Application of Smart Contracts in the Reinsurance Industry

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Executive summary

The reinsurance industry provides insurance companies with coverage by assuming a portion of their risks, thereby assisting insurers in mitigating potential liabilities. Its fundamental objective is to bolster insurers' stability through the distribution of risks, thus safeguarding them from substantial or unforeseen losses.

Current market developments in the reinsurance industry, including high inflation and an increase in claim severity and frequency are exerting financial pressure on the reinsurance industry. In response to these market dynamics, reinsurers employ strict underwriting criteria and raise reinsurance premium. This process, characterized by more meticulous drafting of reinsurance contracts, bears resemblance to an industry-wide formalization that commenced in the 1970s. Presently, this formalization is once again driving up non-productive costs.

The formalization of reinsurance contracts carries substantial ramifications for the operational efficiency of the industry. The escalation of non-productive costs stands in direct contradiction to the fundamental goal of the reinsurance sector, which is the efficient allocation of risk and capital. Given the mounting costs, encompassing administrative costs and dispute resolution costs, it becomes imperative for the reinsurance sector to carefully consider alternative strategies for contract formalization.

This paper aims to explore how smart contracts can contribute to achieving this objective. Smart contracts are computerized transaction protocols that can automate contract clauses, potentially aligning better with the industry's purpose. To assess their efficiency, a focused examination was conducted on the impact of their implementation on transaction costs. These costs pertain to the expenses borne by both the insurer and reinsurer to execute the economic transaction.

To shed light on the potential of smart contracts in reinsurance, I conducted an exploratory design study by translating an existing reinsurance contract into a smart contract using pseudocode. The effectiveness of the design, which incorporated the translated smart contract, was evaluated through expert interviews with professionals from both the reinsurance industry and smart contract experts, with a specific focus on the impact on two types of transaction costs: administrative costs and dispute resolution costs.

Firstly, the results suggest that a smart contract effectively reduces administrative costs in the reinsurance industry. Smart contracts can automate certain administrative tasks, thereby diminishing the need for human intervention in their execution. The trade volume's size and the level of standardization significantly influence the justification for implementing a smart contract.

Secondly, the results suggest that the effect of a smart contract on dispute resolution costs is more nuanced. While a smart contract enhances contract certainty between insurers and reinsurers, formalizing contracts to accommodate fair dispute resolution can be challenging. Additionally, the reinsurance industry benefits to some extent from human interpretation, limiting the potential of a smart contract to reduce dispute resolution costs.

In conclusion, smart contracts can be implemented in the reinsurance industry to reduce transaction costs. However, the industry may not be ideally suited for this technology, considering the significant financial stakes involved and the need for post-implementation adjustments. A specific recommendation is to explore the potential of smart contracts in industries where disputed amounts are generally smaller and trust between contract partners is lower than in the reinsurance industry.

Acknowledgements

This thesis represents an expression of my personal interests and the acquired learning process translated into an academic format. My fascination with smart contracts, blockchain, and their societal impacts was piqued in 2017, following the cryptocurrency bull market. Since then, I have been deeply intrigued by the applications of smart contracts and the value they can bring to industries. The culmination of my designed smart contract framework within the reinsurance industry context—an industry I initially had limited knowledge of—proved to be a compelling learning journey. The thought-provoking conclusions of this research owe much to the active support, discussions, and insights shared with my three supervisors.

First, I extend my gratitude to Prof. Dr. M.J.G. van Eeten for his incisive inquiries at the outset of my research, which significantly sharpened the research's framework. Additionally, S. Renes, Ph.D., LLM, has been invaluable to this study, providing continuous support throughout its execution and elevating the institutional analysis to a higher level. Lastly, I wish to specially thank Dr. Ir. R. van Bergem for his insightful perspectives and optimism during the course of my research. His assistance in crafting a worthy study proved to be essential, particularly during the ideation phase.

I look back with great positivity on the personal guidance and insights gained, and I hope that my work contributes to a better comprehension of the potential of smart contracts in reducing transaction costs, as well as their applicability in the reinsurance industry.

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1. Introduction

Trust plays a pivotal role in facilitating commercial transactions across various industries. Establishing trust is crucial, and one effective method is through the implementation of contracts that outline the rights and obligations of the involved parties. Contracts serve as legally binding documents designed to mitigate potential disputes or misunderstandings in the future, while also deterring opportunistic behavior by the counterparty (Lu et al., 2016). The level of trust between parties significantly influences the manner in which contracts are drafted. Specifically, when there is a lack of trust in the other party, a higher degree of formalization is typically required (Faems et al., 2008). Conversely, when a high level of trust exists, the need for extensive formalization diminishes. In cases where trust is strong and the risk of opportunism is perceived as negligible, contractual relationships may necessitate less formalization. Parties may opt for less formal contractual arrangements, relying more on informal agreements or verbal understandings (Blanchard, 2021).

This research entails an explorative design study conducted within the European reinsurance industry, with a specific focus on bilateral contracts established between insurers and reinsurers. The aim of this study is to scrutinize the contractual dynamics between insurer and reinsurer, exploring whether the formalization of these contracts can be designed more efficiently through smart contracts.

Historically, the reinsurance market operated as a closely-knit community. However, this paradigm has shifted as a result of globalization and the subsequent influx of market participants, leading to its transformation into a more loosely connected business network (Blanchard, 2021). Throughout much of the reinsurance industry's history, spanning from its emergence in the mid-nineteenth century to the latter part of the twentieth century, transactions between reinsurers were primarily characterized by informality. This is corroborated by Blanchard (2021), who asserts that: ''Contracts were drawn up informally, and were often incomplete; they were not subject to formal dispute resolution, and they possessed vague standards and implied reciprocal obligations'' (p. 23).

Starting in 1970, the reinsurance industry underwent a significant transformation due to a rise in the severity and frequency of claims, leading to increased formalization within the industry. This surge in claims was triggered by the recognition of a causal relationship between asbestos use and lung problems in the field of medicine (Wilt & Zimmerman, 2016), along with a growing number of environmental tort litigation cases (G3: 25th April, 2023). As a result, the industry witnessed larger disputed amounts, altering the previously amicable and reputation-based relationships into more commercially focused relationships. This resulted in an increased likelihood of disputes between parties (Blanchard, 2021).

To adapt to these changing circumstances, contracts in the industry began to involve lawyers more frequently. This resulted in more comprehensive contractual agreements and a reduced reliance on informal understandings. However, this shift had inevitable consequences, as reinsurance contracts grew lengthier, and the associated costs of contract placement increased (G3: 25th April, 2023). The formalization process also manifested in the evolution of dispute resolution methods within the industry. Due to concerns surrounding confidentiality and perceived limitations in expertise among traditional judges, arbitration emerged as the preferred approach for resolving disputes (Blanchard, 2021, pp.22-24). While arbitration remains the predominant method for dispute resolution (DRD, 2023), the arbitration processes in the reinsurance sector have gradually taken on characteristics akin to ordinary litigation proceedings (Schiffer, 2010). Consequently, this has led to escalated time and financial costs associated with dispute resolution (G3: 25th April, 2023). In conclusion, the relationship between insurers and reinsurers is subject to constant change, as evident through the evolving nature

of contract drafting, dispute resolution methods, and the accompanying costs. These transformations reflect the industry's response to the increased severity and frequency of claims, and the need for more formalized and structured approaches in addressing contractual disputes (Blanchard, 2021).

Presently, the reinsurance industry is on the verge of another tipping point, prompted by a recent shift in market dynamics. The current landscape is characterized by various factors, including mounting inflation, a surge in claims stemming from environmental catastrophes (Moody's, 2023), and the escalating risks associated with cyber incidents (Jakubik, 2021). These developments have instilled a sense of risk aversion among reinsurers, thereby challenging the existing reinsurance market framework. Given the evolving market dynamics, the reinsurance industry faces the task of reevaluating its formalization strategies. The traditional methods of formalization, which involve lengthy contractual agreements and the establishment of formal arbitration procedures, may require reexamination to ascertain their compatibility with the present market landscape.

The structure of this study is as follows: chapter 2. Research context provides a comprehensive analysis of the issues at hand, specifying my research problem and objective. Moving on to chapter 3. Theoretical perspective, I review the existing literature on the topic, identify knowledge gaps, and formulate my research questions. In chapter 4. Research Methodology, I discuss the research methodology employed to answer these questions. Chapter 5. Transaction costs analysis focuses on defining the costs associated with the execution of reinsurance contracts, while chapter 6. Institutional analysis examines the institutional environment within which the reinsurance industry operates, by examining certain transactions in greater detail. In chapter 7. Design, I present a design proposal aimed at addressing the identified knowledge gaps, and evaluate its effectiveness from various perspectives. Next, in chapter 8. Conclusion, I provide a summary of my findings and address potential limitations of this paper and suggestions for further research. Finally, in chapter 9. Reflection, I will engage in a reflective analysis of this paper, encompassing the research process and the attained conclusions. In addition, I will reflect on possible roles blockchain can play within the reinsurance industry.

2. Research context

The research context will be described by a current dynamic of several factors in the reinsurance industry. Firstly, in section 2.1 Research motivation, I will outline the research motivation. Here, I will delve into the escalating severity and frequency of claims, and draw comparisons between the present response of the reinsurance industry and its formalization process from the 1970s. Subsequently, in section 2.2 Relevance and problem statement I will address the significance of this issue, elucidating the research problem. Following that, in section 2.3 Research objective, I will expound upon my research objective. Lastly, in section 2.4 Summary and scope of research problem, I will provide a summary and outline the scope of my research problem.

2.1 Research motivation

In recent years, the reinsurance industry has witnessed an escalation in both the severity and frequency of claims. These growing claims exert financial pressure on reinsurers, who, under reinsurance contracts, bear partial responsibility for compensating the incurred damages by insurers. The rise in claims can be attributed to two significant factors: natural disasters and cyberattacks. The frequency of natural disasters has surged in recent years, largely due to environmental changes. Floods, storms, droughts, wildfires, and extreme temperatures have significantly increased during the past decade (Moody's, 2023). This surge in natural disasters has led to a 10% decline in reinsurers' profitability over the same period (Moody's, 2023). Furthermore, the reinsurance sector faces pressure due to a rise in cyberattacks. The COVID-19 pandemic has led to an increase in remote work, contributing to a higher number of cyberattacks (Jakubik, 2021). Even after the pandemic, the preference for remote work seems to persist, fueling concerns about the frequency of cyberattacks (Da Silva et al., 2023).

The expectation is that the severity and frequency of claims will continue to rise in the coming years, amplifying the demand for reinsurance (Pande & Mitchell, 2023). Simultaneously, Nordblom (2023), notes that ‘’reinsurers are currently taking little risks due to the unstable economic environment.’’ (para. 4). Considering that the availability of reinsurance is consequently quite restricted, this leads to elevated reinsurance costs due to the law of supply and demand (Nordblom, 2023). These trends have resulted in a reinsurance market that is presently characterized as a "hard reinsurance market," wherein reinsurers adopt a risk-averse approach. This attitude manifests in two significant traits: escalating premiums and stringent underwriting criteria (Nordblom, 2023).

Firstly, with the aim of maintaining profitability, reinsurers are compelled to raise premiums. Significant losses from natural catastrophes, for example, shrink reinsurance companies’ reserves, causing them to raise rates to replenish them (Marx, 2020). The price of reinsurance inherently rises for insurers, who must pay increasing premiums to offload risks onto reinsurers. Secondly, stringent underwriting criteria are employed in the formulation of reinsurance contracts. Underwriters involved in creating these contracts meticulously assess losses, safety records, and financials of their counterparties before accepting a particular risk (Marx, 2020).

