response repertoires, improve informal contacts within the large and complex organizations, which in turn may be useful in case something unexpected happens, and an organization must shift from operating in a normal mode to operating in a crisis mode.

Last but not least, deference to experience should be improved, by promoting flatter organizational structures, and by collecting and structuring information organization-wide on the specific competences, experience and expertise of all staff.

This study's findings suggest that respondents perceived the most plausible extreme event scenarios to be financial crises or cyber security incidents. Parallel to the standard practice of conducting fire drills and similar exercises to assess business continuity, it may be prudent to establish protocols to practice the occurrence of events such as a financial crisis or a cybersecurity related event on a regular basis to be able to swift with agility if the situation requires it.

There was a general opinion within the sampled population that improvements have been made in the financial sector, both for models to be able to account for another extreme event, and for capabilities for preparation and being resilient to the next extreme event to happen. Nonetheless, as can be seen both from recent developments, as well as from the sample perception, the complexity and interconnectedness of the financial sector has not diminished, strongly suggesting that the next extreme event may occur sooner than anticipated. If at all levels an organization is able to spot the small signals and make sense of what is going on, it stands in a good position. This entails exhibiting flexibility, and pivoting when required, while maintaining transparency regarding the strategies employed, the inherent risks and decisive actions taken. Under such conditions, the organizations may be better equipped to handle the next extreme event.

9 Conclusions

This research aimed to investigate strategies to improve the preparedness of financial sector organizations for potential future extreme events. To the best of my knowledge, this study presents the first joint empirical application of three theoretical paradigms for measurement, management or avoidance of extreme events in the banking sector, as symbolized by the Extreme Value Theory (EVT), High Reliability Theory (HRT) and Normal Accident Theory (NAT) respectively.

In this final chapter, I will first report the answers to the research questions together with a summary of the conclusions regarding the research hypotheses that were presented in more detail in chapter 7. Subsequently, the contributions of the research will be discussed, finishing with limitations and areas for further research.

9.1. Answers to the research questions

In the first place, and in line with the first research question, to assess if each of these theoretical frameworks discussed in this research can be identified as separate constructs in the financial sector, I performed an exploratory factor analysis and carried out an internal replication study by dividing the survey randomly into two subsamples. In each of these subsamples the variables for current application in the financial sector predominantly load into three separate factors (one for EVT, one for HRT and one for NAT), with 93% of the variables loading onto the same factor in each subsample and in 85% of the variables with equivalent factor loadings.

By means of a confirmatory factor analysis within the framework of structural equation modeling, I confirmed that a 3-dimension model separating EVT from NAT and from HRT has a significantly better fit than a CFA model where all variables load into the same factor. I performed a further confirmatory factor analysis, to assess if these theoretical frameworks should be represented as unidimensional or multidimensional constructs with a comparison of nested models.

It was observed that in Extreme Value Theory the dimension of a general quantitative approach to risk management could be differentiated from advanced modeling capabilities in the financial sector.

It was also confirmed that the model for High Reliability Theory that differentiates 5 dimensions of organizational mindfulness (preoccupation with failure, reluctance to simplify, sensitivity to operations, commitment to resilience, and deference to expertise) obtains a significantly better fit, although reliability for the individual dimensions is low.

Finally, when differentiating in the Normal Accident Theory between a factor for tight coupling of operations and another for high complexity the chi-square difference test showed a significantly better fit, although in this case, the reliability for each of these dimensions is low.

In line with the second research question, to assess if each of the three theories of EVT, NAT and HRT are associated with better preparation for extreme events, I performed a structural analysis on the retained measurement submodel.

It was found that Extreme Value Theory is associated with a higher perceived level of preparation for extreme events. In High Reliability Theory it was also found that a higher level of current application was associated with a higher perception of preparedness for extreme events, albeit with a lower standardized regression coefficient than for the EVT construct. Both in EVT and in HRT, the positive association with higher preparation is found in second order models, whereas none of the dimensions of EVT and HRT are significantly related to better preparation for extreme events when considered separately. For Normal Accident Theory a significant negative regression was found between higher current application of the aspects of this theory associated with a lower preparation for extreme events.

The third research question revolved around the most important aspects for achieving better preparedness for extreme events.

This was tested with a gap analysis on the difference between the perceived current application for extreme events and the perceived importance for each of these factors. Both in the case of EVT and in the case of HRT, it was seen that on average the factors were perceived to be more important than what is currently applied in the financial sector. However, it was seen that although on average the respondents indicated that currently the variables associated with EVT have a higher level of implementation than those associated with HRT, the importance for the variables of HRT were in general valued with a higher level of agreement, and a larger gap exists between importance and current application of HRT than of EVT. I performed a t-test with a *p*-value lower than 0.001 to confirm this hypothesis.

The variable that was valued as the most important factor was for "*I think it is essential that organizations can talk openly about problems, errors or failures*", coded as HRTANT_5_8IMP, and the largest gap between current application and perceived importance was for the following variables: "*I think it is essential that organizations value knowledge and experience above hierarchical rank*", coded as HRTCON_9_4IMP, and: "*I think it is essential for people in organizations to listen carefully and not dismiss anyone's opinions*", coded as HRTANT_6_7IMP.

The fourth research question focused on the main moderator and mediator factors that influence preparedness for extreme events. The only moderator effect identified as significant was for the understanding of risk models, with a higher understanding associated with better preparation for extreme events. The other moderator effects that were studied in this research were not found to be significant in this survey. On the other hand, the tools that the organization uses to face different phases of an extreme event were found to partially mediate the EVT construct and fully mediate the HRT construct.

In table 18, the summary of the hypotheses associated with each of the research questions is included.

Table 18 Summary of Research Hypotheses

Research Question	Hypo-thesis	Hypothesis	Test	Conclusion
1	1	○ EVT	EFA replication for two subsamples and CFA 3 dimension mode	Accepted
1	2	EVT=EVT0+EVT1 + EVT2	CFA. Chi-square difference test	Accepted
2	3	EVT↑→ PRP	SEM. Significant positive regression coefficient	Accepted
4	4	EVT* MOD_UND ↑ → PR	SEM. Significant interaction (moderator) factor	Accepted
4	5	EVT* POS_PCA ↓ → PRP	SEM. No Significant interaction (moderator) factor	Not Accepted
4	6	EVT* SIZE ↑ → PRP	SEM. No Significant interaction (moderator) factor	Not Accepted
4	7	EVT ↗↖ Tools → PRP	SEM. Sobel test. Partial mediation demonstrated	Accepted
1	8	○ NAT	EFA replication for two subsamples and CFA 3 dimension mode	Accepted
1	9	NAT= NAT1+NAT2	CFA. Chi-square difference test	Accepted
2	10	NAT ↓→ PRP	SEM. Significant negative regression coefficient	Accepted
1	11	○ HRT	EFA replication for two subsamples and CFA 3 dimension mode	Accepted
1	12	HRT=HRT1+HRT2+HRT3+H	CFA. Chi-square difference test	Accepted
2	13	HRT ↑→ PRP	SEM. Significant positive regression coefficient	Accepted
4	14	HRT* POS_PCA ↓ → PRP	SEM. No Significant interaction (moderator) factor	Not Accepted
4	15	HRT* SIZE ↑ → PRP	SEM. No Significant interaction (moderator) factor	Not Accepted
4	16	HRT ↗↖ HER → PRP	SEM. Sobel test. Mediation demonstrated	Accepted
3	17	EVT_IMP-EVT_APL > 0	T-test on difference	Accepted
3	18	HRT_IMP-HRT_APL > 0	T-test on difference	Accepted

EVT_0: Quantitative management of risks
EVT_1: Advanced capabilities for modeling beyond normal distribution
EVT_2: Understanding of risk models
NAT1: Complexity of interactions
NAT2: Tight coupling of operations
HRT1: Preoccupation with failure
HRT2: Reluctance to simplify
HRT3: Sensitivity to operations
HRT4: Commitment to resilience
HRT5: Deference to expertise
MOD_UND Interaction factor for the understanding of risk models with EVT
PRP: Principal Component of preparation of distinct types of extreme events
POS_PCA: Interaction factor for the possibilty of distinct types of extreme events
SIZE: Interaction factor for size, differentiation large (>500 B€) from other organizations
Tools: Principal Component of tools to deal with different phases of extreme events
EVT_IMP: Perceived importance of elements of EVT
HRT_IMP: Perceived importance of elements of HRT
EVT_APL: Perceived current application of elements of EVT
HRT_APL: Perceived current application of elements of HRT

RQ1: Can each of the frameworks of EVT, NAT and HRT be identified as separate theoretical constructs in the financial sector?
RQ2: As perceived by the expert practitioners in the financial sector, are each of the theoretical frameworks of EVT, NAT and HRT associated with better preparation of organizations for extreme events?
RQ3: As perceived by experts within the financial sector, what are the most important aspects for achieving better preparedness for extreme events?
RQ4: What are the moderator and mediator factors that influence the preparedness for extreme events?

9.2. Contributions to the academic literature

This research makes a significant contribution to the field of management and organization studies on extreme or unexpected events.

In the first place, I was able to validate a scale for measurement, management and avoidance of extreme events using elements from Extreme Value Theory, High Reliability Theory (implemented through Organizational Mindfulness) and Normal Accident Theory, where each of these three paradigms were identified as separate theoretical constructs. This opens up possibilities for use of these scales in related research in other sectors or in different geographical settings.

This was not the first time a scale was validated for the application of organizational mindfulness (see Ray et al., 2011 and Eastburn, 2011) but the scale had never been validated in the Spanish Financial sector. The scales for the other two theoretical paradigms were validated for the first time in any organizational setting.

In this study, a novel approach is taken to relate the theoretical frameworks with the perceived preparation for extreme events. While previous studies have tried to establish relationships with historical performance, the option taken in this research, although reflecting a subjective view, represents a forward looking manner of looking at preparation for extreme events, and is therefore not affected by common confounding factors that may have biased arbitrary or random impact effects associated with past extreme events.

The strength of the correlation between the EVT construct and preparation for extreme event confirms the importance of a quantitative approach towards risk assessment and decision making. This implies that incorporating the EVT construct to management research on crisis management and resilience is highly valuable.

As indicated in section 2, the financial sector has a long record on the use of quantitative approaches for risk management, and notwithstanding the criticism this approach received after the global financial crisis, it is still valued as the cornerstone for knowing what to expect. However, the moderator role of understanding of these models with lower understanding associated with less preparation, is an aspect that should be taken into account.

Even though EVT originates outside the financial sector, in the finance literature, the theory has mostly been applied to modeling of financial risk, especially market risk. In the survey I conducted, the scope was not limited to the possibility of a financial crisis. It also encompassed non-financial events including extreme events triggered by climate change, financial crime or market abuse, and cybersecurity events, showing its applicability in these domains.

As far as the contribution of this thesis to the Normal Accident Theory literature is concerned, to my understanding, this is the first research where the expert opinions of participants sector-wide have been collected and contrasted with the preparedness for extreme events. The finding that domain experts perceive the key characteristics of complexity of interactions and tight coupling of operations to be present at the sector-wide level in the financial sector, and that these are associated with lower preparedness for extreme events, offers additional empirical evidence to the analyses conducted on the characteristics of NAT in the financial sector by Mezias (1994), Palmer and Maher (2010) and Min and Borch (2022). These scholars arrived to this conclusion after conducting theoretical research in the first two studies, and performing a case study with one specific company in the financial sector in the third.

With regard to the contribution of this research to High Reliability Theory, this research showed that the five dimensions of organizational mindfulness apply as a scale within the financial sector. However, when these constructs are studied through a structural equation model to understand their influence on the preparation for extreme events, we find that individually, these dimensions are not significantly and positively associated with the preparation for extreme events as an outcome variable. Nevertheless, when these dimensions load into a second order construct for high reliability, this second order construct is positively associated with a better preparation for extreme events.

In contrast with the studies conducted on organizational mindfulness in business schools (Ray et al., 2011) and in community banks (Eastburn, 2018), which primarily concentrated on the perspectives of top management, the present research broadens the scope to encompass functional support areas such as risk management, finance, and compliance. Furthermore, by uniquely incorporating the perception of middle management and analysts besides top management, it provides a more comprehensive understanding of the subject matter and broadens the argument for policies, procedures and strategies to achieve organizational mindfulness in an organization.