This process of higher premiums and rigorous underwriting criteria bears similarity to the reinsurance industry's evolution in the 1970s, when a growing number of claims led to a more formal industry (Blanchard, 2021). As described in the introduction, the formalization process from the 1970s onwards involved legal experts in the drafting of reinsurance contracts (G3: 25th April, 2023) and a more formal dispute resolution approach (Blanchard, 2021). Currently, an increase in the severity and frequency of claims seems once again to be the catalyst for a formalization process in the reinsurance industry, resulting in higher premiums and stricter underwriting criteria. Moreover, disputes are increasingly resolved in a formal manner, with previously informal arbitration disputes beginning to resemble

conventional judicial proceedings (Schiffer, 2010). In the next section (2.2 Relevance and problem statement), I will demonstrate that this formalization process is accompanied by an increase in non-productive costs. For a further explanation of formalization, I refer the reader to appendix C.

2.2 Relevance and problem statement

The reinsurance industry is currently experiencing a rise in non-productive costs. While section 5.3 Approximations of transaction costs aims to quantify this increase, I will focus here on examining the specific causes of this escalation.

Non-productive costs refer to all expenses that are not directly related to the primary productive purpose of the industry, ''which is the efficient allocation of risk and capital.'' (Munich Re, 2016, p.4). The increase in non-productive costs reduces profitability and can hinder the efficiency of the reinsurance industry, limiting its capacity to allocate risk and capital (Deloitte Advisory, 2018). The increase in non-productive costs appears to be a direct result of the increase in claim severity and frequency through two channels:

- **Channel 1:** In the first channel, the growing frequency of claims leads to rising administrative costs (Hannover Re, 2022). Reinsurers simply require more time and resources to process and handle a larger volume of incoming claims (Thorpe, 2004).
- **Channel 2:** In the second channel, the growing severity of claims is causing the industry to formalize. As evidenced in section 2.1 Research motivation, reinsurance contracts are increasingly being more strictly formalized to accommodate the higher risk aversion of reinsurers. The process of stricter formalization of reinsurance contracts entails incurring additional costs, as evident from the formalization process that took place from the 1970s onwards (G3: 25th April, 2023). Additionally, disputes are being resolved in a more formal manner, rendering them more akin to litigation proceedings (Schiffer, 2010). With larger claims, the general expectation is that reinsurers will want to allocate more time and resources to (a) investigating the claim and (b) formally resolving disputes related to these substantial claims (Blanchard & Jennejohn, 2019).

Given the dynamics discussed above, involving the increase in claim frequency and severity alongside the corresponding rise in non-productive costs, I can specify the research problem as follows. The increase in claims in terms of frequency and severity, as in the past, once again triggers a process of formalization in the reinsurance industry, resulting in a rise in non-productive costs. However, this escalation of non-productive costs directly contradicts the efficient allocation of risk and capital, which involves the primary purpose of the reinsurance industry. Munich Re (2016) suggests that the industry is approaching a tipping point in the balance between operational efficiency and the non-productive costs of reinsurance contracts. If the non-productive costs of reinsurance contracts become excessive, reinsurers are, in fact, insufficiently capable of fulfilling their primary objective.

According to Munich Re (2016), this implies that the industry then faces a choice between "(a) transitioning to more formal, commercial contracts [...] that come with higher costs and reduced efficiency, or (b) evolving towards a model that achieves the intended goal of being an economically efficient mechanism for bringing capital into the markets with limited frictional costs." (p.4). For the remainder of this study, I will refer to option 'a' as traditional contract formalization. As Munich Re (2016) indicates, it is known that this approach leads to an increase in non-productive costs. For the latter option, I will explore an alternative method of formalization that potentially better aligns with the industry's objective than the traditional formalization process. In the next section (2.3 Research objective) I will specify my research objective.

2.3 Research objective

Expanding upon the defined research problem, this section will elaborate on my research objective. Recognizing that the current formalization process of reinsurance contracts in the industry results in an increase in non-productive costs, my investigation will strive to enhance the efficiency of this formalization process.

Acknowledging the intricacies of measuring efficiency, I will assess efficiency through the lens of transaction costs. To achieve this, I will apply Williamson's Transaction Cost Economics (TCE) theory, where the transaction serves as the "basic unit of analysis" (Williamson, 1981, p. 548). Transaction costs encompass the costs incurred in the process of conducting economic transactions (Williamson, 1981). In the context of the reinsurance industry, transaction costs are the expenses incurred to facilitate the allocation of risk and capital. These costs do not directly contribute to the transaction's primary objective; instead, they stem ‘’from economic trade within a market.’’(Corporate Finance Institute, 2019, para. 1).

TCE distinguishes between two types of transaction costs: ex ante and ex post transaction costs. Ex ante costs, as defined by Williamson (1989), encompass all costs incurred prior to the actual transaction, while ex post costs refer to all costs incurred after the transaction has taken place. It is crucial to recognize that the formulation of any contract type necessitates a careful equilibrium between these two facets. As scholars indicate, extended contracts may reduce ex post costs, but have a negative effect on ex ante costs (Williamson, 1981; Crocker and Reynolds, 1993). Extended contracts generally lower the probability of disputes because the contract is more 'complete', but the costs related to scheduling the exchange and writing the contract become higher. In chapter 5. Transaction costs analysis, I will undertake a comprehensive examination of the definitions of ex ante and ex post transaction costs within the context of the reinsurance industry. For two types of ex post transaction costs in the reinsurance industry, namely administrative costs and dispute resolution costs, I have been able to obtain data. A database from EIOPA (European Insurance Occupational Pensions Authority) (EIOPA, 2022) has provided me with data on administrative costs, and a database from Dispute Resolution Data (DRD, 2023) has supplied me with data on dispute resolution costs. How I will quantify this data is described in 5.3 Approximations of transaction costs. I will now specify my research objective as follows:

Given that the industry is currently experiencing an increase in non-productive costs related to the formalization of traditional reinsurance contracts, I will explore an alternative method of formalization. If such an alternative method of contract formalization results in lower transaction costs, it could facilitate the industry's ability to achieve more efficient risk and capital allocation. Since I have found data on the administrative costs and dispute resolution costs of traditional reinsurance contracts, I will measure the effectiveness of the alternative contract formalization based on these two ex post transaction costs. First, in section 2.4, I provide a summary of this chapter and define the scope of my research problem.

2.4 Summary and scope of research problem

In summary, the reinsurance sector is confronted with a twofold challenge: the escalation of claims due to natural disasters and cyberattacks, which strains reinsurers financially. In response, reinsurers are raising premiums and implementing stricter underwriting criteria. This has triggered a trend of formalization reminiscent of the 1970s, resulting in elevated non-productive costs that contradict the fundamental objective of the industry. Munich Re (2016), a prominent reinsurer, underscores a pivotal juncture where the industry faces a choice between adopting more expensive, less efficient formal contracts or embracing a model that optimizes capital allocation while minimizing frictional costs. As a solution, this study strives to enhance the efficiency of formalization by leveraging the principles of Transaction Cost Economics to examine the impact of transaction costs on the efficiency and consequences of reinsurance contract formalization. Through an exploration of an alternative formalization approach, this study aims to mitigate ex post transaction costs in comparison to conventional reinsurance contracts, ultimately promoting a more streamlined allocation of risk and capital.

The scope of my research problem is visualized in the causal diagram in Figure 1. A "+" symbol indicates a positive causal link, and vice versa. Furthermore, it is evident that I focus specifically on the role of formalization in reinsurance contracts and the associated transaction costs. My scope is specifically directed towards examining the interplay among these factors, driven by the consensus in interview input (G1: 13th April, 2023, G3: 25th April, 2023, G8: 21st June, 2023) that underscores the formalization of reinsurance contracts as a primary driver behind the escalation of nonproductive costs. The two channels discussed in 2.2 Relevance and problem statement are also depicted in the causal diagram.

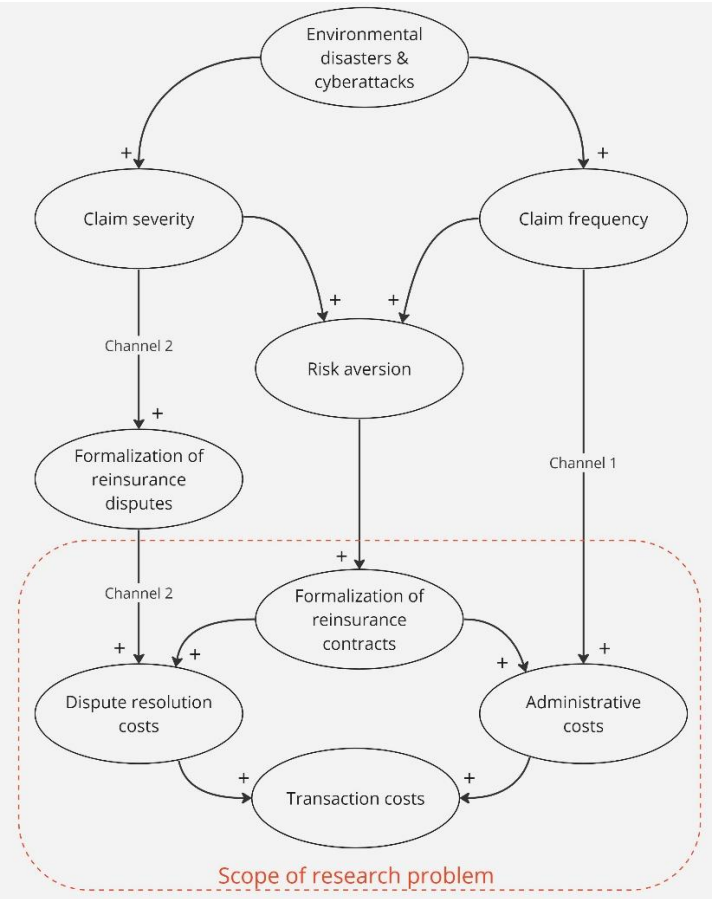

Figure 1: Causal diagram and research scope

3. Theoretical perspective

The evolving landscape of the reinsurance industry, as discussed in chapter 2. Research context, underscores the critical need for innovative solutions to address the challenges posed by escalating claims, rising non-productive costs, and the conflicted nature of current formalization processes.

In light of these challenges, the industry is actively seeking alternative approaches to contract formalization. A rising trend in the reinsurance sector involves the adoption of smart contracts, facilitated through blockchain technology. Smart contracts, powered by blockchain technology, offer a distinctive blend of automation (Zou et al., 2019), transparency, and security (Loukil et al., 2021) that holds promise for the reinsurance industry. Both reinsurers and insurers are placing greater emphasis on the implementation of smart contracts as a means to enhance efficiency in the reinsurance industry and reduce transaction costs (Mukhopadhyay, 2023; Mendoza-Tello et al., 2021).

This chapter delves into the potential of smart contracts as a transformative solution for mitigating transaction costs within the reinsurance industry. To this end, I undertake a comprehensive literature review with several objectives. First, in 3.1.1 Panel A: impact of smart contracts on transaction costs I aim to establish a correlation between smart contract implementation and transaction costs in a general context. Additionally, in 3.1.2 Panel B: Smart contract applications and initiatives in the reinsurance industry I explore existing applications to gain insights into the applicability of smart contracts in the reinsurance sector. Finally, in 3.2 Research questions I will specify my research questions derived from the literature review I conducted.

3.1 Literature review

Here I will reflect on existing literature related to my paper. Section 3.1 Literature review, provides an overview of the findings from the literature review. In total, 12 studies are selected for the review analysis. For all studies, the author(s), research focus, data, methodology/ approach and results are shown.

Table 1: Literature review

Study	Research Focus	Data	Methodology/ Approach	Results
Panel A: Impact of smart contracts on transaction costs				
Zheng et al (2020)	Presenting challenges and technical advances in smart contracts	Literature	Literature research	Smart contracts can cut down administration and save services costs
Ahluwalia et al. (2020)	Analyzing blockchain economics and smart contracts' impact on transaction costs	Literature	Appliance of Transaction Costs Economics (TCE)	Primary cost reduction achieved by reducing search costs and eliminating third-party intermediary in the system
Davidson & Potts (2022)	Theorizing about the impact of blockchain and smart contracts from an economic perspective	Literature	Appliance of Institutional Economics	The most efficient institution to coordinate economic efficiency is the one that achieves the desired outcome at lowest transaction costs
Højlund & Nielsen (2019)	Exploring impact of smart contracts on transaction costs in international trade	Interviews	Maximum variation case study	Smart contracts can be used to economize on transaction costs for transactions of simple to mixed complexity, but do not eliminate the need for integration in complex transactions
Vatiero (2018)	Challenging the claim that smart contracts can reduce transaction costs	Literature	Literature research	A chief drawback of smart contracts is their lack of external adaptive mechanisms
Panel B: Smart contract applications and initiatives in the (re)insurance industry				
PwC (n.d.a)	Blockchain is a $5-10 billion cost saving opportunity for reinsurance	Interviews	Market exploration	The potential wins are automatic processing, entry into new markets or products, and full transparency
Popovic et al. (2020)	Assessing and adopting blockchain in the (re)insurance industry	Literature	Case study	Blockchain (re)insurance applications and use cases will mature, and adoption will increase
Hans et al. (2017)	Analysis of blockchain technologies paired with smart contracts	Two field applications	Case study	The technologies offer extraordinary potential in all areas where a trustful record of every transaction is needed
Albrecher et al. (2019)	Main topics and findings regarding	Swiss Risk and	Summarizing	Unclear whether smart contracts are viable for the

	digitalization of insurance and reinsurance industry	Insurance Forum 2018		greater part of reinsurance type risk transfers
Sayegh & Desoky (2019)	Proposition of smart contracts in insurance and reinsurance	Interviews	Case study	Proponents of initiatives argue adoption of smart contracts will lead to major costs cuts, unclear whether smart contracts will have a disruptive effect
Abramowicz (2019)	Application of smart contracts in (re)insurance	Literature	Case study	Blockchain-based insurance is more transparent and trustworthy than traditional insurance, but the legal system poses barriers for application
Shetty et al. (2022)	Exploring the potential of blockchain and smart contracts in the (re)insurance industry	23 papers	Case study	Blockchain has the potential to improve productivity and mitigate complexity of the reinsurance processes

3.1.1 Panel A: impact of smart contracts on transaction costs

The paper by Coase (1937) marks the initial exploration of the significance of transactions and the associated costs. Building upon Coase's work, the formal theory of transaction costs (TCE) was established through the contributions of Williamson (1979, 1989). This paper is rooted in the central premise of TCE, which asserts that economic agents, whether individuals or organizations, encounter transaction costs when engaging in market transactions. Here, transaction costs play an undeniable role in influencing whether and how economic transactions occur. Hence, if a smart contract influences transaction costs, it also plays a role in determining whether a transaction will occur or not.

Before delving into the potential relationship between smart contracts and transaction costs, it is necessary to define smart contracts. While various definitions of smart contracts can be found in the literature, I will adopt the definition by Szabo (1994): "a computerized transaction protocol that executes the terms of a contract." (para. 1). Interestingly, as implied by Szabo's definition, smart contracts can be implemented in environments beyond blockchain technology (Tippins, 2023). Notably, from the overview of the literature review (Table 1), it is evident that blockchain is frequently associated with smart contracts. Therefore, I will briefly address the use of blockchain as an infrastructure for smart contracts.

Blockchain is a decentralized digital ledger technology that facilitates secure and transparent record-keeping of transactions. It operates through a network of computers, known as nodes, which collaboratively validate and store each transaction within a sequence of interconnected blocks, forming a continuous chain. Miners hold a pivotal role in the verification of transactions through the resolution of cryptographic challenges (Davidson & Potts, 2022). Due to the immutable nature inherent in blockchain-based smart contracts, these contract types, according to the literature, have the capability to mitigate opportunism. Moreover, since consensus mechanisms determine the truth, blockchain has the potential to reduce the costs associated with trust (Potts & Berg, 2019). While these claims hold promise within the reinsurance sector, due to time constraints, this paper does not extensively delve into the role of blockchain. For an analysis of why blockchain is a potentially suitable infrastructure in the context of reinsurance, I direct the reader to appendix D. In addition, in the reflection, I will briefly reflect on two ways in which blockchain has the potential to assist in reducing two types of transaction costs.

Although the vast majority of authors claim that the implementation of smart contracts reduces transaction costs (Zheng et al., 2020; Ahluwalia et al., 2020), Vatiero (2020) claims that this is not the case. For example, Vatiero (2018) argues that smart contracts have a major disadvantage over ordinary contracts, given ''the inflexibility to ex post external adaptation.'' (p.6). The literature widely acknowledges a discernible correlation between the implementation of smart contracts and transaction costs, irrespective of being positive or negative. Consequently, many authors advocate approaching the impact of smart contracts through the lens of Transaction Costs Economics (TCE).

Interestingly, there does not seem to be a clear consensus on what exactly transaction costs comprise, and what types of transaction costs are affected by the implementation of smart contracts. Zheng and colleagues (2020), for example, argue that the implementation of smart contracts can reduce administrative costs and service costs. According to Zheng and colleagues (2020), ‘’smart contracts stored in blockchains can be automatically triggered, reducing third-party intervention.’’ (p.476). Some authors have similar ideas about the effect of smart contract on third-parties, but take that notion even further. According to Ahluwalia and colleagues (2020), for example, the implementation of a smart contract completely eliminates the need for third-parties.

This research will not specifically focus on whether certain third parties are eliminated by the application of smart contracts. However, I will investigate to what extent certain forms of transaction costs are affected by the implementation of a smart contract design. Only if the design reduces transaction costs that are largely or entirely attributed to one specific party can I discuss a potential elimination of a third party. Højlund and Nielsen (2019) add a dimension to the question of whether smart contracts can reduce transaction costs by looking at the complexity of the transaction. They conclude that the greater the transaction's complexity, the lower the reduction in transaction costs (Højlund & Nielsen, 2019).

Two observations can be made, looking at existing literature on the relationship between smart contracts and transaction costs. First, there is no clear overview of the type of transaction costs that smart contracts can reduce, nor is there a consensus on this in the literature. Second, many studies claim that smart contracts can reduce transaction costs without doing an exploration on how this happens or under which circumstances this transaction cost reduction occurs.

3.1.2 Panel B: Smart contract applications and initiatives in the reinsurance industry

The practical implementation of blockchain and smart contracts is notably limited, to put it mildly. One of the practical initiatives was B3i, a collaborative initiative comprising multiple insurance and reinsurance companies that aimed to investigate the potential of blockchain technology in the insurance industry. It was launched in 2016 with the goal of developing blockchain solutions to improve efficiency, transparency, and trust in insurance processes such as reinsurance contracts, claims handling, and data sharing (Meeusen, 2017). B3i introduced a prototype smart contract for a property catastrophe excess of loss contract, aimed at automating claims handling and using blockchain to share a single version of truth.

While B3i initially generated significant interest and support from various industry players, it faced challenges and ultimately underwent a transformation rather than outright failure. In July of 2022, ''the company announced its bankruptcy, explaining that it had not been able to raise the funds it needed to continue its activity'' (Graillot, 2023, para. 14). According to Dacey (2023), Chief Financial Officer at Swiss Re, the initiative was not seeing the volumes and demand that would have justified continued investment in this platform.

A more recent initiative comes from reinsurer Re, which uses blockchain to increase transparency and flexibility (Canny, 2022). According to Mukhopadhyay (2023), Re showed significant growth in Q1 of 2023, ''backing $34 million in premiums and insuring tens of thousands of small businesses across various industries since its launch in late 2022.'' (para. 1). Re uses a smart contract protocol built on the Avalanche blockchain. According to CEO and co-founder Karn Saroya, this design was inspired by Lloyd's of London, with the ecosystem representing a reinsurance marketplace (Mukhopadhyay, 2023). Saroya further revealed that they have a significant advantage over traditional reinsurers in terms of administrative costs (Mukhopadhyay, 2023). The company consists of only 7 full-time employees due to a high degree of automation. Saroya indicated that their expenses related to legislative compliance is also very low, as all information can be standardized and presented to regulators in real-time (Mukhopadhyay, 2023).

Whereas the practical implementation of blockchain and smart contracts is generally inconclusive about its applicability within the reinsurance industry, theory does not seem to be able to formulate a conclusive answer either. Theoretical assessments regarding the impact of a smart contract on the industry range from extremely negative (Edmonds, 2019), to extremely positive (PwC, n.d.a). For instance, Edmonds (2019) concludes that the implementation of smart contracts and blockchain to increase trust makes little sense, since ‘’the (re)insurance industry is by nature a 'trust entity’’’(para. 19). According to Edmonds (2019), ‘’implementation would be expensive, highly inefficient, and involve additional cost layers.’’ (para.19). At the other end of the spectrum is PwC's market exploration (n.d.a), which claims that the application of smart contracts can positively impact the industry in several ways. According to PwC (n.d.a), reinsurance expense ratios average 5-10 percent of premiums, and blockchain applications like smart contracts can reduce these costs by 15-25 percent, ''delivering an industry-wide saving of $5-10 billion.'' (p.4). Literature positioned between these two extremes suggests, for instance, that uncertainty persists regarding whether smart contracts are applicable to the majority of reinsurance transfers (Albrecher et al., 2019) or if smart contracts might potentially exert a disruptive influence on the industry (Sayegh & Desoky, 2019).

Abramowicz (2019) investigates the insurance industry, claiming that smart contracts in blockchain-based insurance have certain legal challenges. According to Abramowicz (2019), the succession of smart contracts in blockchain-based insurance ‘’requires a legislative commitment that the ECB will exchange cryptocurrency units for dollars’’, for example; ‘’otherwise, excessive volatility could arise’’ (p.23). In addition, the author argues that both the risk of legislative prohibition of blockchain-based insurance and the complete absence of legislation could lead to alternative inefficiencies (Abramowicz, 2019).

Now, I will briefly summarize the outcomes of the two panels and formulate two hypotheses that will be used to formulate the research questions in Section 3.2. From the literature review, it can be concluded that the application of blockchain and smart contracts is a highly contentious subject within the (re)insurance industry. The theoretical perspectives on this form of application vary dramatically, ranging from concerns over an unnecessary increase in complexity and decrease in efficiency to the potential cost savings of up to $10 billion across the industry. In practical terms, blockchain and smart contracts can be applied in industry, but to what extent it can reduce transaction costs is not clear. Simultaneously, the Re initiative suggests a potential reduction in administrative and regulatory costs. Additionally, Meeusen (2017) suggests that the implementation of blockchain-based smart contracts can lead to a decrease in dispute resolution costs.