Whereas previous research has focused on analyzing performance, mostly with mixed results, in this research the outcome of interest is the level of perceived preparation for extreme events, thereby emphasizing an aspect of prevention, not of past successes. Studies that have focused on historical performance may not have datasets large enough to be able to capture events that are unexpected, might happen only once every 1,000 years, or may never have taken place before. As indicated, the survey sample comprises people who specialize in risk mitigation, establishing a control environment, formulating procedures, and modeling, measuring and reporting. These roles, while crucial, are not primarily focused on directly enhancing the organization’s performance, but rather on preserving it.

9.3. Limitations

Even though the structural equation models described in section 7 show reasonable fit, there are several limitations of this research that should be disclosed.

First, the sample population. Because the contact data from the people that were approached for the questionnaire were obtained from my personal or work related contacts, a sample selection bias may have been incurred in by including a large percentage of persons from the same area of the author's expertise, experience, and employer. However, in one sense this was done deliberately, as the goal was to understand the perception of those persons in the financial sector most watchful or exposed to analysis of events that may have a negative impact on the organization.

Although the survey was conducted anonymously, there remains a possibility that respondents may have reported answers they deemed socially desirable, rather than reflecting their actual beliefs or experiences, due to the self-reported nature of the data. Nonetheless, the application of the Harman single-factor test to all variables reveals that the first factor accounts for only 19% of the variance, indicating that common method variance does not pose a concern in this dataset.

It should also be pointed out that, as a cross sectional study, the survey captures respondents' opinions in one point of time, and thereby does not track changes over time in the perception of the respondents, particularly in response to extreme events. Nonetheless, this study incorporates retrospective questions aimed at understanding how perceptions have changed since the financial crisis, which was a significant extreme event for the financial sector. This retrospective approach helps to mitigate the limitation of not tracking real-time changes by providing insights into how respondents perceive shifts in their situation after this major disruption.

The sample size is reasonable with 315 valid responses. However, both the number of questions asked and the number of estimated parameters was large if taken into account the accumulated parameters of the three theories (EVT, NAT, HRT). Kline (2023, p. 16) recommends using as a rule of thumb the N:q rule of sample size (N) vs model parameters that require statistical estimate (q). The retained 9 factor CFA model for the three theoretical paradigms together had 86 parameters. In Kline (2023) the recommended sample-size-to-parameter relation is established as a 20:1 relation. Applying this recommendation to this study with 315 valid responses, it can be seen that the model would not comply with this rule. This likely contributes to the fact that the *p*-value of the regression coefficient for HRT is above the 0.01 level, even though it remains significant, at below 0.05.

Even though the multi-dimensional models showed significantly better fit than the one-dimensional models, the factors of AVE, alfa and omega however were not very high. When evaluating each of the three theoretical paradigms separately, it can be seen that reliability improves.

The research results demonstrate that both advanced modeling capacities and organizational mindfulness may help prepare organizations for extreme events and also demonstrate that there is room for improvement in the application of both paradigms in the financial sector. However, the survey did not ask for methods on how both theories might best be implemented.

The objective of this research was to approach extreme events from three different points of view: measurement, management, and avoidance. For assessing each of these points of view, a representative theoretical framework was chosen. However, there may be other aspects of the organizational preparation for extreme events that were not specifically addressed in this research. Gephart et al. (2009) for instance, reference various socio-cultural theories of risk, including the cultural-symbolic approach, which examines cultural values and social norms in addressing risks; the risk society perspective, which highlights the growing awareness of risks and uncertainties in modern society; and the perspective of *governmentality*, which explores how risk is managed within the context of neoliberalism. These theories are described by them alongside High Reliability Theory and Normal Accident Theory, but they are not addressed in this thesis.

9.4. Areas for further research

Based on the academic contributions and limitations of this research, some areas for further research may be suggested.

In the first place, in this research, the only moderator effect that could be demonstrated was the factor of understanding of risk models for the effectiveness of preparation for extreme events by the EVT theory. Other moderator factors that were hypothesized were not always possible to demonstrate in a statistically significant manner, possibly due to characteristics of the sampled population or the methodology applied. Therefore, it may be interesting to apply the survey in other countries or with a larger sample, or apply the Process Macro (Hayes, 2015) instead of SEM for analyzing moderator and mediation effects.

On the other hand, it might be interesting to delve into the specific mathematical properties of Extreme Value Theory that are perceived as most useful for data science and analytics specialists in the risk management area or for quants working on financial models. This should be addressed with a very focused survey exclusively among these specialists and may pave the way for raising awareness of the possibilities of the modeling capacities to a broader public, once the key areas of focus are identified.

In the context of Normal Accident Theory, it might be interesting to develop and test a longer survey scale to investigate whether complexity and tight coupling can be identified with a more reliable scale in the financial sector. This may contribute to evaluate which of these factors has a stronger impact on the preparation for extreme events.

In the context of High Reliability Theory, now that the interrelated 5-dimensional organizational mindfulness model was seen to apply in the Spanish Banking sector, it might be interesting to analyze whether the same applies outside Spain. Another possible research topic may be on the ways each of the different dimensions of organizational mindfulness may be encouraged in a banking organization for better preparation for extreme events and how they may be integrated into risk management practices. A third research topic may be to test the applicability of mindful organizing, as a bottom-up approach, in contrast to the more top-down approach of organizational mindfulness.

This research has been involved basically with extreme events, which were defined in chapter 2 to be events with a low probability and large consequences, be it a perfect storm or a black swan. While both of these types may occur and be unbearable for a bank, there may be other kinds of events that build up very slowly, without anyone noticing them, or where nobody takes action until nothing can be done anymore and the consequences are devastating. Take for instance the policies of extending and pretending that were followed in the Greek sovereign debt crisis (Tooze, 2018a). It may be interesting to dig deeper into ways on how to specifically identify if a crisis of this sort is slowly building up, and how bold action may be taken from an early point to avoid worse, but also on how to avoid overreacting to other kinds of small incidents that may not have any relevance.

This might be particularly relevant to test in the financial sector, where the stakes may not involve direct risks to human lives, yet the very survival of the banking institutions is undeniably at stake. This research has identified possibilities for further study on this topic which is crucial not only for banking organizations, but also for the broader economy.

In the future, it is inevitable that new and surprising extreme events will arise. Therefore, it is essential that banks devote efforts to plan for worst-case scenarios, striving to measure, manage and avoid the impacts of extreme events: At the same time, banks must effectively manage daily circumstances to ensure ongoing profitability and stability.

Uncertainty and unpredictability is what makes the landscape dynamic and engaging. While it is crucial to measure, manage and try to avoid the worst, an important element of luck will always remain. Extreme circumstances can also lead to extreme opportunities.

References:

Academy of Management (1995). The academy of management code of ethical conduct. *Academy of Management Journal, 38(2)*, 573-577.

Ahmed, H. (2021). Extreme value theory in a nutshell with various applications. *Towards Data Science*, https://towardsdatascience.com/extreme-value-theory-in-a-nutshell-with-various-applications-3260b6a84316

Allen, F., & Santomero, A. M. (1997). The theory of financial intermediation. *Journal of Banking & Finance*, *21*(11-12), 1461-1485.

Allendesalazar, P. (2019). El tribunal de cuentas eleva el coste público del rescate a 45.344 millones. *El Periódico*, https://www.elperiodico.com/es/economia/20191205/tribunal-cuentas-eleva-rescate-bancario-44344-millones-7764187

Alsunbul, S., Alzugaiby, B., Chaudhry, S., & Boujlil, R. (2024). The fatter the tail, the shorter the sail. *Accounting and Finance (Parkville), 64(1)*, 331-380.

Anderson, J. C., & Gerbing, D. W. (1988). Structural equation modeling in practice. *Psychological Bulletin*, *103*(3), 411-423.

Andriani, P., & Mckelvey, B. (2011). Managing in a Pareto world calls for new thinking. *M@n@gement*, *14*(2), 89.

Åsljung, D., Nilsson, J., & Fredriksson, J. (2017). Using extreme value theory for vehicle level safety validation and implications for autonomous vehicles. *IEEE Transactions on Intelligent Vehicles*, *2*(4), 288-297.

Ausserhofer, D., Schubert, M., Blegen, M., De Geest, S., & Schwendimann, R. (2013). Validity and reliability on three European language versions of the safety organizing scale. *International Journal for Quality in Health Care, 25*(2), 157-166.

Aven, T., & Krohn, B. S. (2014). A new perspective on how to understand, assess and manage risk and the unforeseen. *Reliability Engineering & System Safety, 121*, 1-10.

Baron, R. M., & Kenny, D. A. (1986). The moderator–mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations. *Journal of Personality and Social Psychology, 51*(6), 1173.

Barton, M. A., & Sutcliffe, K. M. (2009). Overcoming dysfunctional momentum: Organizational safety as a social achievement. *Human Relations, 62*(9), 1327-1356.

Basel Committee on Banking Supervision. (1988). *International Convergence of Capital Measurement and Capital Standards*. Bank for International Settlements (Basel I).

Basel Committee on Banking Supervision. (2004). *International Convergence of Capital Measurement and Capital Standards*. Bank for International Settlements (Basel II).

Basel Committee on Banking Supervision. (2015). *Corporate governance principles for banks*. Bank for International Settlements.

Basel Committee on Banking Supervision. (2022). *Evaluation of the impact and efficacy of the Basel III reforms*. Bank for International Settlements.

Baum, J. A., & McKelvey, B. (2006). Analysis of extremes in management studies. In D.J. Ketchen & D.D Bergh (Eds), *Research methodology in strategy and management Vol 3*(pp. 123-196). Emerald Group Publishing Limited, Leeds.

Beguería, S., Angulo-Martínez, M., Vicente-Serrano, S. M., López-Moreno, J. I., & El-Kenawy, A. (2011). Assessing trends in extreme precipitation events intensity and magnitude using non-stationary peaks-over-threshold analysis: A case study in northeast Spain from 1930 to 2006. *International Journal of Climatology, 31*(14), 2102-2114.

Beirlant, J., Goegebeur, Y., Segers, J., & Teugels, J. L. (2006). *Statistics of extremes: Theory and applications*. John Wiley & Sons.

Beirlant, J., Schoutens, W., De Spiegeleer, J., Reynkens, T., & Herrmann, K. (2016). Hunting for black swans in the european banking sector using extreme value analysis. In *Advanced modelling in mathematical finance: In Honour of Ernst Eberlein* (pp. 147-166). Springer International Publishing.

Beirlant, J., Schoutens, W., & Segers, J. (2004). *Mandelbrot's extremism.* K.U.Leuven U.C.S. Report. https://lirias.kuleuven.be/handle/123456789/138038

Bensalah, Y. (2000). Steps in applying extreme value theory to finance: A review. https://www.bankofcanada.ca/wp-content/uploads/2010/01/wp00-20.pdf

Bierly III, P. E., & Spender, J. (1995). Culture and high reliability organizations: The case of the nuclear submarine. *Journal of Management, 21*(4), 639-656.

Blatt, R., Christianson, M. K., Sutcliffe, K. M., & Rosenthal, M. M. (2006). A sensemaking lens on reliability. *Journal of Organizational Behavior: The*

International Journal of Industrial, Occupational and Organizational Psychology and Behavior, 27(7), 897-917.

Bollen, K. A., Fisher, Z., Lilly, A., Brehm, C., Luo, L., Martinez, A., & Ye, A. (2022). Fifty years of structural equation modeling: A history of generalization, unification, and diffusion. *Social Science Research, 107*, 102769.

Bollen, K. A., & Pearl, J. (2013). Eight myths about causality and structural equation models. In *Handbook of Causal Analysis for Social Research*, (pp 301-328). Dordrecht: Springer Netherlands.

Bookstaber, R. (2017). *The end of theory*. Princeton University Press.

Bradshaw, R. A. (2008). Application of high reliability theory in the water utility sector. [Unplished EngD Thesis] Cranfield University https://dspace.lib.cranfield.ac.uk/bitstream/handle/1826/4075/Bradshaw_Thesis_2008.pdf?sequence=1&isAllowed=y

Buchanan, D. A. (2011). Reflections: Good practice, not rocket science–understanding failures to change after extreme events. *Journal of Change Management, 11*(3), 273-288.

Busby, J., & Iszatt-White, M. (2014). The relational aspect to high reliability organization. *Journal of Contingencies and Crisis Management, 22*(2), 69-80.

Caldwell, J. H. (2021). Global risk management survey, 12th edition. A moving target: Refocusing risk and resiliency amidst continued uncertainty. https://www2.deloitte.com/content/dam/Deloitte/rs/Documents/risk/rs_Global-risk-management-survey-12th-edition.pdf

Caruana, J. (2005). Implementation of Basel II. *Financial Markets, Institutions & Instruments, 14(5),* 253-265.