As described in Section 2.4, this research will specifically focus on the ex post transaction costs for which data has been obtained, namely administrative costs and dispute resolution costs. Based on this information, the following hypotheses can be formulated:

1. The implementation of smart contracts in the reinsurance industry leads to a reduction in administrative costs.

2. The implementation of smart contracts in the reinsurance industry leads to a reduction in dispute resolution costs.

What is noteworthy about these two hypotheses is that both administrative costs and dispute resolution costs are forms of ex post transaction costs. It is possible that the application of smart contracts may result in an increase in ex ante transaction costs, given that a smart contract potentially formalizes more aspects than a traditional reinsurance contract. Whether this is indeed the case is beyond the immediate focus of this paper. I am specifically investigating the impact of smart contract implementation on two ex post transaction costs. In the conclusion, I will further discuss the implications of this in addressing the research questions.

3.2 Research questions

The application of smart contracts within the reinsurance industry has sparked controversy both in theory and practice. The theoretical perspective presents conflicting views, with proponents suggesting that blockchain and smart contracts are ideally suited for reinsurance, while detractors argue that their implementation could significantly decrease efficiency.

Despite some reinsurers like Re already employing blockchain and smart contracts, the relatively low demand for this application, as seen in B3i's initiative, raises questions about its broader suitability and acceptance within the industry. A primary knowledge gap lies in determining whether smart contracts can be effectively applied in the reinsurance sector. Furthermore, the relationship between the implementation of smart contracts and transaction costs remains largely uncertain, and there is a lack of clarity regarding the mechanisms through which smart contracts may impact ex post transaction costs.

Given these uncertainties and knowledge gaps, my research aims to address the extent to which the implementation of smart contracts is applicable in the reinsurance industry. Additionally, I seek to gain clarity on how smart contracts contribute to reducing ex post transaction costs.

The main research question of this study reads: How can the implementation of smart contracts reduce ex post transaction costs in the reinsurance industry?

To address this main research question, I have formulated two sub-questions, namely sub-question 1 (SQ1) and sub-question 2 (SQ2). Both sub-questions are then subdivided into two additional sub-questions, resulting in a total of 6 sub-questions. I will first elaborate on SQ1 and its sub-questions in Section 3.2.1 and subsequently delve into SQ2 and its sub-questions in Section 3.2.2. For each sub-question, I will briefly specify its relevance and briefly discuss the methods employed for its answer. The complete details of the applied methods in this paper are described in Chapter 4.

3.2.1 SQ1 and corresponding sub-questions

Sub-question 1 (SQ1) focuses on the measurement aspect, aiming to determine how to assess whether the design of smart contracts effectively reduces ex post transaction costs in the reinsurance industry.

> **SQ1 reads: How can the reduction of ex post transaction costs in the reinsurance industry due to smart contract design be evaluated?**

By addressing this sub-question, the paper establishes a framework or methodology for evaluating the impact of smart contracts on ex post transaction costs. To this end, it is firstly crucial to acquire an overview of the distinct types of transaction costs, as emphasized in sub-question 1.1.

> **SQ1.1 reads: What types of transaction costs can be distinguished in the reinsurance industry?**

Additionally, obtaining an estimate of the magnitude of these costs before and after the implementation of smart contracts holds significance. Sub-question 1.2 is devoted to approximating these transaction costs.

> **SQ1.2 reads: For which of these types of transaction costs can we find approximations?**

The methodologies utilized to address sub-questions 1.1 and 1.2 are delineated in chapter 4 and also visualized in figure 2.

3.2.2 SQ2 and corresponding sub-questions

Sub-question 2 (SQ2) delves into the specific mechanisms through which smart contracts lower transaction costs. This sub-question aims to identify and analyze the key features and functionalities of smart contracts that contribute to the reduction of transaction costs in the reinsurance industry.

SQ2 reads: How does a smart contract lower transaction costs?

It explores the potential benefits, such as automation, transparency and improved efficiency that smart contracts can bring to the reinsurance processes. To address this question, a reengineering approach will be employed (see 4.4 Development of smart contract: Reengineering), wherein a traditional reinsurance contract will be translated into a smart contract. Following the establishment of the smart contract, its efficacy in reducing transaction costs will be assessed through semi-structured interviews (see 4.5 Semi-structured interviews). Additionally, for SQ2, I have formulated two supplementary sub-questions (2.1 and 2.2).

SQ2.1 reads: How can a reinsurance contract be translated into a smart contract?

For the translation into the smart contract, I will follow the reengineering approach as described in section 4.4 Development of smart contract: Reengineering. To achieve this, I will begin by applying reverse engineering to a conventional reinsurance contract. This will help me extract design requirements and functions. Next, I will abstract this information into a swimlane diagram. Subsequently, through a forward engineering process, I will translate the swimlane into a smart contract.

Lastly, to assess the effectiveness of the smart contract design, I will examine the influence on various types of transaction costs. This is particularly relevant for the types of transaction costs where I have identified approximations, as it allows me to discuss the potential reduction compared to the conventional scenario.

SQ2.2. Reads: What types of transaction costs of a traditional reinsurance contract are impacted through the smart contract?

In figure 2, all research questions are visualized with their corresponding methodologies.

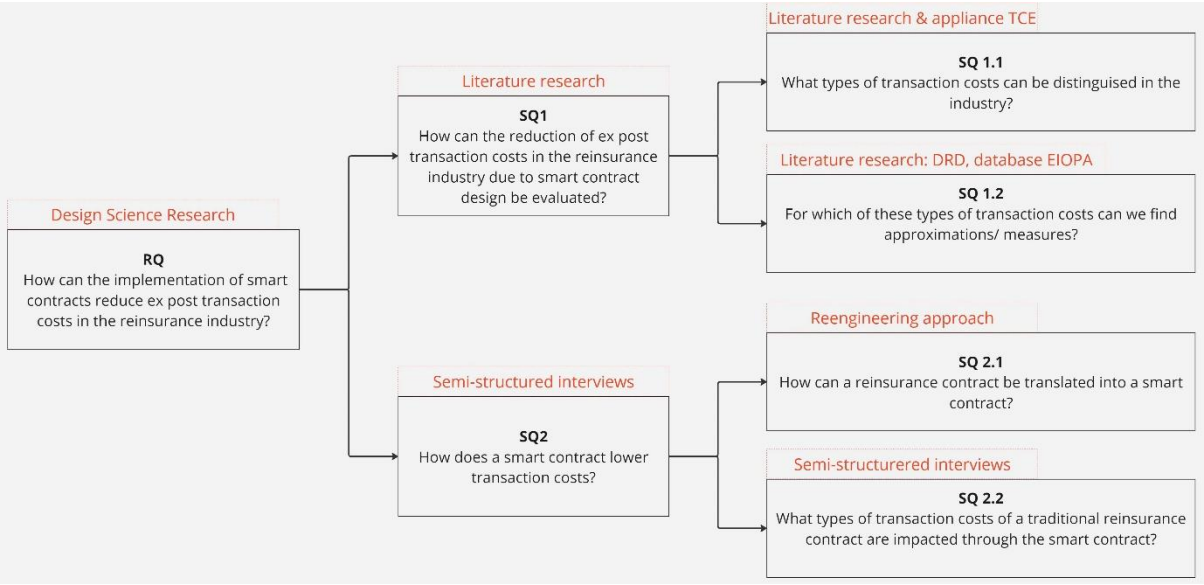

Figure 2: Issue-tree of research questions and corresponding methodologies

4. Research Methodology

This chapter explains the research methodology used to investigate the research questions specified in 3.2 Research questions. Herein I will explicitly name which methodologies I used to answer each of the sub-questions as shown in figure 2.

First, in 4.1 Literature research I illustrate how I used literature to identify transaction costs in the reinsurance industry. I then indicate how I selected the reinsurance contract to be translated from a database of delivered reinsurance contracts released by one of my interviewees in 4.2 Selection of reinsurance contract. Next, in 4.3 Design Science Research will then outline how I applied design science research in my study, to arrive at a design. Also, I will reflect on the reengineering approach I applied for the development of the smart contract design in 4.4 Development of smart contract: Reengineering. Finally, I will briefly illustrate how semi-structured interviews were used to improve my understanding of the research problem, to validate the effectiveness of my design, and to answer my main research question. An overview of the interviews conducted will be presented in 4.5 Semi-structured interviews.

4.1 Literature research

Initially, I conducted literature research to investigate what classes of transaction costs can be distinguished in the reinsurance industry. This enabled me to formulate an answer to sub-question 1.1. During the process of conducting research, the literature examining different types of transaction costs in the reinsurance industry proved to be limited. Therefore, I decided to approach the problem from a broader perspective, using Transaction Costs Economics (TCE).

Perceiving transaction costs as all costs not used for productive purposes, I delineated different categories of transaction costs, classifying them into either ex ante or ex post forms of transaction costs. I then applied this theoretical framework to the reinsurance industry by brainstorming what forms of transaction costs exist before and after a contract is signed.

As indicated in 2.2 Relevance and problem statement, I am specifically focusing on two types of ex post transaction costs, namely administrative costs and dispute resolution costs. There are two primary reasons for this choice. Firstly, based on section 3.1 Literature review, I have been able to formulate two hypotheses. The literature suggests a decrease in both administrative costs and dispute resolution costs through the implementation of a smart contract. Secondly, I am specifically concentrating on these two ex post transaction costs because I have found data regarding the magnitude of these cost components in reinsurance contracts. Without this data, it would be impossible to make a comparison between the traditional contract and the smart contract in terms of efficiency. 5.3 Approximations of transaction costs will provide approximations of these two types of ex post transaction costs.

4.2 Selection of reinsurance contract

In order to say something about a reduction of administrative costs and dispute resolution costs, I must make a direct comparison between a traditional reinsurance contract and the smart contract. To this purpose, I needed an existing reinsurance contract for which I could analyze the associated transaction costs. Reinsurance agreements are, however, confidential agreements (Schiffer, 2017), which made it impossible to access existing reinsurance contracts on the internet, besides exemplary templates. However, one of my interviewees was able to share a limited dataset of historical, anonymized reinsurance contracts.

This database contained 42 reinsurance contracts, of which 11 were facultative and 31 were treaty reinsurance contracts. The difference between these two types of contracts is described in appendix E. Three contracts were found to be unreadable and could not be translated. Table 2 shows the type of reinsurance offered for both facultative and treaty reinsurance contracts.

Table 2: Classification of reinsurance contracts in database

Type/ Classification	**Facultative**	**Type/ Classification**	**Treaty**
Excess-of-Loss (XoL)	9	Excess-of-Loss (XoL)	14
Illegible	2	Quota Share	10
		Surplus	4
		Other (coinsurance/ combination)	2
		Illegible	1
Total	11	Total	31

After analyzing the given database, it appeared that the treaty contracts were not sufficiently specific to be translated into a smart contract. The interviewee supported this notion, stating that facultative contracts are inherently more specific, smaller, and better suited for translation into if-then statements compared to treaty contracts (G1: 13th April, 2023). The question of whether treaty contracts can also be translated into a smart contract is interesting but falls outside the scope of this analysis.

Due to the fact that the provided treaty contracts were too unspecific and contained many legal clauses that are difficult to formalize into binary clauses in the smart contract, I chose to translate a facultative reinsurance contract. According to a study by the OECD (2018), administrative costs related to surplus contracts are the highest, higher than those of excess of loss contracts and quota share. What surplus contracts are and why their administrative costs are generally higher than excess of loss contracts can be found in appendix E. However, since I was bound to facultative contracts, I was obliged to translate an excess of loss (XoL) contract. From these 9 contracts, I made an arbitrary choice.

4.3 Design Science Research

In this study, design science research was applied so that the design could iteratively be improved based on input from experts. To operationalize this framework, the first step involved articulating the problem, which is described in 2. Research context. After the problem was identified, I focused on delineating the research objective, initially described in 2.3 Research objective. This includes the reduction of transaction costs, so that the industry is better able to fulfill its primary purpose.

As already described in 3.2 Research questions, to determine a potential reduction in transaction costs, it is important to have an indication of the magnitude of these different cost categories. A database provided by Dispute Resolution Data (DRD, 2023), provided me with data on the magnitude of dispute resolution costs. In addition, a published dataset from the European Insurance and Occupational Pensions Authority (EIOPA, 2022) provided me with insights into the magnitude of administrative costs. As a result of finding approximations for these specific transaction costs the design goals were further refined to center on the reduction of dispute resolution costs and administrative costs. In appendix F, the established cost categories are combined with my research scope.

To develop the design, I applied reengineering, which is a sequence of reverse engineering, and forward engineering. A more detailed explanation of this method is described in 4.4 Development of smart contract: Reengineering. To investigate the extent to which the design can reduce transaction costs, I used semi-structured interviews. Based on the input provided by experts, I was able to evaluate the design and report my findings. I reflect on the implications of this approach in the conclusion. Each step undertaken in this methodology is linked to a particular design activity, as shown in figure 3.

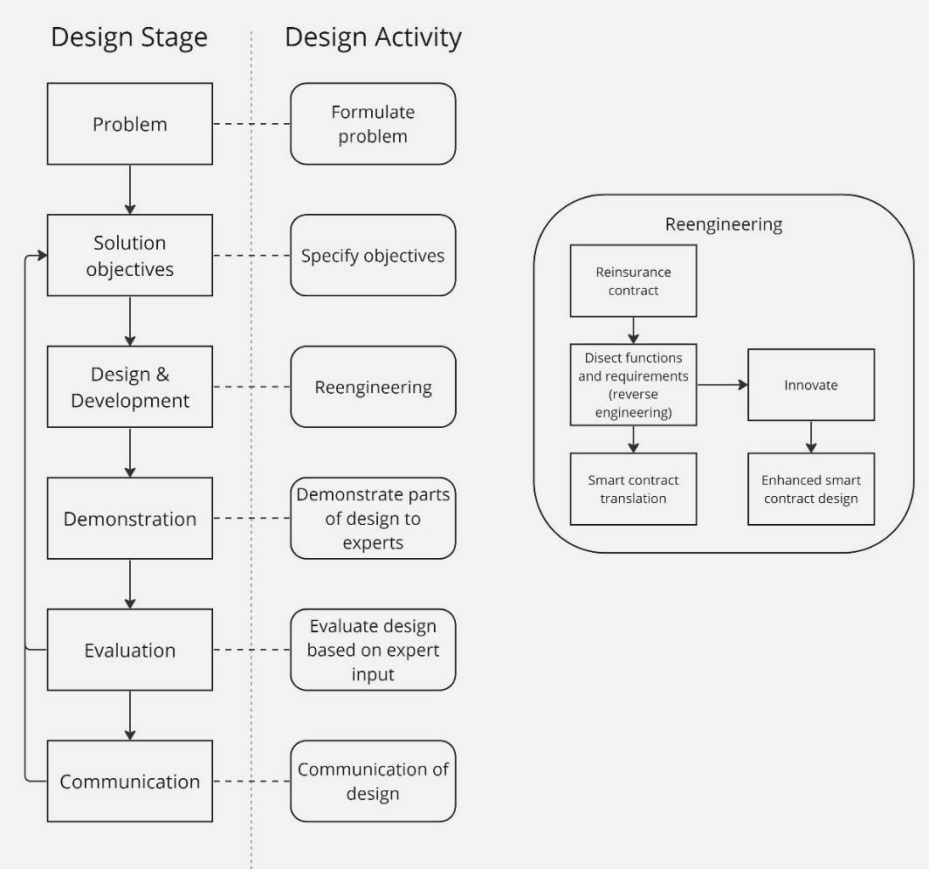

Figure 3: Application of Design Science Research

4.4 Development of smart contract: Reengineering

For the development of the design, I applied reengineering. Reengineering consists of two consecutive steps: reverse engineering and (forward) engineering. The approach of this paper was consistent with this, using reengineering for the construction of the design. According to Hevner (2007), who views Design Science Research as three closely related cycles of activities, the central design cycle forms a closer loop of research activities for the construction and evaluation of design artefacts and processes. The application of the reengineering method allowed me to address the manner in which a traditional contract can be translated into a smart contract, thereby providing a resolution to sub-question 2.1.

4.4.1 Reverse engineering

Reverse engineering is a methodology often used in Industrial Design Engineering (Raja & Fernandes, 2007) or Software Engineering (Tonella, 2005). What I want to do here is most akin to software engineering, since my design goal is to produce a pseudocode smart contract. Pseudocode is a high-level informal programming language-like notation used to describe the steps or algorithms of a computer program (Geeks for Geeks, 2023). It is not a specific programming language, but rather a simplified and human-readable representation of the logic of a code. The objective is to design a smart contract that is both implementable by a smart contract developer and geared towards reducing administrative and dispute resolution costs.

According to Canfora and Di Penta (2007), reverse engineering is ''a two-step process: information extraction and abstraction'' (p.2). What is different about this process compared to traditional software engineering is that the input to my reverse engineering process is a contract rather than code. Therefore, I could not fully rely on the traditional steps of software reverse engineering, but rather adapted the process to my needs. I applied the first step of reverse engineering by taking the most important functions from the traditional contract and translating these functions into requirements (Canfora & Di Penta, 2007). Having established the functions and requirements of the contract, I used a swimlane diagram to specify the operations of the smart contract. The swimlane visualization involved the second step of the reverse engineering approach: abstraction.

4.4.2 Forward engineering

I used the output from the reverse engineering process, which encompassed the established requirements and swimlane diagram, as input for the forward engineering process. The forward engineering step involved the translation of the traditional contract to the smart contract.

For the translation to the smart contract, I used pseudocode. Considering the objective of this paper, the utilization of pseudocode simplified the research process. In particular, the independence of pseudocode from the syntax or rules of a specific programming language made communication with experts more straightforward, eliminating concerns about language-specific intricacies.

4.5 Semi-structured interviews

A total of eight interviews were conducted with either reinsurance industry experts or smart contract/blockchain experts. The purpose of these interviews was twofold. First, because the amount of available information on the reinsurance industry proved marginal, the first four interviews were exploratory in nature. In these interviews, I gathered information about the problem situation in the reinsurance industry, certain forms of transaction costs, and how smart contracts and blockchain could potentially provide a solution to this. Then, after developing my design, I conducted the last four interviews to evaluate the effectiveness of my design. By posing questions regarding how the design impacts particular transaction costs in comparison to the traditional reinsurance contract, I enabled the resolution of sub question 2.2. Moreover, through the employment of interviews, I achieved a broader evaluation of the design, encompassing its efficacy within the context of relevant contextual factors (see 7.4.3 Design implications: three lenses). The experts estimated the extent to which the design could potentially reduce certain transaction costs, and the degree of applicability in the reinsurance industry. The experts' input is summarized and presented in appendix G.

Table 3 presents an anonymous listing of my respondents, including their expertise, interview type, position, organizational affiliation, and the corresponding interview reference in the appendix. Please take note that the third interview conducted involves the same respondent as the eighth interview conducted.

Table 3: Interviews conducted

Expertise	**Interview type**	**Position**	**Organizational affiliation**	**Appendix**
Reinsurance, formalization	Exploratory	Associate Professor of Law	Notre Dame Law School	G1
Smart contracts and blockchain	Exploratory	Lecturer	Tiber AFM, TU Delft Blockchain Lab	G2
Reinsurance and arbitration	Exploratory	Lawyer, arbiter	Schiffer Law & Consulting PLLC, member ABA, executive director ARIAS US	G3
Smart contracts and blockchain	Exploratory	Board Room advisor	Emerging Horizons, PhD Candidate TU Delft, Technology Policy and Management	G4
Smart contracts and blockchain	Design evaluation	PhD Student	TU Delft Blockchain Lab, Distributed systems	G5
Smart contracts and blockchain	Design evaluation	Senior Innovation Consultant	Capgemini	G6
Reinsurance	Design evaluation	Manager Operations Reinsurance Solutions	Aon	G7
Reinsurance and arbitration	Design evaluation	Lawyer, arbiter	Schiffer Law & Consulting PLLC, member ABA, executive director ARIAS US	G8

5. Transaction costs analysis

Transaction costs play a critical role in the reinsurance industry, impacting various aspects of the market. These costs encompass the resources expended in activities such as information acquisition (Gibson et al., 2014) and the negotiation of reinsurance contracts (G8: 21st June, 2023).

One of the knowledge gaps that emerged from conducting the literature review in 3. Theoretical perspective is that it is mostly unclear what type of transaction costs are affected by the implementation of a smart contract. Before I can pronounce on what types of transaction costs are affected by a smart contract, it is important to have a clear overview of what types of transaction costs can be intercepted in the execution of reinsurance contracts. To do this, I will apply the theory of Transaction Costs Economics (TCE) to categorize the types of transaction costs.

In 5.1 Transaction Costs Economics, I will discuss the meaning of TCE in a general sense. Using the interviews conducted and literature research, I was able to categorize and define the types of transaction costs, which are described in 5.2 Transaction costs in reinsurance. This enabled me to provide an answer to sub-question 1.1. Using available data surrounding two of these types (dispute resolution costs and administrative costs) I was able to make an approximation. How these two types of transaction costs are approximated is described in section 5.3 Approximations of transaction costs, which enabled me to provide an answer to sub-question 1.2. Finally, in section 5.4 Summary analysis, I will provide a summary of this chapter.

5.1 Transaction Costs Economics

For the establishment of types of transaction costs, I used the theory of Transaction Costs Economics (TCE) (Williamson, 1981). According to Williamson (1981), “The transaction cost approach to the study of economic organization regards the transaction as the basic unit of analysis and holds that an understanding of transaction cost economizing is central to the study of organizations.” (p.548). TCE emphasizes the role of transaction costs in shaping the structure and governance of these transactions. According to Williamson (1981), transaction costs include the various costs incurred in conducting economic exchanges in addition to the actual price of the goods or services involved. These costs arise due to factors such as information asymmetry, opportunism, uncertainty (appendix I) and the complexity of coordinating and enforcing agreements. The decision to execute a transaction within a market or through hierarchical governance depends on which option minimizes total transaction costs (Williamson, 1981). Now, I will define the different types of transaction costs in the reinsurance industry as defined in the literature.

5.2 Transaction costs in reinsurance

5.2.1 Search costs

To build a business relationship, cedents first search for suitable counterparties. Because the search for a counterparty occurs before the contract is drafted, search costs are a form of ex ante transaction costs. In the realm of reinsurance, the term "cedent" pertains to the original insurance company or insurer that shifts a portion of its insurance risk to a reinsurer through a process known as 'ceding'. Cedents and reinsurers select their counterparties based on reputation. Reputation includes factors such as solvency ratio, speed of claim payment, loss ratio and soundness of reinsurance (Blanchard, 2021). Based on statistical analysis, mathematical models and financial theory, companies try to calculate the probability of future events and their potential impact on the financial performance of their counterparties. In the reinsurance industry, actuaries and credit rating agencies are primarily responsible for these analyses (G3: 25th April, 2023). Actuaries are trained professionals working for a (re)insurance company, using mathematical, statistical and financial techniques to analyze risks, estimate future events, and determine appropriate pricing of reinsurance products. Credit rating agencies, on the other hand, are external, independent institutions that provide ratings on the financial stability of (re)insurance companies and brokers.