Chakraborty, G., Chandrashekhar, G. R., & Balasubramanian, G. (2021). Measurement of extreme market risk: Insights from a comprehensive literature review. *Cogent Economics & Finance, 9*(1)

Chavez-Demoulin, V., Embrechts, P., & Hofert, M. (2016). An extreme value approach for modeling operational risk losses depending on covariates. *Journal of Risk and Insurance, 83*(3), 735-776.

Chavez-Demoulin, V., Embrechts, P., & Nešlehová, J. (2006). Quantitative models for operational risk: Extremes, dependence and aggregation. *Journal of Banking & Finance, 30*(10), 2635-2658.

Chesley, J., & Wylson, A. (2016). Ambiguity: The emerging impact of mindfulness for change leaders. *Journal of Change Management, 16*(4), 317-336.

Cheung, G. W., Cooper-Thomas, H. D., Lau, R. S., & Wang, L. C. (2023). Reporting reliability, convergent and discriminant validity with structural equation modeling: A review and best-practice recommendations. *Asia Pacific Journal of Management*, 1-39.

Claessens, M. S., & Kose, M. A. (2013). Financial crises explanations, types, and implications. International Monetary Fund.

Coronado Vaca, M., & Carabias López, S. (2019). Evolución de la medición del riesgo financiero en los últimos 40 años: Una panorámica con especial mención en la banca. *Revista Icade. Revista de las Facultades de Derecho y Ciencias Económicas y Empresariales (105).*

Costello, A., & Osborne, J. (2005). Best practices in exploratory factor analysis: Four recommendations for getting the most from your analysis. *Practical Assessment, Research & Evaluation, 10 (1)*, 7.

Crouhy, M., Galai, D., & Mark, R. (2000). *Risk management*. McGraw-Hill Professional.

Curran, P. J., West, S. G., & Finch, J. F. (1996). The robustness of test statistics to nonnormality and specification error in confirmatory factor analysis. *Psychological Methods, 1(1),* 16.

Danielsson, J., Embrechts, P., Goodhart, C. A. E., Keating, C., Muennich, F., Renault, O., & Shin, H. S. (2001). *An academic response to Basel II*. ETH Zurich. https://doi.org/10.3929/ethz-a-004259443

De Barrón, I. (2014, Jul 22,). *El Estado pierde 11.500 millones al vender Catalunya Banc al BBVA*. El País. https://elpais.com/economia/2014/07/21/actualidad/1405965093_478597.html

De Haan, L. (1990). Fighting the arch–enemy with mathematics. *Statistica Neerlandica*, *44*(2), 45-68.

Dernbecher, S., & Beck, R. (2017). The concept of mindfulness in information systems research: A multi-dimensional analysis. *European Journal of Information Systems*, *26*(2), 121-142.

Dev, A. (2004). *Economic capital: A practitioner guide*. Risk Books.

Diebold, F. X., Schuermann, T., & Stroughair, J. D. (2000). Pitfalls and opportunities in the use of extreme value theory in risk management. *The Journal of Risk Finance*, *1*(2), 30-35. https://10.1108/eb043443

Dionne, G. (2013). Risk management: History, definition, and critique. *Risk Management and Insurance Review, 16*(2), 147-166.

DiStefano, C., & Morgan, G. B. (2014). A comparison of diagonal weighted least squares robust estimation techniques for ordinal data. *Structural Equation Modeling: A Multidisciplinary Journal*, 21(3), 425-438.

Dridi, A., El Ghourabi, M., & Limam, M. (2012). On monitoring financial stress index with extreme value theory. *Quantitative Finance, 12*(3), 329-339.

Dwyer, J., Karanikas, N., & Sav, A. (2023). Scoping review of peer-reviewed empirical studies on implementing high reliability organisation theory. *Safety Science, 164*, 106178.

Eastburn, R. W. (2011). *Managing the unexpected: Detecting, preventing and mitigating surprises in the banking industry.* http://rave.ohiolink.edu/etdc/view?acc_num=casedm1568627761609807

Eastburn, R. W. (2018). Organizational mindfulness in banking: A discriminating factor for firm performance. *Journal of Managerial Issues*, 122-147.

Edwards, J. R. (2011). The fallacy of formative measurement. *Organizational Research Methods, 14(2)*, 370-388.

Eichengreen, B. (2023). Financial regulation in the age of the platform economy. *Journal of Banking Regulation, 24(1)*, 40-50.

Embrechts, P. (2000). Extreme value theory: Potential and limitations as an integrated risk management tool. *Derivatives use, Trading & Regulation*, *6*(1), 449-456.

Embrechts, P. (2017). A Darwinian view on internal models. *The Journal of Risk*, *20*(1), 1-21. https://10.21314/JOR.2017.394

Embrechts, P., Klüppelberg, C., & Mikosch, T. (2013). *Modelling extremal events: For insurance and finance*. Springer Science & Business Media.

Embrechts, P., Resnick, S. I., & Samorodnitsky, G. (1999). Extreme value theory as a risk management tool. *North American Actuarial Journal*, *3*(2), 30-41.

Enria, A. (2023). Well-run banks don't fail -why governance is an enduring theme in banking crises. *22nd Annual International Conference on Policy Challenges for the Financial Sector organised by the World Bank, International Monetary Fund and Federal Reserve System*.

Enya, A., Pillay, M., & Dempsey, S. (2018). A systematic review on high reliability organisational theory as a safety management strategy in construction. *Safety*, *4*(1), 6.

Etchegaray, J. M., Thomas, E. J., & Profit, J. (2019). Preoccupation with failure and adherence to shared baselines: Measuring high-reliability organizational culture. *Journal of Patient Safety and Risk Management, 24*(4), 147-152.

European Commission. (2014). *State aid n° SA.39402 (2014/N) – Spain: restructuring of Catalunya Banc S.A. through its acquisition by BBVA.* https://ec.europa.eu/competition/state_aid/cases/255638/255638_1647742_125_2.pdf

Fabrigar, L. R., Wegener, D. T., MacCallum, R. C., & Strahan, E. J. (1999). Evaluating the use of exploratory factor analysis in psychological research. *Psychological Methods, 4(3),* 272.

Feduzi, A., & Runde, J. (2014). Uncovering unknown unknowns: Towards a baconian approach to management decision-making. *Organizational Behavior and Human Decision Processes*, *124*(2), 268-283. https://10.1016/j.obhdp.2014.04.001

Ferreira, A., & De Haan, L. (2015). On the block maxima method in extreme value theory: PWM estimators. *The Annals of Statistics*, 276-298.

Fisher, R. A., & Tippett, L. H. C. (1928). (1928). Limiting forms of the frequency distribution of the largest or smallest member of a sample. Paper presented at the *Mathematical Proceedings of the Cambridge Philosophical Society*, *24*(2) 180-190.

Fornell, C., & Larcker, D. F. (1981). Evaluating structural equation models with unobservable variables and measurement error. *Journal of marketing research, 18(1)*, 39-50.

Fowler, K. L., Kling, N. D., & Larson, M. D. (2007). Organizational preparedness for coping with a major crisis or disaster. *Business & Society, 46(1)*, 88-103.

Furió, D., & Climent, F. J. (2013). Extreme value theory versus traditional GARCH approaches applied to financial data: A comparative evaluation. *Quantitative Finance*, *13*(1), 45-63.

Gabaix, X. (2016). Power laws in economics: An introduction. *The Journal of Economic Perspectives*, *30*(1), 185-205. https://10.1257/jep.30.1.185

Gephart Jr, R. P., Van Maanen, J., & Oberlechner, T. (2009). Organizations and risk in late modernity. *Organization Studies*, 30(2-3), 141-155.

Gilli, M., & Këllezi, E. (2006). An application of extreme value theory for measuring financial risk. *Computational Economics*, *27*, 207-228.

Gius, D., Mieszala, J., Panayiotou, E., & Poppensieker, T. (2018). Value and resilience through better risk management. Vol.6. *McKinsey on Risk*, 1-10.

Gobat, J. (2012). Banks: At the heart of the matter. *Finance & Development,*

Gordy, M. B. (2003). A risk-factor model foundation for ratings-based bank capital rules. *Journal of Financial Intermediation, 12*(3), 199-232.

Grabchak, M., & Samorodnitsky, G. (2010). Do financial returns have finite or infinite variance? A paradox and an explanation. *Quantitative Finance, 10(8)*, 883-893.

Grind, K. (2012). *The lost bank: The story of Washington Mutual-the biggest bank failure in American history*. Simon and Schuster.

Gumbel, E. J. (1958). *Statistics of extremes*. Columbia university press.

Haldane, A. G., & May, R. M. (2011). Systemic risk in banking ecosystems. *Nature (London), 469*(7330), 351-355. https://10.1038/nature09659

Haldane, A. G., & Nelson, B. (2012). Tails of the unexpected. Paper presented at the *Presentation at the Conference the Credit Crisis Five Years on: Unpacking the crisis–University of Edinburgh Business School*, 8-9.

Hales, D. N., & Chakravorty, S. S. (2016). Creating high reliability organizations using mindfulness. *Journal of Business Research, 69*(8), 2873-2881.

Hällgren, M., Rouleau, L., & De Rond, M. (2018). A matter of life or death: How extreme context research matters for management and organization studies. *Academy of Management Annals, 12*(1), 111-153.

Hannah, S. T., Uhl-Bien, M., Avolio, B. J., & Cavarretta, F. L. (2009). A framework for examining leadership in extreme contexts. *The Leadership Quarterly, 20*(6), 897-919.

Hardy, C., Maguire, S., Power, M., & Tsoukas, H. (2020). Organizing risk: Organization and management theory for the risk society. *Academy of Management Annals, 14(2),* 1032-1066.

Hayduk, L., Cummings, G., Boadu, K., Pazderka-Robinson, H., & Boulianne, S. (2007). Testing! testing! one, two, three–Testing the theory in structural equation models! *Personality and Individual Differences, 42*(5), 841-850.

Hayes, A. F. (2015). An index and test of linear moderated mediation. *Multivariate behavioral research, 50(1),* 1-22.

Heinz, F. F., & Rusinova, D. (2015). *An Alternative View of Exchange Market Pressure Episodes in Emerging Europe: An Analysis using Extreme Value Theory.* European Central Bank. Working Paper No. 1818

Herberg, M., & Torgersen, G. (2021). Resilience competence face framework for the unforeseen: Relations, emotions and cognition. A qualitative study. *Frontiers in Psychology, 12*, 669904. https://10.3389/fpsyg.2021.669904

Hillmann, J., & Guenther, E. (2021). Organizational resilience: A valuable construct for management research? *International Journal of Management Reviews, 23*(1), 7-44.

Hinkin, T. R. (1998). A brief tutorial on the development of measures for use in survey questionnaires. *Organizational Research Methods, 1(1)*, 104-121.

Ho, L., Burridge, P., Cadle, J., & Theobald, M. (2000). Value-at-risk: Applying the extreme value approach to Asian markets in the recent financial turmoil. *Pacific-Basin Finance Journal, 8*(2), 249-275.

Hooper, D., Coughlan, J., & Mullen, M. (2008). Evaluating model fit: A synthesis of the structural equation modelling literature. Paper presented at the *7th European Conference on Research Methodology for Business and Management Studies, 2008,* 195-200.

Howard, M. C. (2023). A systematic literature review of exploratory factor analyses in management. *Journal of Business Research*, 164, 113969.

Hull, J. (2000). *Options, futures, & other derivatives* (4. ed.). Prentice-Hall.

Igolkina, A. A., & Meshcheryakov, G. (2020). Semopy: A python package for structural equation modeling. *Structural Equation Modeling: A Multidisciplinary Journal, 27*(6), 952-963.

IMF (International Monetary Fund). (2018). *Global financial stability report-a decade after the global financial crisis: Are we safer.* International Monetary Fund

IMF (International Monetary Fund). (2024) *Financial Stability Report. The last mile: Financial vulnerabilities and risks*. International Monetary Fund

James, G., Witten, D., Hastie, T., & Tibshirani, R. (2021). *An introduction to statistical learning* (Second edition ed.). Springer. https://10.1007/978-1-0716-1418-1

Jöreskog, K. G. (1970). A general method for estimating a linear structural equation system. *ETS Research Bulletin Series, 1970*(2), i-41.

Jorion, P. (2003). *Financial risk manager handbook*. John Wiley & Sons.