Thus, unlike actuaries' costs, the search costs incurred by credit rating agencies are not borne by (re)insurance companies and brokers. However, according to the Insurance Information Institute (n.d.), companies should not rely on what insurance companies say about their ratings from these agencies. Companies are ''likely to highlight a higher rating from one agency and ignore a lower rating from another or select the most favorable comments from a rating agency's report.'' (Insurance Information Institute, n.d., para. 3).

5.2.2 Placement costs

Whenever an insurance company finds a suitable counterpart, a contract has to be compiled. The placement costs refer to all costs incurred to compile the reinsurance contract. Just like the search costs, the placement costs are a form of ex ante transaction costs. Over the years, the placement costs have gone up significantly (G3: 25th April, 2023; Blanchard, 2021). One of my interviewees highlighted that whereas prior to the 1970s contracts were drafted on an informal 'back-on-a-napkin' basis, there are now lawyers involved in the placement process (G3: 25th April, 2023). This is one of the examples of how the market has become increasingly formal, as described in chapter 2. Research context. For a more comprehensive understanding regarding the placement of facultative reinsurance contracts, I direct the reader to appendix H. Based on literature by Hoffman (2002), I was able to visualize the placement process of facultative reinsurance contracts in a swimlane diagram.

5.2.3 Monitoring costs

Another large expense in the reinsurance industry is monitoring costs. In reinsurance, monitoring costs refer to the expenses incurred by the ceding insurer and reinsurer in overseeing and monitoring the activities of their respective counterparties. Since monitoring only occurs after the contract is drafted, this is a form of ex post transaction costs. For the reinsurer, these costs arise from the need to collect and review information on the ceding insurer's underwriting practices, claims handling procedures, risk management strategies and overall financial performance. Monitoring costs are an essential part of the reinsurance contract as the reinsurer seeks to protect its interests and manage the potential risks of the ceded policies. By actively supervising the ceding insurer, the reinsurer can ensure compliance with the agreed terms of the reinsurance contract and confirm that the ceding insurer has sound underwriting practices. Unlike search costs, which are costs incurred prior to contract placement, monitoring concerns costs are incurred after contract placement. Monitoring is one of the

resources in the reinsurance industry to mitigate moral hazard. Moral hazard occurs when ‘‘coverage against a loss induces the insured to take riskier or less cautious actions, resulting in higher probability of loss.’’ (Yan, 2013, p.4). In the reinsurance market, moral hazard can play a role in multiple ways. One example is when a reinsurer is more likely to pay out claims (and investigate claims less carefully) when the insurer knows that these claims are reinsured anyway. Conversely Niehaus and Mann (1992) indicate that ‘‘ceding companies’ monitoring of reinsurers is also important’’ (p.607), to mitigate the chance of insolvencies.

5.2.4 Administrative costs

Administrative costs are ‘‘all cost associated with opening, maintaining, changing or closing an insurance policy.’’ (Kagan & Brock, 2023, para.1). This technically makes administrative costs both an ex ante and an ex post form of transaction cost. Since the ex ante administrative cost only concerns the opening of a reinsurance contract, I choose to consider administrative costs as an ex post transaction cost in this report. The administrative costs related to opening a reinsurance contract are included in the placement costs. According to reinsurer Hannover Re (2023), a lower administrative expense ratio plays an important role in their competitive advantage. Hannover Re claims to have on average 2.9% lower administration costs compared to their competitors (Hannover Re, 2023). Insurers have the obligation to pay a premium to the reinsurer, while reinsurers are obligated to cover claims if the claim fall within the liability scope of the reinsurance contract. All costs associated with the processing of claims and premium are in this research allocated under the administrative costs.

5.2.5 Legal costs

Legal costs refer to all costs incurred by insurance and reinsurance companies to adhere to existing legislation. These costs are incurred after a reinsurance contract has been drafted, making this cost category a form of ex post transaction costs. According to one of my interviewees, legal costs in the European Union are much generally higher than legal costs in the United States, because there is much less regulation in the US (G3: 25th April, 2023). In the EU, there are a lot of legal requirements related to solvency, capital adequacy, and risk management, as outlined in the EU directive Solvency that entered into effect on January first, 2016 (De Nederlandsche Bank, 2023). The complete analysis of legislation with which the reinsurance industry must comply in the EU is described in appendix J2.

5.2.6 Dispute resolution costs

Finally, dispute resolution costs are borne when parties disagree about the interpretation of the contract. Dispute resolution costs are incurred when there is a dispute over the content of a previously drafted contract, thereby categorizing dispute resolution costs as a form of ex post transaction costs. As illustrated in 2. Research context, disputes in reinsurance are often resolved using arbitration, because companies in the reinsurance industry ‘‘do not want to rely on generalist courts to decide on the dispute, and the reinsurance industry values confidentiality.’’ (Blanchard, 2021, p.62). However, these costs are not marginal, and appear to have increased over time. The database shows that the average cost of an arbitration process in the reinsurance sector is about 350 thousand euro (DRD, 2023), which includes the arbitration institution’s fees, arbiter’s fees, and reimbursement for the legal costs for the prevailing party. Furthermore, the average time incurred to the award stands at 91 weeks (DRD, 2023). However, this is the data of arbitration cases that are resolved with arbitration; the cost and time may increase further, if there is non-compliance with the provided award. In that case, the dispute has to be brought to court (Schiffer, 2006). Even though the majority of cases (74%) are resolved through arbitration (DRD, 2023), there is no denying that the arbitration process, the most widely used method of dispute resolution in the reinsurance industry, is a costly and lengthy process.

5.3 Approximations of transaction costs

The types of transaction costs for which an approximation or measure was identified are the dispute resolution costs and the administrative costs. I will now attempt to quantify the dispute resolution costs and administrative costs successively, based on the available data.

5.3.1 Approximation of dispute resolution costs

To approximate dispute resolution costs, I will consider data regarding arbitration, which is the most commonly used method for resolving disputes in the reinsurance industry (DRD, 2023). The Dispute Resolution Data (DRD) database indicates that 74 percent of cases were handled through arbitration, whereas 26 percent underwent mediation processes (DRD, 2023). As a result, I am excluding mediation as a means of dispute resolution.

Arbitration costs in reinsurance were measured in two ways in the database of DRD: in terms of monetary costs, and in terms of time. As specified in 5.2.6 Dispute resolution costs, the monetary cost of an average arbitration process in reinsurance equals 350 thousand euros, and an arbitration process is settled in an average time span of 91 weeks.

Arbitration processes in the reinsurance industry are organized ad hoc by the parties together with the arbiters (Schiffer, 2006). Therefore, there is no standard arbitration process. Nevertheless, there are certain traditions in reinsurance disputes regarding the steps to be followed. Usually, an arbitration process starts with a written notice from one of the parties, wherein that party grants its counterparty a certain amount of time to select an arbiter. This written notice often contains a brief indication about the dispute (Schiffer, 2006). Once both parties have selected an arbiter, it is up to the arbiters to select an umpire. An umpire is a neutral third party appointed to resolve disputes between the ceding insurer (cedent) and the reinsurer when the appointed arbiters cannot reach a unanimous decision.

After the arbiters and umpire have been selected, a preliminary hearing is usually held. During this hearing, the initial 'written notices' from the parties are presented alongside the arbiters and the umpire, with the purpose of briefly discussing the essence of the dispute. Additionally, dates are agreed on for the scheduled hearing (Schiffer, 2006). Once the hearing is scheduled, the involved parties are afforded the chance to collect all relevant information, documents, and evidence. It is anticipated that they will subsequently present these materials to their respective arbiter. This process is called discovery (Schiffer, 2015). Then, the hearing will take place on the scheduled date, during which witness statements are taken and the arbiters form a decision. The award is either given immediately after the hearing, ''or may take place over the phone or in a series of conferences between the arbiters over a few weeks.'' (Schiffer, 2006, para.20). Often the arbitration clause within the contract states that the award of the arbiters (and possibly the umpire) is binding, i.e. there is no possibility to appeal the award. In certain cases, according to Schiffer (2006), the losing party does not comply with the award of the arbitration procedure. In that case an arbitral award must be brought before the court (Schiffer, 2006). The arbitration process is visualized in appendix K, where the steps of the arbitration process are set out in an IDEF-0 diagram.

5.3.2 Approximation of administrative costs

To approximate administrative costs in the reinsurance industry, I used a publication from the European Insurance Occupational Pensions Authority (EIOPA) (EIOPA, 2022). The EIOPA supervises and regulates insurance and reinsurance activities within the European Union to ensure financial stability and consumer protection. Its role as an institution is further analyzed in the stakeholder analysis in appendix L2.

The database provides information on premiums written, claims/damages incurred, and various expenses incurred by the EU reinsurance industry as a whole per year. The database provided by EIOPA is divided into five years, running from 2017 to 2021. Furthermore, a distinction is made between non-life and life reinsurance. What is also noticeable is that the database makes a distinction between administrative expenses and expenses related to claims management. This is different from how I defined administrative expenses (see 5.2.4 Administrative costs), where I include expenses related to claims and premium payments under administrative expenses. I will first show the extracted data, before discussing the implication of this difference in definition. I converted the administrative expense and claims management expense data into two line charts, figure 4 for the non-life sector and figure 5 for the life sector.

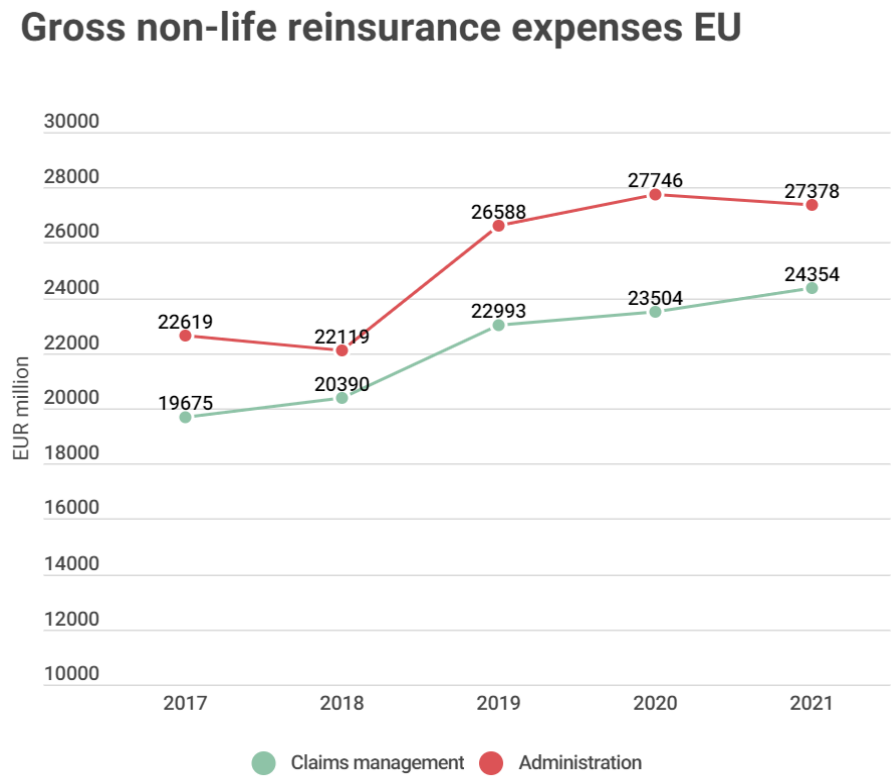

Figure 4: Gross non-life reinsurance expenses EU in millions of euros (EIOPA, 2022)

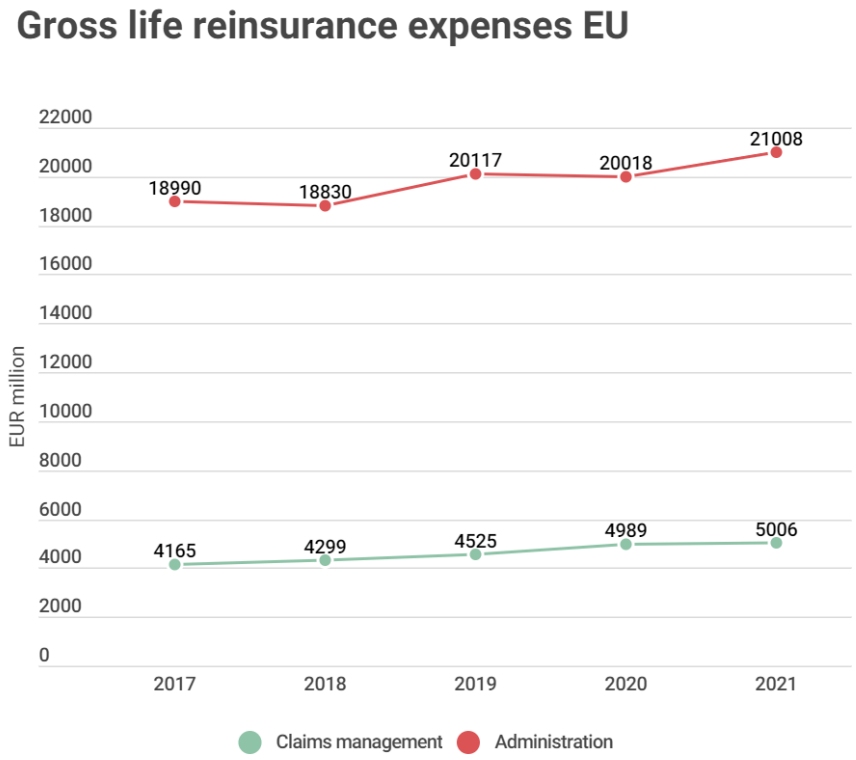

Figure 5: Gross life reinsurance expenses EU in millions of euros (EIOPA, 2022)

What is striking is that the gross claims management expenses for the life reinsurance sector are much lower than the gross claims management expenses for the non-life reinsurance sector. The gross average of life reinsurance was approximately 4.6 billion euros per year over the period 2017-2021, while the gross average of non-life reinsurance was 22.2 billion euros per year over the same period. According to one of my interviewees, this difference can be explained due to the fact that the determination of claims in life reinsurance is much easier than in non-life reinsurance (G8: 21st June, 2023). The respondent continued to explain that the loss suffered in life reinsurance is simply about whether someone actually died, while the loss suffered in non-life reinsurance is much more difficult to establish (G8: 21st June, 2023). The interviewee indicated that instances of fraud in life reinsurance are extremely rare, so I will leave this aspect aside for the sake of convenience. According to the interviewee, this means that disputes also hardly occur in this sector.

This implies that part of EIOPA's definition of claims management is a cost that I place under other types of transaction costs in my study. EIOPA (2014) defines claims management expenses as: ''expenses that will be incurred in processing and resolving claims, including legal and adjuster's fees and internal costs of processing claims and premium payments.'' (p.71). Indeed, processing claims and premium payments are only part of EIOPA's definition of claims management. Part of this definition (legal and adjuster's fees) seems to relate to what I define as 'legal costs', and part of the definition (resolving claims) seems to relate to what I define as 'monitoring costs'. Given that claims management expenses for life reinsurance are much lower than non-life reinsurance, this implies that a large part of EIOPA's definition relates to monitoring costs or legal costs.

EIOPA (2014) defines administrative expenses as: ''expenses incurred by the undertaking during the reporting period, on accrual basis are expenses which are connected with policy administration including expenses in respect of reinsurance contracts and special purpose vehicles.'' (p.70). This shows that administrative expenses have little connection with the given forms of transaction costs as defined in 5.2 Transaction costs in reinsurance. For the sake of convenience, moving forward in this study, I will subsume EIOPA's definition of claims management expenses within my definition of administrative costs.

If I assume, based on the interview, that monitoring costs and legal costs related to claims management in the life reinsurance sector are negligible, this means that approximately 4.6 billion is used annually for premium and claims payment processes. I realize that this is a simplistic assumption, given that some costs undoubtedly have to be incurred in relation to monitoring and legal aspects, including in the life reinsurance sector. Whether monitoring costs and legal aspects for life reinsurance are indeed negligible is beyond the scope of this analysis. In any case, what I assume is that a large part of the costs related to claims management expenses from figure 5 relate to the processes of claims and premium payment. Furthermore, I assume that, as far as the non-life reinsurance sector is concerned, the costs of processing claims and premium processes are similar to those of the life reinsurance sector. This would mean that the cost related to the claims and premium processes in the non-life reinsurance sector is also approximately 4.6 billion annually for the EU as a whole. Therefore, I will assume that the average annual costs related to the administration of claims and premium payments for the life and non-life reinsurance sectors combined are approximately €9.2 billion. I will examine what implications this has on administrative costs, as I have defined them, in the evaluation of my design (7.4 Design evaluation).

5.4 Summary analysis

Now, I will provide a summary analysis of the information presented in this chapter. Using an application of TCE in the context of the reinsurance industry, a total of six different types of transaction costs have been formulated. These transaction costs include search costs, placement costs, administrative costs, dispute resolution costs, legal costs, and monitoring costs. Since search costs and placement costs are incurred before the contract is drafted, they represent typical forms of ex ante transaction costs. The rest, namely administrative costs, dispute resolution costs, legal costs, and monitoring costs, are ex post transaction costs and are incurred after the contract is drafted.

The implementation of a smart contract potentially impacts all six types of transaction costs. However, for the purpose of making a comparison, it is important to have an approximation of the amount of transaction costs incurred in the execution of traditional reinsurance contracts. For two types of transaction costs, namely administrative costs and dispute resolution costs, I have been able to find approximations. Therefore, these two types of costs are central to the evaluation of the design (7.4 Design evaluation). For completeness, I have visualized the six classes of transaction costs in appendix F. The two testing relationships are derived directly from the hypotheses described earlier in 3.1.2 Panel B: Smart contract applications and initiatives in the reinsurance industry.

Based on a database from DRD, I can assume that the average cost of a dispute is €350,000, with an average duration of 91 weeks to resolve the dispute. Furthermore, from a database from EIOPA, I can infer that the average aggregate annual costs related to claims and premium payments for all insurers and reinsurers amount to €9.2 billion. These costs apply to both the life and non-life reinsurance sectors combined.

6. Institutional analysis

Beyond the goal that the smart contract should reduce transaction costs, it is important that this technical design fit within the institutional context of the reinsurance industry. Without considering the institutional framework, a lack of understanding of the actors, interests and transactions will result in a technological implementation that does not work as it should.

To address this institutional design problem, I will structure this chapter as follows. First, in 6.1 Critical transactions, I will examine the critical transactions involved in the execution of reinsurance contracts. Where chapter 5. Transaction costs analysis already provides a general description of the various categories of transaction costs that can be distinguished, in section 6.1 Critical transactions, I will delve into the specific transactions that take place within these categories. For this purpose, I will only focus on the two categories of transaction costs for which I have found an approximation, namely administrative costs and dispute resolution costs. Subsequently, in section 6.2 Conflict of interest in ex post transactions I will zoom in further on transactions where there is a conflict of interest between the insurer and reinsurer. I will conclude this chapter by giving a summary.

For a comprehensive institutional analysis, considering the institutional context from four different levels, I refer the reader to appendix J. The institutional analysis in appendix J has been established using a classification system based of Williamson (1998), in which the reinsurance market will be approached within a broader context.

6.1 Critical transactions

A transaction is ‘’a transfer of 'rights to use' goods or services across technologically separable interfaces.’’ (Williamson, 1985, p.1). In the socio-technical system (the reinsurance industry), which is the subject of the analysis, many transactions can be identified between parties. However, for the purpose of this analysis, I will only consider critical transactions. Künneke (2021) considers critical transactions as those related to safeguarding the critical functions in the reinsurance industry.

Four critical functions have been identified in this paper, namely: (1) Premium payment; (2) Claims payment; (3) Dispute settlement and (4) Contract placement. Since I focus specifically on administrative costs and dispute resolution costs, the fourth critical function (contract placement) will be excluded.

The first column in table 4 lists the critical functions, and the second column lists the corresponding critical transactions. Column three lists the actors involved in carrying out the transaction. I have indicated whether the transaction is unilateral, meaning there is only one party making a legally enforceable promise or commitment, with the auxiliary word 'to'. Lastly, column four, I specify under which type of transaction cost the corresponding transaction falls. These categories refer to the transaction costs defined in 5.2 Transaction costs in reinsurance.

Table 4: Critical transactions and corresponding type of transaction costs

Critical Functions	Critical transactions	Actor(s) involved	Type of transaction costs
1. Premium payment	*(a) Negotiation of premium*	*Insurer and reinsurer*	*Placement*
	(b) Exchange of premium amount	Insurer to reinsurer	Administrative
	(c) Monitor premium payment	*Reinsurer*	*Monitoring*
	(d) Report premium	*Insurer to Reinsurer and Reinsurer to regulator*	*Legal*
	(e) Pay premium pro-rata in case of cancellation	Insurer to reinsurer	Administrative
2. Claims payment	*(a) Negotiation of coverage*	*Insurer and reinsurer*	*Placement*
	(b) Exchange of proof of loss	Insurer to reinsurer	Administrative/ monitoring
	(c) Exchange of date of loss	Insurer to reinsurer	Administrative/ monitoring
	(d) Investigate claim	*Reinsurer*	*Monitoring*
	(e) Calculate claim	Insurer	Administrative
	(f) Calculate aggregate of claims	Reinsurer	Administrative
	(g) Exchange of claim amount	Reinsurer to insurer	Administrative
	(h) Monitor claim payment	*Insurer*	*Monitoring*
	(i) Report claim	*Insurer to regulator and insurer to reinsurer*	*Legal*
3. Dispute settlement	(a) Notify of dispute	Reinsurer or insurer	Dispute resolution
	(b) Select arbiter	Insurer and reinsurer	Dispute resolution
	(c) Select umpire	Arbiters	Dispute resolution
	(d) Present case	Insurer to arbiter and reinsurer to arbiter	Dispute resolution
	(e) Hold preliminary hearing	Insurer; reinsurer; arbiters; umpire	Dispute resolution
	(f) Hold hearing	Insurer; reinsurer; arbiters; umpire	Dispute resolution
	(g) Deliberate award	Arbiters and umpire	Dispute resolution
	(h) Enforce award	Arbiters; umpire; attorney; insurer and reinsurer	Dispute resolution/ legal
	(i) Pay arbiters and umpire	Reinsurer and insurer to arbiters and umpire	Dispute resolution
4. Contract placement	N.A: out of scope	N.A: out of scope	N.A: out of scope

N.B. The impact of the smart contract design on transactions in cursive will not be evaluated in this paper.

What is striking in table 4 is that even within the three critical functions, the transactions may relate to different types of transaction costs as defined in 5.2 Transaction costs in reinsurance. For example, the critical function premium payment consists of 5 transactions, of which two relate to administrative costs (1b and 1e), one relates to placement costs (1a), one relates to monitoring costs (1c), and one relates to legal costs (1d).