Karpov, O. E., Grubov, V. V., Maksimenko, V. A., Kurkin, S. A., Smirnov, N. M., Utyashev, N. P., Andrikov, D. A., Shusharina, N. N., & Hramov, A. E. (2022). Extreme value theory inspires explainable machine learning approach for seizure detection. *Scientific Reports, 12*(1), 11474.

Kay, J. A., & King, M. A. (2020). *Radical uncertainty*. Bridge Street Press Decision

Kline, R. B. (2023). *Principles and practice of structural equation modeling*. Fifth edition. Guilford publications.

Knight, F. H. (1921). *Risk, uncertainty and profit*. Houghton Mifflin.

Koufteros, X., Babbar, S., & Kaighobadi, M. (2009). A paradigm for examining second-order factor models employing structural equation modeling. *International Journal of Production Economics*, 120(2), 633-652.

Kunz, J., & Heitz, M. (2021). Banks' risk culture and management control systems: A systematic literature review. *Journal of Management Control, 32*(4), 439-493.

Kyndt, E., & Onghena, P. (2014). The integration of work and learning: Tackling the complexity with structural equation modelling. In: *Discourses on professional learning: On the boundary between learning and working* (pp. 255-291). Springer.

La Porte, T. R. (1996). High reliability organizations: Unlikely, demanding and at risk. *Journal of Contingencies and Crisis Management, 4*(2), 60-71.

LaPorte, T. R., & Consolini, P. M. (1991). Working in practice but not in theory: Theoretical challenges of "High-reliability organizations". *Journal of Public Administration Research and Theory, 1*(1), 19-48.

Leveson, N., Dulac, N., Marais, K., & Carroll, J. (2009). Moving beyond normal accidents and high reliability organizations: A systems approach to safety in complex systems. *Organization Studies, 30*(2-3), 227-249.

Little, T. D., Bovaird, J. A., & Widaman, K. F. (2006). On the merits of orthogonalizing powered and product terms: Implications for modeling interactions among latent variables. *Structural Equation Modeling, 13(4)*, 497-519.

Longin, F. M. (2000). From value at risk to stress testing: The extreme value approach. *Journal of Banking & Finance, 24*(7), 1097-1130.

Magnano, P., Platania, S., Ramaci, T., Santisi, G., & Di Nuovo, S. (2017). Validation of the italian version of the mindfulness organizing scale (MOS) in organizational contexts. *TPM: Testing, Psychometrics, Methodology in Applied Psychology, 24(1).*

Mandelbrot, B. (1963). The variation of certain speculative prices. *The Journal of Business (Chicago, Ill.), 36*(4), 394-419. https://10.1086/294632

Mandelbrot, B. B., & Taleb, N. N. (2010). Mild vs. wild randomness. *The Known, the Unknown, and the Unknowable in Financial Risk Management*, 47-58. http://www.econis.eu/PPNSET?PPN=632365870

Marsh, H. W., Morin, A. J., Parker, P. D., & Kaur, G. (2014). Exploratory structural equation modeling: An integration of the best features of exploratory and confirmatory factor analysis. *Annual Review of Clinical Psychology, 10*, 85-110.

McNeil, A. J. (1999). Extreme value theory for risk managers. *Departement Mathematik ETH Zentrum, 12*(5), 217-237.

McNeil, A. J., Frey, R., & Embrechts, P. (2015). *Quantitative risk management: Concepts, techniques and tools* (Revised edition ed.). Princeton University Press.

Mezias, S. J. (1994). Financial meltdown as normal accident: The case of the American savings and loan industry. *Accounting, Organizations and Society, 19*(2), 181-192.

Mikes, A. (2011). From counting risk to making risk count: Boundary-work in risk management. *Accounting, Organizations and Society, 36*(4), 226-245.

Mikes, A., & Kaplan, R. S. (2015). When one size doesn't fit all: Evolving directions in the research and practice of enterprise risk management. *Journal of Applied Corporate Finance, 27*(1), 37-40.

Min, B. H., & Borch, C. (2022). Systemic failures and organizational risk management in algorithmic trading: Normal accidents and high reliability in financial markets. *Social Studies of Science, 52*(2), 277-302.

Ndubisi, N. O., & Al-Shuridah, O. (2019). Organizational mindfulness, mindful organizing, and environmental and resource sustainability. *Business Strategy and the Environment, 28*(3), 436-446.

Nolde, N., & Zhou, C. (2021). Extreme value analysis for financial risk management. *Annual Review of Statistics and its Application, 8*, 217-240.

OECD. (2022). *States of fragility 2022*. OECD.

Orsini, F., Gecchele, G., Gastaldi, M., & Rossi, R. (2020). Large-scale road safety evaluation using extreme value theory. *IET Intelligent Transport Systems, 14*(9), 1004-1012.

Osborne, J. W., & Overbay, A. (2004). The power of outliers (and why researchers should always check for them). *Practical Assessment, Research, and Evaluation, 9*(1), 6.

Osborne, J. W, & Fitzpatrick, D. (2012). Replication analysis in exploratory factor analysis: What it is and why it makes your analysis better. *Practical Assessment, Research & Evaluation, 17*(15), 5.

Otero-Iglesias, M., Royo, S., & Steinberg, F. (2016). The Spanish financial crisis: Lessons for the European banking union.

Palmer, D., & Maher, M. (2010). A normal accident analysis of the mortgage meltdown. *Markets on trial: The economic sociology of the US financial crisis: Part A* (pp. 219-256). Emerald Group Publishing Limited.

Paté-Cornell, E. (2012). On "black swans" and "perfect storms": Risk analysis and management when statistics are not enough. *Risk Analysis, 32*(11), 1823-1833. https://10.1111/j.1539-6924.2011.01787.x

Paul, P. (2023). Banks, maturity transformation, and monetary policy. *Journal of Financial Intermediation, 53*, 101011.

Pearl, J., & Mackenzie, D. (2018). *The book of why: The new science of cause and effect*. Basic books.

Perrow, C. (1981). Normal accident at Three mile island. *Society, 18*(5), 17-26.

Perrow, C. (1994). The limits of safety: The enhancement of a theory of accidents. *Journal of Contingencies and Crisis Management, 2*(4), 212-220.

Perrow, C. (1999a). *Normal accidents: Living with high risk technologies*. Princeton university press.

Perrow, C. (1999b). Organizing to reduce the vulnerabilities of complexity. *Journal of Contingencies and Crisis Management, 7*(3), 150-155.

Perrow, C. (2009). What's needed is application, not reconciliation: A response to Shrivastava, Sonpar and Pazzaglia (2009). *Human Relations, 62*(9), 1391-1393.

Perrow, C. (2011a). Fukushima and the inevitability of accidents. *Bulletin of the Atomic Scientists, 67*(6), 44-52.

Perrow, C. (2011b). *The next catastrophe: Reducing our vulnerabilities to natural, industrial, and terrorist disasters*. Princeton University Press.

Pidgeon, N. (2011). In retrospect: Normal accidents. *Nature, 477*(7365), 404-405.

Prasad, E. S. (2021). *The future of money: How the digital revolution is transforming currencies and finance*. Harvard University Press.

Ray, J. L., Baker, L. T., & Plowman, D. A. (2011). Organizational mindfulness in business schools. *Academy of Management Learning & Education, 10*(2), 188-203. https://10.5465/AMLE.2011.62798929

Renecle, M., Tomás, I., Gracia, F. J., & Peiró, J. M. (2020). Spanish validation of the mindful organizing scale: A questionnaire for the assessment of collective mindfulness. *Accident Analysis & Prevention, 134*, 105351.

Rerup, C. (2005). Learning from past experience: Footnotes on mindfulness and habitual entrepreneurship. *Scandinavian Journal of Management, 21(4)*, 451-472.

Rijpma, J. A. (1997). Complexity, tight–coupling and reliability: Connecting normal accidents theory and high reliability theory. *Journal of Contingencies and Crisis Management, 5*(1), 15-23.

Roberts, K. H. (1990). Some characteristics of one type of high reliability organization. *Organization Science (Providence, R.I.), 1*(2), 160-176.

Roberts, K. H., & Libuser, C. (1993). From Bhopal to banking: Organizational design can mitigate risk. *Organizational Dynamics*, *21*(4), 15-26.

Roberts, K. H., Stout, S. K., & Halpern, J. J. (1994). Decision dynamics in two high reliability military organizations. *Management Science, 40*(5), 614-624.

Rocco, M. (2014). Extreme value theory in finance: A survey. *Journal of Economic Surveys*, *28*(1), 82-108.

Rochlin, G. I. (2011). How to hunt a very reliable organization. *Journal of Contingencies and Crisis Management, 19(1),* 14-20.

Rochlin, G. I., La Porte, T. R., & Roberts, K. H. (1987). The self-designing high-reliability organization: Aircraft carrier flight operations at sea. *Naval War College Review*, *40(4),* 76-92.

Rosa, E. A. (2005). Celebrating a citation classic—and more: Symposium on Charles Perrow’s normal accidents. *Organization & Environment*, *18*(2), 229-234.

Rosseel, Y. (2012). Lavaan: An R package for structural equation modeling. *Journal of Statistical Software*, *48*, 1-36.

Rosseel, Y. (2018). The lavaan tutorial. *Department of Data Analysis: Ghent University*.

Sagan, S. D. (1995). *The limits of safety: Organizations, accidents, and nuclear weapons*. Princeton University Press.

Salmon, F. (2009). Recipe for disaster: The formula that killed Wall Street. *Wired Magazine, 17*(3), 17-03.

Sarraf, H. (2021). Climate change risk: The next frontier in banking risk management. *Journal of Risk Management in Financial Institutions, 15*(1), 85-92.

Schmidt, K. W. (2020). Normal accidents in interior firefighting operations–a study on the German system. *International Journal of Emergency Services, 9(2),* 167-177.

Schoenmaker, D. (1996). *Contagion risk in banking*. LSE Financial Markets Group London, UK.

Schwert, G. W. (1990). Stock volatility and the crash of'87. *The Review of Financial Studies, 3(1)*, 77-102.

Shrivastava, P. (1987). *Bhopal: Anatomy of a crisis*. Ballinger Pub. Co.

Shrivastava, S., Sonpar, K., & Pazzaglia, F. (2009). Normal accident theory versus high reliability theory: A resolution and call for an open systems view of accidents. *Human Relations, 62*(9), 1357-1390.

Siffer, A., Fouque, P., Termier, A., & Largouet, C. (2017). Anomaly detection in streams with extreme value theory. Paper presented at the *Proceedings of the 23rd ACM SIGKDD International Conference on Knowledge Discovery and Data Mining*, 1067-1075.

Silvast, A., & Kelman, I. (2013). Is the normal accidents perspective falsifiable? *Disaster Prevention and Management, 22*(1), 7-16.

Singh, A. K., Allen, D. E., & Robert, P. J. (2013). Extreme market risk and extreme value theory. *Mathematics and Computers in Simulation, 94*, 310-328.

Sornette, D. (2009). Dragon-kings, black swans and the prediction of crises. *International Journal of Terraspace Science and Engineering,* https://arxiv.org/abs/0907.4290

Stiglitz, J. E. (2018). Where modern macroeconomics went wrong. *Oxford Review of Economic Policy, 34*(1-2), 70-106.

Stulz, R. M. (2015). Risk-taking and risk management by banks. *Journal of Applied Corporate Finance, 27*(1), 8-18.

Su, H., & Linderman, K. (2016). An empirical investigation in sustaining high-quality performance. *Decision Sciences, 47*(5), 787-819.

Sutcliffe, K. M. (2011). High reliability organizations (HROs). *Best Practice & Research Clinical Anaesthesiology, 25*(2), 133-144.

Sutcliffe, K. M., Vogus, T. J., & Dane, E. (2016). Mindfulness in organizations: A cross-level review. *Annual Review of Organizational Psychology and Organizational Behavior, 3*(1), 55-81.

Szubzda, F., & Chlebus, M. (2019). Comparison of block maxima and peaks over threshold value-at-risk models for market risk in various economic conditions. *Central European Economic Journal, 6*(53), 70-85.

Taleb, N. N. (2007). *The black swan: The impact of the highly improbable*. Random house.

Taleb, N. N. (2020). *Statistical consequences of fat tails: Real world preasymptotics, epistemology, and applications*. Stem academic press.

Taleb, N. N., Goldstein, D. G., & Spitznagel, M. W. (2009). The six mistakes executives make in risk management. *Harvard Business Review, 87*(10), 78-81.

Tamuz, M., & Harrison, M. I. (2006). Improving patient safety in hospitals: Contributions of high-reliability theory and normal accident theory. *Health Services Research, 41*(42), 1654-1676.

Teske, B. E., & Adjekum, D. K. (2022). Understanding the relationship between high reliability theory (HRT) of mindful organizing and safety management systems (SMS) within the aerospace industry: A cross-sectional quantitative assessment. *Journal of Safety Science and Resilience, 3*(2), 105-114.

Trillas, A. (2008). La morosidad de Caixa Catalunya se cuadruplica en un año. *El Pais.* https://elpais.com/diario/2008/10/29/economia/1225234801_850215.html

Tooze, A. (2018a). *Crashed: How a decade of financial crises changed the world*. Penguin.

Tooze, A. (2018b). The forgotten history of the financial crisis: What the world should have learned in 2008. *Foreign Affairs, 97(5),* 199-210.

Van den Brink, H. W., Können, G. P., Opsteegh, J. D., Van Oldenborgh, G. J., & Burgers, G. (2005). Estimating return periods of extreme events from ECMWF seasonal forecast ensembles. *International Journal of Climatology: A Journal of the Royal Meteorological Society, 25*(10), 1345-1354.

Van Den Eede, G., Van de Walle, B., & Rutkowski, A. (2006). (2006). Dealing with risk in incident management: An application of high reliability theory. Paper presented at the *Proceedings of the 39th Annual Hawaii International Conference on System Sciences (HICSS'06), 2* 37c.

Vaughan, D. (1996). *The challenger launch decision: Risky technology, culture, and deviance at NASA*. University of Chicago press.

Vaughan, D. (1997). The trickle-down effect: Policy decisions, risky work. *California Management Review, 39*(2), 80-102.

Villoria, M., & Jimenez, F. (2016). Exploring citizen's perceptions of political finance and political corruption: Lifting the lid on legal corruption in Spain. In: *Corruption and Governmental Legitimacy. A Twenty-First Century Perspective*, 197-222.

Vogus, T. J., & Sutcliffe, K. M. (2007). The safety organizing scale: Development and validation of a behavioral measure of safety culture in hospital nursing units. *Medical Care*, 46-54.

Vogus, T. J., & Sutcliffe, K. M. (2012). Organizational mindfulness and mindful organizing: A reconciliation and path forward. *Academy of Management Learning & Education*, *11*(4), 722-735.

Vogus, T. J., & Welbourne, T. M. (2003). Structuring for high reliability: HR practices and mindful processes in reliability-seeking organizations. *Journal of Organizational Behavior: The International Journal of Industrial, Occupational and Organizational Psychology and Behavior*, *24*(7), 877-903.

Weick, K. E., Sutcliffe, K. M., & Obstfeld, D. (1999). Organizing for high reliability. processes of collective mindfulness. *Research in Organizational Behavior, 3* (1), 81-123.

Weick, K. E. (1987). Organizational culture as a source of high reliability. *California Management Review*, *29*(2), 112-127. https://10.2307/41165243

Weick, K. E., & Roberts, K. H. (1993). Collective mind in organizations: Heedful interrelating on flight decks. *Administrative Science Quarterly*, 357-381.

Weick, K. E., & Sutcliffe, K. M. (2001). *Managing the unexpected*. San Francisco: Jossey-Bass.

Weick, K. E., & Sutcliffe, K. M. (2011). *Managing the unexpected: Resilient performance in an age of uncertainty*. John Wiley & Sons.

Weick, K. E., & Sutcliffe, K. M. (2015). *Managing the unexpected: Sustained performance in a complex world*. John Wiley & Sons.

Weick, K. E., Sutcliffe, K. M., & Obstfeld, D. (2005). Organizing and the process of sensemaking. *Organization Science, 16*(4), 409-421.

Williams, T. A., Gruber, D. A., Sutcliffe, K. M., Shepherd, D. A., & Zhao, E. Y. (2017). Organizational response to adversity: Fusing crisis management and resilience research streams. *Academy of Management Annals, 11*(2), 733-769.

Wolf, F. G. (2001). Operationalizing and testing normal accident theory in petrochemical plants and refineries. *Production and Operations Management*, *10*(3), 292-305.

Wright, S. (1920). The relative importance of heredity and environment in determining the piebald pattern of guinea-pigs. *Proceedings of the National Academy of Sciences, 6*(6), 320-332.

Young, B. (2011). Leadership and high-reliability organizations: Why banks fail. *The Journal of Operational Risk, 6*(4), 67.

Appendices:

I: List of questionnaire items

Coding	Question in Spanish	Question (English Translation)	Source
	Posibilidad de que alguno de los siguientes eventos extremos vaya a afectar a su organización durante los próximos 10 años	Possibility that one of the following extreme events will affect your organization over the next 10 years	
EXTPOS1	Un evento asociado al cambio climático	An event associated with climate change	
EXTPOS2	Una nueva crisis financiera	A new financial crisis	
EXTPOS3	Un evento asociado a la seguridad informático o ciberseguridad	An event associated with information security or cybersecurity	
EXTPOS4	La imposición de una sanción muy significativa por condena por un delito financiero o abuso de mercado	A very significant fine for financial crime or market abuse	
EXTPOS5	Una pérdida muy significativa debido a una disrupción tecnológica	A very significant loss due to technological disruption	
	En qué medida piensa que su organización está preparada para resistir alguno de los siguientes eventos extremos	To what extent do you think your organization is prepared to withstand any of the following extreme events?	
EXTPRP1	Un evento asociado al cambio climático	An event associated with climate change	
EXTPRP2	Una nueva crisis financiera	A new financial crisis	
EXTPRP3	Un evento asociado a la seguridad informático o ciberseguridad	An event associated with computer security or cybersecurity	
EXTPRP4	La imposición de una sanción muy significativa por condena por un delito financiero o abuso de mercado	A very significant fine for financial crime or market abuse	
EXTPRP5	Una pérdida muy significativa debido a una disrupción tecnológica	A very significant loss due to technological disruption	
	Las herramientas con las que contamos son suficientes para poder:	The tools we have are sufficient to be able to:	
EXTHER1	Calcular la probabilidad que ocurra un evento extremo	Calculate the probability of an extreme event occurring	
EXTHER2	Prepararnos de forma anticipada por si ocurre	Prepare in advance in case it happens	
EXTHER3	Realizar una buena gestión de la crisis o evento extremo una vez que ocurra	Carry out good management of the crisis or extreme event	
EXTHER4	Recuperarnos una vez ha ocurrido	Recover once it has happened	
	La capacidad del banco para modelizar la ocurrencia de un evento extremo	The bank's ability to model the occurrence of an extreme event	
EVT0.1APL	En mi organización se fomenta activamente la valoración cuantitativa de los riesgos usando los sistemas de medición adecuados	In our organization a more quantified approach to risk assessment is advocated using proper measurement systems	Mikes, A. (2011)
EVT0.1IMP	Pienso que es indispensable que en las organizaciones se fomente activamente la valoración cuantitativa de los riesgos usando los sistemas de medición adecuados	I think it is essential that organizations actively promote the quantitative assessment of risks using appropriate measurement systems.	
EVT0.2APL	En mi organización los modelos de riesgos se consideran herramientas indispensables para la toma de decisiones	In my organization, risk models are considered essential tools for decision making.	Mikes, A. (2011)
EVT0.2IMP	Pienso que los modelos de riesgos son herramientas indispensables para la toma de decisiones en las entidades financieras	I think that risk models are essential tools for decision-making in financial sector entities.	
EVT0.3APL	En mi organización existe la capacidad de medir todos los riesgos de manera consistente para obtener un mapa real de nuestra exposición a los riesgos.	In our organization we are able to measure all risks consistently to be able to have the true map of our risk exposure	Mikes, A. (2011)
EVT0.3IMP	Pienso que es indispensable que las organizaciones tengan la capacidad de medir todos los riesgos de manera consistente para poder tomar las decisiones adecuadas	I think it is essential that organizations have the ability to measure all risks consistently in order to make appropriate decisions.	
EVT1.1APL	Los modelos que usamos en mi organización se entienden a todos los niveles	The models we use in my organization are understood at all levels	Embrechts, P. (2017)
EVT1.1IMP	Pienso que es indispensable que los modelos que se usan en las entidades financieras se entiendan a todos los niveles	I think it is essential that the models used in financial sector entities are understood at all levels.	
EVT1.3APL	Los modelos que usamos en nuestra organización recogen el riesgo en las colas de la distribución	The models we use in our organization capture risk in the tails of the distribution	Mikes, A. (2011)
EVT1.3IMP	Pienso que es indispensable que los modelos que se usen en las entidades financieras recojan el riesgo en las colas de la distribución	I think it is essential that the models used in financial sector entities include the risk in the tails of the distribution.	
EVT3.3APL	En mi organización analizamos puntos de inflexión en los datos para ver si están ocurriendo fenómenos que pueden marcar el inicio de cambios muy significativos	In my organization we analyze tipping points in our data to see if pheno-mena are occurring that can mark the beginning of very significant changes	Haldane, A. G., & Nelson, B. (2012).
EVT3.3IMP	Pienso que es indispensable que las entidades financieras analicen puntos de inflexión en los datos para ver si están ocurriendo fenómenos que pueden marcar el inicio de cambios muy significativos	I think it is essential for financial sector entities to analyze turning points in the data to see if phenomena are occurring that can mark the beginning of very significant changes.	
EVT3.5APL	En mi organización modelizamos los sistemas económicos y financieros como redes complejas y adaptativas	We model economic and financial systems as complex, adaptive networks	Haldane, A. G., & Nelson, B. (2012).
EVT3.5IMP	Pienso que es indispensable que las entidades financieras modelicen los sistemas económicos y financieros como redes complejas y adaptativas	I think it is essential that financial sector entities model economic and financial systems as complex and adaptive networks.	
EVT4.1CRI	Como consecuencia de la crisis financiera, los modelos que se utilizan en mi organización han mejorado para tener en cuenta la posibilidad de otro evento extremo	As a result of the financial crisis, the models used in my organization have improved to account for the possibility of another extreme event	

Coding	Question in Spanish	Question (English Translation)	Source
	La capacidad organizativa del banco para anticipar un evento extremo	The bank's organizational capacity to anticipate an extreme event	
HRTANT_5_1APL	En mi organización nos enfocamos más en nuestros fracasos y errores que en nuestros éxitos	In my organization, we focus more on our failures and mistakes than on our successes	Ray, J. L., Baker, L. T., & Plowman, D. A. (2011)
HRTANT_5_1IMP	Pienso que es indispensable que las organizaciones se enfoquen más en sus fracasos y errores que en sus éxitos	I think it is essential that organizations focus more on their failures and errors than on their successes.	
HRTANT_5_4APL	En mi organización actualizamos habitualmente nuestros procedimientos después de experimentar un problema	In my organization, we regularly update our procedures after experiencing a problem	Ray, J. L., Baker, L. T., & Plowman, D. A. (2011)
HRTANT_5_4IMP	Pienso que es indispensable que las organizaciones actualicen habitualmente sus procedimientos después de experimentar un problema	I think it is essential that organizations regularly update their procedures after experiencing a problem.	
HRTANT_5_8APL	En mi organización las personas se sienten libres de hablar con sus superiores jerárquicos sobre problemas	In my organization, people feel free to talk to their superiors about problems	Ray, J. L., Baker, L. T., & Plowman, D. A. (2011)
HRTANT_5_8IMP	Pienso que es indispensable que en las organizaciones se pueda hablar abiertamente sobre problemas, errores o fallos	I think it is essential that organizations can talk openly about problems, errors or failures.	
HRTANT_6_1APL	En mi organización se anima a no tomar nada por sentado	In my organization, people are encouraged not to take anything for granted	Ray, J. L., Baker, L. T., & Plowman, D. A. (2011)
HRTANT_6_1IMP	Pienso que es indispensable que en las organizaciones se anime a no tomar nada por sentado	I think it is essential that organizations be encouraged not to take anything for granted.	
HRTANT_6_5APL	Las personas de mi organización generalmente profundizan su análisis para comprender la naturaleza de los problemas que surgen	People in my organization generally prolong their analysis to understand the nature of the problems that come up	Ray, J. L., Baker, L. T., & Plowman, D. A. (2011)
HRTANT_6_5IMP	Pienso que es indispensable que en las organizaciones se profundicen los análisis para comprender la naturaleza de los problemas que surgen	I think it is essential that organizations deepen the analysis to understand the nature of the problems that arise.	
HRTANT_6_7APL	Las personas en mi organización escuchan atentamente; es raro que se descarte la opinión de alguien	People in my organization listen carefully; it is rare that anyone's view is dismissed	Ray, J. L., Baker, L. T., & Plowman, D. A. (2011)
HRTANT_6_7IMP	Pienso que es indispensable que las personas en las organizaciones escuchen atentamente y no descarten las opiniones de nadie	I think it is essential for people in organizations to listen carefully and not dismiss anyone's opinions.	
HRTANT_7_1APL	Los líderes de nuestra organización prestan mucha atención a las operaciones diarias de la empresa	The leaders of our organization pay close attention to the day-to-day operations of the company	Ray, J. L., Baker, L. T., & Plowman, D. A. (2011)
HRTANT_7_1IMP	Pienso que es indispensable que los líderes de nuestra organización presten mucha atención a las operaciones diarias de la empresa	I think it is essential to have a good “map” of the capabilities and competencies of each person in organizations.	
HRTANT_7_4_APL	Durante un día normal, las personas entran en contacto suficiente entre sí para formarse una imagen clara de la situación actual	During an average day, people come into enough contact with each other to build a clear picture of the current situation	Ray, J. L., Baker, L. T., & Plowman, D. A. (2011)
HRTANT_7_4_IMP	Pienso que es indispensable que las personas entran en contacto suficiente entre sí para formarse una imagen clara de la situación actual	I think it is essential that people come into sufficient contact with each other to form a clear picture of the current situation.	
HRTANT_7_8APL	Si surgen sorpresas inesperadas en mi organización tenemos acceso a recursos	If unexpected surprises arise in my organization, we have access to resources	Ray, J. L., Baker, L. T., & Plowman, D. A. (2011)
HRTANT_7_8IMP	Pienso que es indispensable que las organizaciones tengan flexibilidad para obtener recursos si surgen sorpresas inesperadas	I think it is essential that organizations have flexibility to obtain resources if unexpected surprises arise.	
HRTANT_CRI	Como consecuencia de la crisis financiera, la cultura de atención y anticipación ha mejorado para estar más preparado para un evento extremo	As a consequence of the financial crisis, the culture of attention and anticipation has improved to be more prepared for an extreme event	
	La capacidad organizativa del banco para reaccionar ante un evento extremo	The bank's organizational capacity to react to an extreme event	
HRTCON_8_2APL	En mi organización se dedican continuamente recursos a capacitar y reciclar a las personas en sus áreas de especialización	In my organization, resources are continually devoted to training and retraining people in their areas of expertise	Ray, J. L., Baker, L. T., & Plowman, D. A. (2011)
HRTCON_8_2IMP	Pienso que es indispensable que las organizaciones dediquen recursos continuamente para la capacitación y el reciclaje de las personas en sus áreas de especialización	I think it is essential that organizations continually dedicate resources to training and retraining people in their areas of specialization.	
HRTCON_8_8APL	Las personas del mi organización tienen varios contactos informales que a veces usan para resolver problemas	People in my organization have a number of informal contacts that they sometimes use to solve problems	Ray, J. L., Baker, L. T., & Plowman, D. A. (2011)
HRTCON_8_8IMP	Pienso que es indispensables que en las organizaciones existan redes de contactos informales para resolver problemas	I think it is essential that organizations have networks of informal contacts to solve problems.	
HRTCON_8_9APL	Las personas en mi organización en general aprenden de sus errores	People in my organization generally learn from their mistakes	Ray, J. L., Baker, L. T., & Plowman, D. A. (2011)
HRTCON_8_9IMP	Pienso que es indispensable que en las organizaciones las personas aprendan de sus errores	I think it is essential that in organizations people learn from their mistakes.	
HRTCON_9_3APL	Si sucede algo fuera de lo común, las personas en mi organización saben quién tiene el conocimiento experto para responder.	If something out of the ordinary happens, people in my organization know who has the expertise to respond	Ray, J. L., Baker, L. T., & Plowman, D. A. (2011)
HRTCON_9_3IMP	Pienso que es indispensable que en las organizaciones se sepa quién tiene el conocimiento experto para responder si ocurre algo fuera de lo común.	I think it is essential that organizations know who has the expert knowledge to respond if something out of the ordinary happens.	
HRTCON_9_4APL	Las personas de mi organización valoran los conocimientos y la experiencia por encima del rango jerárquico	People in my organization value expertise and experience over hierarchical rank	Ray, J. L., Baker, L. T., & Plowman, D. A. (2011)
HRTCON_9_4IMP	Pienso que es indispensable que en las organizaciones se valoren los conocimientos y la experiencia por encima del rango jerárquico	I think it is essential that organizations value knowledge and experience above the hierarchical rank.	
HRTCON_9_8APL	Por lo general, es fácil obtener asistencia de expertos en mi organización cuando surge algo que no sabemos cómo manejar	It is generally easy to obtain assistance from experts in my organization when something comes up that we don't know how to handle	Ray, J. L., Baker, L. T., & Plowman, D. A. (2011)
HRTCON_9_8IMP	Pienso que es indispensable que sea fácil obtener asistencia de expertos cuando surge algo que no se sabe cómo manejarlo	I think it is essential that it is easy to get expert assistance when something comes up that you don't know how to handle.	Ray, J. L., Baker, L. T., & Plowman, D. A. (2011)
HRTCON_CRI	Como consecuencia de la crisis financiera, la cultura de resiliencia y reacción ha mejorado para estar más preparado para un evento extremo	As a consequence of the financial crisis, the culture of resilience and reaction has improved to be more prepared for an extreme event	

Coding	Question in Spanish	Question (English Translation)	Source
	El grado de complejidad y de integración estrecha de las operaciones del banco	The degree of complexity and tight coupling of the bank's operations	
NAT1.4APL	En mi organización puede ocurrir una sucesión de giros inesperados de acontecimientos que ni siquiera una persona con conocimientos íntimos de la situación puede prever	A series of unexpected turns of events can occur in my organization that not even a person with intimate knowledge of the situation can foresee	Min, B. H., & Borch, C. (2022).
NAT1.2APL	Pienso que existe gran complejidad de los procesos en las entidades financieras que incrementan el riesgo que algo vaya mal	I think there is great complexity in the processes within financial institutions that increase the risk of something going wrong	Shrivastava, S., Sonpar, K., & Pazzaglia, F. (2009).
NAT2.4APL	En mi organización cuando las cosas empiezan a ir mal, tenemos poco margen de maniobra para alterar la cadena de eventos	In my organization, when things start to go wrong, we have little margin to alter the chain of events	Min, B. H., & Borch, C. (2022).
NAT2.6APL	Pienso que en las entidades financieras existen muchas interdependencias que provocan que errores en una parte puedan extenderse a todo el sistema	I think that in financial sector entities there are many interdependencies that may lead to errors in one part extending to the entire system	Min, B. H., & Borch, C. (2022).
NAT3.1IMP	Pienso que el tamaño de las organizaciones influye para incrementar el posible impacto de un evento extremo, en caso que ocurre	I think that the size of the organizations influences to increase the possible impact of an extreme event, in case it occurs	Perrow, C. (2011)
NAT3.2IMP	Pienso que la regulación juega un papel importante para reducir las posibles consecuencias de la ocurrencia de un evento extremo	I think that regulation plays an important role in reducing the possible consequences of the occurrence of an extreme event	Perrow, C. (2011)
NATCRI	Como consecuencia de la crisis financiera, la complejidad y la interconexión de los procesos en el sector financiero ha disminuido y así se han reducido los posibles impactos de otro evento extremo	As a consequence of the financial crisis, the complexity and interconnection of processes in the financial sector has decreased and thus the possible impacts of another extreme event have been reduced.	

II: Residuals Statistics

	HRTANT_5_1	HRTANT_5_4	HRTANT_5_8	HRTANT_6_1	HRTANT_6_5	HRTANT_6_7	HRTANT_7_1	HRTANT_7_4	HRTANT_7_8	HRTCON_8_2	HRTCON_8_8	HRTCON_8_9	HRTCON_9_3	HRTCON_9_4	HRTCON_9_8
HRTANT_5_1APL	0														
HRTANT_5_4APL	0.086	0													
HRTANT_5_8APL	0.015	-0.034	0												
HRTANT_6_1APL	-0.007	0.012	0.029	0											
HRTANT_6_5APL	-0.033	0.05	-0.039	0.051	0										
HRTANT_6_7APL	-0.017	-0.079	0.023	-0.038	-0.011	0									
HRTANT_7_1APL	-0.011	0.055	0.015	0.005	0.01	0.091	0								
HRTANT_7_4_APL	0.052	0.018	-0.015	0.007	0.009	-0.02	-0.032	0							
HRTANT_7_8APL	0.051	0.045	-0.042	-0.064	-0.027	-0.009	0.003	0.029	0						
HRTCON_8_2APL	-0.055	0.024	-0.08	-0.026	0.008	-0.031	0.022	-0.022	0.036	0					
HRTCON_8_8APL	-0.001	0.054	-0.049	-0.034	-0.077	-0.028	-0.048	0.099	0.025	-0.016	0				
HRTCON_8_9APL	0.066	0.062	0.047	0.049	0.032	-0.003	-0.057	0.008	-0.003	-0.001	0.015	0			
HRTCON_9_3APL	0.04	0.022	-0.034	-0.034	-0.001	0.02	0.007	0.039	-0.023	-0.01	-0.018	0.023	0		
HRTCON_9_4APL	0.051	-0.006	0.059	0.016	-0.035	0.08	0.043	0.005	-0.054	-0.013	-0.008	0.017	-0.035	0	
HRTCON_9_8APL	0.012	-0.027	-0.024	-0.012	-0.054	0.033	0.013	-0.031	0.004	-0.012	0.047	-0.017	0.03	-0.009	0
EVT0.1APL	0.007	0.088	0	-0.033	0.031	-0.009	0.018	-0.026	0.001	-0.001	-0.075	0.014	0.057	-0.015	0.019
EVT0.2APL	-0.016	0.047	-0.024	-0.013	0.046	-0.019	-0.02	0.03	0.018	0.036	-0.088	-0.011	-0.028	-0.028	-0.026
EVT0.3APL	-0.012	0.085	-0.015	-0.025	0.034	-0.007	-0.02	-0.008	0.007	0.01	-0.087	0.038	0.023	0	-0.009
EVT1.3APL	0.038	0.075	-0.032	-0.016	0.053	-0.024	0.035	-0.011	0.011	0.028	-0.032	0.02	-0.003	0.007	0.023
EVT3.3APL	0.066	0.095	0.028	-0.005	0.044	0.012	0.057	-0.018	0.032	0.05	-0.092	0.002	0.029	0.042	0.036
EVT3.5APL	0.005	0.04	-0.094	-0.02	0.015	-0.08	-0.058	-0.057	-0.023	0.047	-0.109	-0.053	-0.067	-0.066	-0.065
NAT1.2APL	0.058	-0.001	0.004	0.029	-0.021	-0.016	-0.006	-0.012	-0.013	-0.044	0.191	-0.053	-0.026	0.036	0.007
NAT1.4APL	0.056	-0.003	-0.043	0.05	-0.017	-0.018	-0.023	0.032	0.052	-0.022	0.207	0.009	-0.041	0.022	0.005
NAT2.4APL	0.083	-0.09	0.024	0.006	-0.012	0.06	-0.028	-0.063	-0.037	-0.068	0.083	-0.032	-0.045	-0.023	-0.045
NAT2.6APL	0.064	-0.052	-0.018	0.017	-0.041	-0.014	0.015	0.031	0.039	-0.011	0.217	-0.02	0.01	0.039	0.03

	EVT0.1	EVT0.2	EVT0.3	EVT1.3	EVT3.3	EVT3.5	NAT1.2	NAT1.4	NAT2.4	NAT2.6
HRTANT_5_1APL										
HRTANT_5_4APL										
HRTANT_5_8APL										
HRTANT_6_1APL										
HRTANT_6_5APL										
HRTANT_6_7APL										
HRTANT_7_1APL										
HRTANT_7_4_APL										
HRTANT_7_8APL										
HRTCON_8_2APL										
HRTCON_8_8APL										
HRTCON_8_9APL										
HRTCON_9_3APL										
HRTCON_9_4APL										
HRTCON_9_8APL										
EVT0.1APL	0									
EVT0.2APL	0.025	0								
EVT0.3APL	-0.003	-0.019	0							
EVT1.3APL	-0.022	-0.03	0.03	0						
EVT3.3APL	0.017	-0.033	-0.002	-0.007	0					
EVT3.5APL	-0.04	0.066	0.02	0.005	0.005	0				
NAT1.2APL	-0.034	0.01	-0.003	-0.05	-0.009	0.022	0			
NAT1.4APL	0.008	0.046	-0.001	0.002	0.018	0.07	0	0		
NAT2.4APL	-0.01	-0.033	0.015	-0.055	-0.003	-0.01	0.002	0.032	0	
NAT2.6APL	0.006	0.01	0.001	0.047	-0.005	0.005	0.001	-0.025	0	0

III: Detailed Parameter Estimates (Standardized and Non Standardized)

CFA Non Standardized parameter estimates

lhs	op	rhs	est	se	z	pvalue	ci.lower	ci.upper
HRT_1	=~	HRTANT_5_1APL	1	0	NA	NA	1	1
HRT_1	=~	HRTANT_5_4APL	0.86021745	0.23401116	3.67596759	2.37E-04	0.401564	1.31887091
HRT_1	=~	HRTANT_5_8APL	3.1063409	0.59260333	5.24185527	1.59E-07	1.94485971	4.26782209
HRT_2	=~	HRTANT_6_1APL	1	0	NA	NA	1	1
HRT_2	=~	HRTANT_6_5APL	0.88197569	0.07382085	11.9475147	0	0.73728948	1.02666189
HRT_2	=~	HRTANT_6_7APL	1.10281935	0.08625587	12.7854416	0	0.93376096	1.27187774
HRT_3	=~	HRTANT_7_1APL	1	0	NA	NA	1	1
HRT_3	=~	HRTANT_7_4_APL	0.86201357	0.08341392	10.3341689	0	0.69852529	1.02550186
HRT_3	=~	HRTANT_7_8APL	0.83353919	0.08339566	9.99499429	0	0.67008669	0.99699169
HRT_4	=~	HRTCON_8_2APL	1	0	NA	NA	1	1
HRT_4	=~	HRTCON_8_8APL	0.68322834	0.11408666	5.98867885	2.12E-09	0.45962261	0.90683408
HRT_4	=~	HRTCON_8_9APL	0.92239889	0.09726648	9.48321473	0	0.7317601	1.11303769
HRT_5	=~	HRTCON_9_3APL	1	0	NA	NA	1	1
HRT_5	=~	HRTCON_9_4APL	1.05729801	0.09272741	11.4022167	0	0.87555563	1.23904039
HRT_5	=~	HRTCON_9_8APL	1.13886228	0.09014984	12.6329933	0	0.96217184	1.31555271
EVT_1	=~	EVT0.1APL	1	0	NA	NA	1	1
EVT_1	=~	EVT0.2APL	0.8751707	0.08041411	10.8832982	0	0.71756195	1.03277946
EVT_1	=~	EVT0.3APL	1.07230754	0.09271059	11.5661818	0	0.89059812	1.25401696
EVT_2	=~	EVT1.3APL	1	0	NA	NA	1	1
EVT_2	=~	EVT3.3APL	1.17329368	0.09692518	12.1051481	0	0.98332381	1.36326354
EVT_2	=~	EVT3.5APL	1.09941492	0.09897657	11.1078303	0	0.90542441	1.29340543
NAT_1	=~	NAT1.2APL	1	0	NA	NA	1	1
NAT_1	=~	NAT1.4APL	0.85718643	0.09975381	8.5930191	0	0.66167255	1.05270032
NAT_2	=~	NAT2.4APL	1	0	NA	NA	1	1
NAT_2	=~	NAT2.6APL	1.22901038	0.14864824	8.26791059	2.22E-16	0.93766518	1.52035558
HRTANT_5_1APL	~~	HRTANT_5_1APL	0.67601281	0.05485021	12.3247088	0	0.56850838	0.78351724
HRTANT_5_4APL	~~	HRTANT_5_4APL	0.6063853	0.04901691	12.3709414	0	0.51031393	0.70245667
HRTANT_5_8APL	~~	HRTANT_5_8APL	0.44861092	0.08851867	5.06798056	4.02E-07	0.27511751	0.62210433
HRTANT_6_1APL	~~	HRTANT_6_1APL	0.37120154	0.0347039	10.6962474	0	0.30318314	0.43921995
HRTANT_6_5APL	~~	HRTANT_6_5APL	0.33968245	0.03081107	11.0246895	0	0.27929387	0.40007103
HRTANT_6_7APL	~~	HRTANT_6_7APL	0.402072	0.03861307	10.4128482	0	0.32639178	0.47775222
HRTANT_7_1APL	~~	HRTANT_7_1APL	0.56267414	0.05250862	10.7158438	0	0.45975914	0.66558914
HRTANT_7_4_APL	~~	HRTANT_7_4_APL	0.42544612	0.03955565	10.7556354	0	0.34791847	0.50297376
HRTANT_7_8APL	~~	HRTANT_7_8APL	0.45446108	0.04120281	11.0298556	0	0.37370505	0.53521711
HRTCON_8_2APL	~~	HRTCON_8_2APL	0.4838152	0.04472357	10.8179019	0	0.39615861	0.57147178
HRTCON_8_8APL	~~	HRTCON_8_8APL	0.79053601	0.06460092	12.2372259	0	0.66392054	0.91715148
HRTCON_8_9APL	~~	HRTCON_8_9APL	0.31913793	0.03174495	10.0531878	0	0.25691897	0.38135688
HRTCON_9_3APL	~~	HRTCON_9_3APL	0.36055467	0.03622103	9.95429132	0	0.28956276	0.43154658
HRTCON_9_4APL	~~	HRTCON_9_4APL	0.49765336	0.04752484	10.4714362	0	0.40450638	0.59080035
HRTCON_9_8APL	~~	HRTCON_9_8APL	0.3527356	0.03901359	9.0413521	0	0.27627037	0.42920083
EVT0.1APL	~~	EVT0.1APL	0.3378673	0.03340758	10.1134907	0	0.27238963	0.40334496
EVT0.2APL	~~	EVT0.2APL	0.28677138	0.02766	10.3677302	0	0.23255878	0.34098397
EVT0.3APL	~~	EVT0.3APL	0.3230022	0.03374721	9.57122742	0	0.25685889	0.38914552
EVT1.3APL	~~	EVT1.3APL	0.35017862	0.03521518	9.94396762	0	0.28115814	0.41919911
EVT3.3APL	~~	EVT3.3APL	0.31681514	0.03717574	8.52209357	0	0.24395203	0.38967825
EVT3.5APL	~~	EVT3.5APL	0.45206714	0.044684	10.1169792	0	0.3644881	0.53964618
NAT1.2APL	~~	NAT1.2APL	0.39491498	0.0727905	5.42536422	5.78E-08	0.25224822	0.53758174
NAT1.4APL	~~	NAT1.4APL	0.67516689	0.07225127	9.3447062	0	0.533557	0.81677678
NAT2.4APL	~~	NAT2.4APL	0.57895719	0.06084083	9.51593255	0	0.45971136	0.69820301
NAT2.6APL	~~	NAT2.6APL	0.46785003	0.07056542	6.63001825	3.36E-11	0.32954435	0.60615571

lhs	op	rhs	est	se	z	pvalue	ci.lower	ci.upper
HRT_1	~~	HRT_1	0.072831	0.02767455	2.63169533	0.008496	0.01858987	0.12707213
HRT_2	~~	HRT_2	0.41563712	0.0581853	7.14333601	9.11E-13	0.30159603	0.5296782
HRT_3	~~	HRT_3	0.45192983	0.07261417	6.22371425	4.86E-10	0.30960868	0.59425099
HRT_4	~~	HRT_4	0.27792877	0.0520763	5.33695295	9.45E-08	0.17586109	0.37999644
HRT_5	~~	HRT_5	0.41912818	0.05933709	7.06351121	1.62E-12	0.30282963	0.53542673
EVT_1	~~	EVT_1	0.34133613	0.05094592	6.69996978	2.08E-11	0.24148396	0.4411883
EVT_2	~~	EVT_2	0.3703661	0.05458366	6.7852924	1.16E-11	0.26338409	0.47734811
NAT_1	~~	NAT_1	0.66070893	0.10194717	6.48089499	9.12E-11	0.46089614	0.86052172
NAT_2	~~	NAT_2	0.37560261	0.07232223	5.19346008	2.06E-07	0.23385364	0.51735157
HRT_1	~~	HRT_2	0.17713041	0.0369326	4.79604457	1.62E-06	0.10474384	0.24951698
HRT_1	~~	HRT_3	0.15237552	0.03346636	4.55309498	5.29E-06	0.08678266	0.21796838
HRT_1	~~	HRT_4	0.10930809	0.02517424	4.34206169	1.41E-05	0.05996749	0.15864869
HRT_1	~~	HRT_5	0.1457507	0.03146169	4.63264064	3.61E-06	0.08408692	0.20741448
HRT_1	~~	EVT_1	0.09371873	0.02225731	4.21069476	2.55E-05	0.05009521	0.13734226
HRT_1	~~	EVT_2	0.08755371	0.02148865	4.0744173	4.61E-05	0.04543674	0.12967069
HRT_1	~~	NAT_1	-0.0530886	0.02101976	-2.5256533	0.01154834	-0.0942866	-0.0118907
HRT_1	~~	NAT_2	-0.0527336	0.01800155	-2.929391	0.00339627	-0.088016	-0.0174512
HRT_2	~~	HRT_3	0.38181642	0.04825492	7.91248654	2.44E-15	0.28723851	0.47639433
HRT_2	~~	HRT_4	0.28976434	0.03958397	7.32024526	2.48E-13	0.21218119	0.36734749
HRT_2	~~	HRT_5	0.35393024	0.04338911	8.15712104	4.44E-16	0.26888914	0.43897134
HRT_2	~~	EVT_1	0.25503957	0.03600823	7.08281236	1.41E-12	0.18446473	0.32561441
HRT_2	~~	EVT_2	0.24631032	0.03612545	6.81819305	9.22E-12	0.17550573	0.31711491
HRT_2	~~	NAT_1	-0.1338999	0.04153192	-3.2240227	0.00126403	-0.2153009	-0.0524988
HRT_2	~~	NAT_2	-0.1257953	0.03425074	-3.6727754	2.40E-04	-0.1929255	-0.0586651
HRT_3	~~	HRT_4	0.35557028	0.04718131	7.53625329	4.84E-14	0.26309662	0.44804394
HRT_3	~~	HRT_5	0.36964413	0.04768397	7.75195725	9.10E-15	0.27618525	0.463103
HRT_3	~~	EVT_1	0.26835552	0.03963882	6.77001731	1.29E-11	0.19066486	0.34604619
HRT_3	~~	EVT_2	0.26996917	0.04039247	6.68365032	2.33E-11	0.19080138	0.34913697
HRT_3	~~	NAT_1	-0.0635423	0.04430309	-1.4342639	0.15149697	-0.1503748	0.02329014
HRT_3	~~	NAT_2	-0.0636669	0.03523318	-1.8070152	0.07075991	-0.1327227	0.00538887
HRT_4	~~	HRT_5	0.29290886	0.03994853	7.33215536	2.26E-13	0.21461117	0.37120655
HRT_4	~~	EVT_1	0.23440537	0.03465399	6.76416704	1.34E-11	0.1664848	0.30232594
HRT_4	~~	EVT_2	0.19922492	0.03299303	6.03839472	1.56E-09	0.13455977	0.26389006
HRT_4	~~	NAT_1	0.00127526	0.03722093	0.03426194	0.97266827	-0.0716764	0.07422695
HRT_4	~~	NAT_2	-0.0653943	0.03017033	-2.1675023	0.03019658	-0.124527	-0.0062615
HRT_5	~~	EVT_1	0.20139207	0.03317199	6.07114748	1.27E-09	0.13637615	0.26640798
HRT_5	~~	EVT_2	0.19691738	0.03356166	5.86733151	4.43E-09	0.13113774	0.26269703
HRT_5	~~	NAT_1	-0.0274675	0.0399219	-0.6880312	0.49143316	-0.105713	0.05077797
HRT_5	~~	NAT_2	-0.0621609	0.03200826	-1.9420261	0.05213394	-0.1248959	5.74E-04
EVT_1	~~	EVT_2	0.3050175	0.03860056	7.90189286	2.66E-15	0.22936179	0.38067321
EVT_1	~~	NAT_1	-0.1214347	0.03800226	-3.1954601	0.00139608	-0.1959178	-0.0469516
EVT_1	~~	NAT_2	-0.1371511	0.03245275	-4.226177	2.38E-05	-0.2007573	-0.0735448
EVT_2	~~	NAT_1	-0.1317116	0.03909767	-3.3687827	7.55E-04	-0.2083416	-0.0550815
EVT_2	~~	NAT_2	-0.0798453	0.03070045	-2.6007848	0.00930108	-0.140017	-0.0196735
NAT_1	~~	NAT_2	0.39339541	0.05795571	6.78786236	1.14E-11	0.2798043	0.50698652

CFA Standardized parameter estimates

lhs	op	rhs	est.std	se	z	pvalue	ci.lower	ci.upper
HRT_1	=~	HRTANT_5_1APL	0.31186203	0.05547609	5.62155791	1.89E-08	0.2031309	0.42059316
HRT_1	=~	HRTANT_5_4APL	0.28569514	0.05617381	5.08591319	3.66E-07	0.17559649	0.39579379
HRT_1	=~	HRTANT_5_8APL	0.78126315	0.05008033	15.6001987	0	0.6831075	0.8794188
HRT_2	=~	HRTANT_6_1APL	0.72679899	0.0309584	23.476634	0	0.66612165	0.78747634
HRT_2	=~	HRTANT_6_5APL	0.69832475	0.03295567	21.1898214	0	0.63373282	0.76291667
HRT_2	=~	HRTANT_6_7APL	0.74631206	0.02960076	25.2126009	0	0.68829564	0.80432848
HRT_3	=~	HRTANT_7_1APL	0.66740157	0.03719719	17.9422587	0	0.59449642	0.74030672
HRT_3	=~	HRTANT_7_4_APL	0.66417569	0.03738704	17.7648655	0	0.59089845	0.73745294
HRT_3	=~	HRTANT_7_8APL	0.63922233	0.03886635	16.4466781	0	0.56304568	0.71539897
HRT_4	=~	HRTCON_8_2APL	0.60403519	0.04344655	13.9029482	0	0.51888151	0.68918887
HRT_4	=~	HRTCON_8_8APL	0.37546908	0.05265557	7.13066181	9.99E-13	0.27226606	0.47867211
HRT_4	=~	HRTCON_8_9APL	0.6523826	0.04164713	15.6645282	0	0.57075573	0.73400947
HRT_5	=~	HRTCON_9_3APL	0.73318647	0.03242099	22.614561	0	0.66964249	0.79673044
HRT_5	=~	HRTCON_9_4APL	0.69636996	0.03494495	19.9276284	0	0.62787912	0.7648608
HRT_5	=~	HRTCON_9_8APL	0.77876484	0.02944878	26.4447273	0	0.7210463	0.83648338
EVT_1	=~	EVT0.1APL	0.70891015	0.03474906	20.4008458	0	0.64080325	0.77701705
EVT_1	=~	EVT0.2APL	0.69057506	0.03595062	19.2089906	0	0.62011315	0.76103697
EVT_1	=~	EVT0.3APL	0.74064505	0.03272866	22.6298585	0	0.67649805	0.80479206
EVT_2	=~	EVT1.3APL	0.71694385	0.03438272	20.8518669	0	0.64955496	0.78433274
EVT_2	=~	EVT3.3APL	0.7853384	0.03013341	26.0620465	0	0.726278	0.84439881
EVT_2	=~	EVT3.5APL	0.70537537	0.03514767	20.0689076	0	0.6364872	0.77426354
NAT_1	=~	NAT1.2APL	0.79113478	0.04459333	17.7411005	0	0.70373346	0.87853611
NAT_1	=~	NAT1.4APL	0.64674419	0.04589445	14.0919903	0	0.55679271	0.73669567
NAT_2	=~	NAT2.4APL	0.62728186	0.04759126	13.1806109	0	0.53400471	0.72055901
NAT_2	=~	NAT2.6APL	0.74030524	0.04665311	15.8682929	0	0.64886682	0.83174366
HRTANT_5_1APL	~~	HRTANT_5_1APL	0.90274207	0.03460177	26.0894757	0	0.83492385	0.9705603
HRTANT_5_4APL	~~	HRTANT_5_4APL	0.91837829	0.03209717	28.6124369	0	0.85546899	0.98128759
HRTANT_5_8APL	~~	HRTANT_5_8APL	0.38962789	0.07825184	4.97915325	6.39E-07	0.23625711	0.54299868
HRTANT_6_1APL	~~	HRTANT_6_1APL	0.47176323	0.04500107	10.483379	0	0.38356276	0.55996369
HRTANT_6_5APL	~~	HRTANT_6_5APL	0.51234255	0.04602752	11.1312224	0	0.42213027	0.60255483
HRTANT_6_7APL	~~	HRTANT_6_7APL	0.44301831	0.0441828	10.02694	0	0.35642161	0.52961501
HRTANT_7_1APL	~~	HRTANT_7_1APL	0.55457514	0.04965092	11.1694827	0	0.45726112	0.65188916
HRTANT_7_4_APL	~~	HRTANT_7_4_APL	0.55887065	0.04966312	11.2532319	0	0.46153271	0.65620858
HRTANT_7_8APL	~~	HRTANT_7_8APL	0.59139482	0.04968848	11.9020519	0	0.49400719	0.68878244
HRTCON_8_2APL	~~	HRTCON_8_2APL	0.63514149	0.0524865	12.101046	0	0.53226985	0.73801313
HRTCON_8_8APL	~~	HRTCON_8_8APL	0.85902297	0.03954108	21.7248232	0	0.78152387	0.93652206
HRTCON_8_9APL	~~	HRTCON_8_9APL	0.57439694	0.05433972	10.5704799	0	0.46789304	0.68090084
HRTCON_9_3APL	~~	HRTCON_9_3APL	0.4624376	0.04754126	9.72707863	0	0.36925844	0.55561677
HRTCON_9_4APL	~~	HRTCON_9_4APL	0.51506888	0.04866923	10.5830506	0	0.41967895	0.61045881
HRTCON_9_8APL	~~	HRTCON_9_8APL	0.39352533	0.04586734	8.5796411	0	0.30362699	0.48342366
EVT0.1APL	~~	EVT0.1APL	0.49744639	0.04926792	10.0967608	0	0.40088305	0.59400974
EVT0.2APL	~~	EVT0.2APL	0.52310609	0.0496532	10.5351943	0	0.42578761	0.62042457
EVT0.3APL	~~	EVT0.3APL	0.4514449	0.04848065	9.31185788	0	0.35642458	0.54646523
EVT1.3APL	~~	EVT1.3APL	0.48599152	0.04930096	9.85764888	0	0.38936342	0.58261961
EVT3.3APL	~~	EVT3.3APL	0.38324359	0.04732985	8.09729096	6.66E-16	0.29047878	0.4760084
EVT3.5APL	~~	EVT3.5APL	0.50244558	0.0495846	10.1330966	0	0.40526155	0.59962962
NAT1.2APL	~~	NAT1.2APL	0.37410576	0.07055867	5.30205212	1.15E-07	0.2358133	0.51239821
NAT1.4APL	~~	NAT1.4APL	0.58172195	0.05936394	9.79924751	0	0.46537077	0.69807314
NAT2.4APL	~~	NAT2.4APL	0.60651747	0.05970627	10.1583552	0	0.48949533	0.7235396
NAT2.6APL	~~	NAT2.6APL	0.45194815	0.06907509	6.54285316	6.04E-11	0.31656347	0.58733283

lhs	op	rhs	est.std	se	z	pvalue	ci.lower	ci.upper
HRT_1	~~	HRT_1	1	0	NA	NA	1	1
HRT_2	~~	HRT_2	1	0	NA	NA	1	1
HRT_3	~~	HRT_3	1	0	NA	NA	1	1
HRT_4	~~	HRT_4	1	0	NA	NA	1	1
HRT_5	~~	HRT_5	1	0	NA	NA	1	1
EVT_1	~~	EVT_1	1	0	NA	NA	1	1
EVT_2	~~	EVT_2	1	0	NA	NA	1	1
NAT_1	~~	NAT_1	1	0	NA	NA	1	1
NAT_2	~~	NAT_2	1	0	NA	NA	1	1
HRT_1	~~	HRT_2	1.01807048	0.06149333	16.5557875	0	0.89754577	1.13859519
HRT_1	~~	HRT_3	0.83988837	0.06667168	12.5973784	0	0.70921428	0.97056246
HRT_1	~~	HRT_4	0.768294	0.07665456	10.0228084	0	0.61805382	0.91853419
HRT_1	~~	HRT_5	0.83421711	0.06179671	13.4993782	0	0.71309779	0.95533643
HRT_1	~~	EVT_1	0.59439775	0.06976971	8.51942417	0	0.45765164	0.73114387
HRT_1	~~	EVT_2	0.53309036	0.07025561	7.58786941	3.24E-14	0.39539191	0.67078882
HRT_1	~~	NAT_1	-0.2420128	0.08211048	-2.9474048	0.00320453	-0.4029464	-0.0810792
HRT_1	~~	NAT_2	-0.3188341	0.08428087	-3.7829949	1.55E-04	-0.4840216	-0.1536466
HRT_2	~~	HRT_3	0.88097166	0.04031235	21.8536434	0	0.80196091	0.95998241
HRT_2	~~	HRT_4	0.8525523	0.05284654	16.1326026	0	0.74897497	0.95612962
HRT_2	~~	HRT_5	0.84798287	0.03625207	23.3912971	0	0.77693013	0.91903562
HRT_2	~~	EVT_1	0.67711007	0.05010986	13.5125117	0	0.57889655	0.77532359
HRT_2	~~	EVT_2	0.62778341	0.0518589	12.1056053	0	0.52614182	0.72942499
HRT_2	~~	NAT_1	-0.2555159	0.07334978	-3.4835261	4.95E-04	-0.3992788	-0.1117529
HRT_2	~~	NAT_2	-0.3183779	0.07487584	-4.2520779	2.12E-05	-0.4651318	-0.1716239
HRT_3	~~	HRT_4	1.00328242	0.05132071	19.5492717	0	0.90269568	1.10386915
HRT_3	~~	HRT_5	0.84932689	0.04150125	20.465092	0	0.76798593	0.93066784
HRT_3	~~	EVT_1	0.6832567	0.0543549	12.5702867	0	0.57672305	0.78979035
HRT_3	~~	EVT_2	0.6598771	0.05429664	12.1531859	0	0.55345765	0.76629655
HRT_3	~~	NAT_1	-0.1162847	0.07981356	-1.456954	0.14512907	-0.2727164	0.04014701
HRT_3	~~	NAT_2	-0.1545304	0.08265876	-1.8694978	0.06155359	-0.3165386	0.00747782
HRT_4	~~	HRT_5	0.85820755	0.05157579	16.639735	0	0.75712085	0.95929425
HRT_4	~~	EVT_1	0.76104383	0.05864883	12.976283	0	0.64609423	0.87599342
HRT_4	~~	EVT_2	0.62095667	0.0647341	9.59242044	0	0.49408017	0.74783316
HRT_4	~~	NAT_1	0.00297596	0.08685831	0.03426226	0.97266802	-0.1672632	0.17321512
HRT_4	~~	NAT_2	-0.2023991	0.08868559	-2.2822096	0.02247697	-0.3762197	-0.0285785
HRT_5	~~	EVT_1	0.53244874	0.05812568	9.16030156	0	0.4185245	0.64637297
HRT_5	~~	EVT_2	0.49979857	0.05850425	8.5429441	0	0.38513234	0.6144648
HRT_5	~~	NAT_1	-0.0521964	0.07560807	-0.6903553	0.48997081	-0.2003855	0.09599266
HRT_5	~~	NAT_2	-0.1566677	0.07768578	-2.0166842	0.04372848	-0.308929	-0.0044064
EVT_1	~~	EVT_2	0.85786313	0.03623522	23.6748397	0	0.7868434	0.92888287
EVT_1	~~	NAT_1	-0.2557094	0.07389305	-3.4605333	5.39E-04	-0.4005371	-0.1108816
EVT_1	~~	NAT_2	-0.3830396	0.07336018	-5.2213565	1.78E-07	-0.526823	-0.2392563
EVT_2	~~	NAT_1	-0.2662583	0.07227267	-3.68408	2.30E-04	-0.4079101	-0.1246065
EVT_2	~~	NAT_2	-0.2140766	0.07664556	-2.7930721	0.00522101	-0.3642991	-0.063854
NAT_1	~~	NAT_2	0.78969593	0.06021455	13.1147026	0	0.67167758	0.90771429