Since I am looking specifically at administrative costs and dispute resolution costs in my study, I will also look at how to reduce these types of transaction costs in the evaluation of my draft. In the table, all transactions not related to either administrative costs or dispute resolution costs are in italics. The transactions in italics were not evaluated in the design chapter (7. Design). For the premium payment, this means that I investigated whether the smart contract design has an impact on transaction 1b and 1e. For example, if (parts of) the premium payment can automate these critical transactions through the smart contract application, I can say that the costs related to transaction 1b and 1e are (partially) reduced. Technically, I still cannot say much about the impact on the premium payment as a whole, given that I cannot say anything about transactions 1a, 1c and 1d when implementing a smart contract. For the sake of simplicity, however, I will assume that the transactions are independent of each other in this study. By this I mean that a change in transactions 1b and 1e do not directly affect transactions 1a, 1c and 1d. Whether the transactions are indeed mutually independent is beyond the scope of this study and remains a task for future research.

6.1.1 Premium payment

a. Negotiation of premium. During the placement process ex ante, the reinsurer and insurer negotiate on a suitable premium to be paid by the insurer to cede the underlying risk. As specified in 5.2.1 Search costs, actuaries are involved in this process; they calculate the risks associated with future events and the financial impact involved, to determine the appropriate pricing of a reinsurance product. Furthermore, I can conclude from appendix E, on the distinction between treaty and facultative contract, that in treaty contracts, the reinsurer is generally dependent on the underwriting terms of the insurer and is forced to accept them. In facultative contracts, there is more room for negotiation. The premium amount agreed between the insurer and reinsurer is a 'flat premium' in the contract studied (appendix A). This implies that the premium amount is fixed and does not vary based on factors such as the level of risk or the amount of coverage, as seen in other premium structures. As one of my interviewees revealed (G7: 20th June, 2023), a certain promillage is often specified nowadays, which is a portion of the sum insured.

b. Exchange of premium amount. After the premium amount is agreed and the contract is in place, the insurer usually pays the reinsurer the premium annually. This was also the case in our traditional contract (appendix A).

c. Monitor premium payment. The reinsurer monitors whether it received the premium as specified in the contract.

d. Report premium. Premium reporting is two-sided. The insurer has a reporting obligation to the reinsurer, and the reinsurer to the regulator. The insurer reports ''its premium (or losses) required under the reinsurance contract […] to the reinsurer.'' (Schiffer, 2011, para. 8). This premium report is called a Bordereau. Second, under the Solvency II directive (7.2.2.1), reinsurers are required to report their received premiums, and make them available to the EIOPA if requested.

e. Pay premium pro-rata in case of cancellation. In case one of the parties cancels the contract (which is possible on a minimum 30-day notice), the premium must be shared pro-rata between the insurer and reinsurer. To illustrate, if the contract is cancelled exactly after six months - given that the premium payment is annual – 50 percent of the agreed premium must be paid from the insurer to the reinsurer.

6.1.2 Claims payment

a. Negotiation of coverage. During the placement process ex ante, the reinsurer and insurer negotiate on what is a suitable coverage. As specified in 5.2.1 Search costs actuaries are involved in this process. Just like the negotiation process of the premium, the flexibility of the negotiation process concerning the coverage of a treaty contract is generally much lower than in facultative contracts (appendix E).

b. Exchange of proof of loss. After the insurer incurs a loss for which the reinsurer is liable, the insurer is obliged under the contract to provide proof of loss. This might include loss details, coverage details, photographs, a breakdown of the claimed amount, and, in some cases, claimant information (Munich Re, n.d.a).

c. Exchange of date of loss. Although generally included in the proof of loss (transaction 2b), I specify the exchange of the date of loss as a separate transaction. I made this distinction since the proof of loss is utilized for ascertaining the legitimacy of the claim, whereas the date of loss serves to determine whether the insurer promptly notified the reinsurer of the incurred loss. Indeed, reinsurance contracts often contain a 'prompt notice clause' (Schiffer, 2005), which allows the reinsurer to confirm or disprove the cause of the loss.

d. Investigate claim. The reinsurer investigates the claim based on the information presented by the insurer. Note that the reinsurer will not investigate the claim in all cases; this depends on the amount claimed and the insurer's reputation with the reinsurer.

e. Calculate claim. Whenever the insurer suffers a loss, the insurer will calculate the extent to which the reinsurer can be held liable for this according to the contract. Our analyzed contract (appendix A) is an XoL contract, which means that the reinsurer can be held liable for the portion that exceeds the insurer's retention.

f. Calculate aggregate of claims. In most contracts, an aggregate is specified. An aggregate in a reinsurance policy is a limit in an insurance policy stipulating the most it will pay for all covered losses during a specified period of time, usually a year (International Risk Management Institute, n.d.b). In our contract, the aggregate is 4 million, meaning this is the maximum amount the insurer can claim on the reinsurer during the contract period (which is also 1 year here).

g. Exchange of claim amount. Once the claim has been investigated and accepted by the reinsurer, the reinsurer is responsible for paying the claim.

h. Monitor claim payment. The insurer monitors whether it has received the claim.

i. Report claim. The insurer is obliged under the contract to report its claims to the reinsurer (Hildebrand, n.d.) and to the regulator under the Solvency II directive.

6.1.3 Dispute settlement

Here, I should first note that there is no standard way of dispute resolution. Reinsurance disputes can be conducted according to standard procedures or settled ad hoc by the parties in dispute. Since it is difficult to make general statements about a dispute resolution process, I describe here the transactions resulting from the dispute resolution process as stipulated in Article 16 of the traditional contract to be translated (appendix A).

a. Notify of dispute. The dispute resolution process starts with a written demand for arbitration from either the reinsurer or insurer.

b. Select arbiter. Each party in dispute selects its own arbiter. It can happen that parties choose an arbiter who advocates their case as best as possible, due to the fact that the parties want to win the dispute (Hall, 2016). This inherently leads to a conflict of interest on the part of the arbiters, as they are simultaneously expected to resolve the dispute as fairly as possible. Often, the choice of the umpire in this kind of partisan dispute is decisive (Schiffer, 2010). If one of the parties fails to select an arbiter within a specified timeframe, the counterpart can exercise the right to select the second arbiter as well. In the traditional contract, the parties get 60 days to select an arbiter.

c. Select umpire. It is up to the two arbiters to select an umpire. Interestingly, the reinsurance contract provided does not specify a methodology by which to select an umpire. According to Hall (2018), ''the lack of procedures in choosing the umpire has led to considerable delays and disputes over umpire-selection.'' (p.1).

d. Present case. After the parties in dispute have selected their arbiter, they get a certain timeframe to present their case to their arbiter. In the traditional contract to be translated, this timeframe is 60 days. In this timeframe, the parties specify their arguments and present it to their arbiter. As highlighted in 5.3.1 Approximation of dispute resolution costs, this procedure is alternatively referred to as the process of discovery.

e. Hold preliminary hearing. Once the umpire is appointed, they will schedule a meeting between the arbitration panel and the parties (Schiffer, 2006). In the preliminary hearing, the parties and arbitration panel will develop the arbitration schedule ''and resolve any interim or preliminary issues'' (Schiffer, 2006, para. 17).

f. Hold hearing. Following the submission of arbitration briefs, a hearing takes place where both parties present opening and closing statements, examine witnesses, and respond to arbiters' inquiries. While post-hearing briefs are now less prevalent, arbiters rely on closing arguments and the hearing transcript to make their decisions (Schiffer, 2006).

g. Deliberate award. Immediately after the hearing, or within a few weeks at the latest, it is up to the arbiters to reach a decision. If the arbiters do not reach a joint decision, the umpire's verdict is decisive.

h. Enforce award. After the arbiters render their decision, a written arbitration award is issued. This typically provides a concise statement of the winning party, the resolved issues, and the amount to be paid. Interestingly, one of my interviewees (G8: 21st June, 2023) indicated that in approximately 10 percent of cases, the loser does not comply with the award. In that case, it is up to the winner to scale up the arbitration dispute to judicial proceedings. This means additional costs have to be incurred, relating to court registry fees and attorney costs.

i. Pay arbiters and umpire. The arbiters and umpire generally charge an hourly fee which has to be paid by the parties in dispute. In our contract, ''each party shall bear the expenses of its own arbiter, and shall jointly and equally bear with the other the expense of the umpire and of the arbitration''

(see Article 16 of traditional reinsurance contract). The costs of the arbitration refer to the costs of hiring the hearing room, use of any audiovisual equipment, travelling expenses, etc.

6.2 Conflict of interest in ex post transactions

Certain critical transactions outlined in 6.1 Critical transactions are distinguished by a conflict of interest between the insurer and the reinsurer. As elucidated in the introduction, one of the objectives of drafting a reinsurance contract is to mitigate opportunistic behavior for both parties by incorporating contractual obligations into the agreement, thereby addressing relevant conflicts of interest.

For the critical transactions concerning administrative costs and dispute resolution costs, I will examine the transactions with conflicts of interest in more detail. I will begin by explicitly delineating the conflicts of interest through a description of the conflict. Subsequently, I will briefly consider the implications of the smart contract implementation on these conflicts of interest.

In 6.1 Critical transactions, I identified what the critical functions (CF) are in reinsurance contracts, and specified which critical transactions underlie them. Of these critical transactions, I specifically focus on those related to (a) administrative costs or (b) dispute resolution costs. The transactions related to these costs concern:

- 1b: Exchange of premium amount;
- 1e: Pay premium pro-rata in case of cancellation;

- 2b: Exchange of proof of loss;
- 2c: Exchange of date of loss;
- 2e: Calculate claim;
- 2f: Calculate aggregate of loss;
- 2g: Exchange of claim amount;

- 3a: Notify of dispute;
- 3b: Select arbiter;
- 3c: Select umpire;
- 3d: Present case;
- 3e: Hold preliminary hearing;
- 3f: Hold hearing;
- 3g: Deliberate award;
- 3h: Enforce award.

First, it should be noted that not all transactions are subject to a clear conflict of interest. For instance, the transactions related to the dispute resolution process (transactions 3a through 3g) do not involve a conflict of interest. While the starting point of a dispute includes a monetary conflict of interest between the insurer and reinsurer in 99% of cases (DRD, 2023), both parties are motivated to resolve the dispute fairly in the event of such disputes (Hall, 2016).

On the other hand, the transactions related to administrative actions (transactions 1b, 1e, 2b, 2c, 2e, 2f, and 2g) do indeed involve a conflict of interest. These transactions are listed in Table 5, accompanied by an explanation of the underlying conflict of interest.

Table 5: Critical transactions characterized by a conflict of interest

Critical transaction	Specification	Rationale of conflict of interest
1b	Exchange of premium amount	The reinsurer has an interest in receiving the premium, while the insurer has an interest in forsaking payment of the premium.
1e	Pay premium pro-rata in case of cancellation	
2b	Exchange of proof of loss	The liability of the reinsurer is ascertained through the insurer's submission of proof of loss and date of loss. The disbursement of the claim by the reinsurer constitutes a gain for the insurer.
2c	Exchange of date of loss	
2e	Calculate claim	The reinsurer’s liability is contingent upon the calculation of the claim. The disbursement of the claim by the reinsurer constitutes a gain for the insurer.
2f	Calculate aggregate of loss	The reinsurer’s liability is contingent upon the aggregate of loss. The disbursement of the claim by the reinsurer constitutes a gain for the insurer.
2g	Exchange of claim amount	Once the claim has been investigated and accepted by the reinsurer, the reinsurer pays the claim amount. The disbursement of the claim by the reinsurer constitutes a gain for the insurer.

From table 5, it can be observed that the conflict of interest emerges due to the insurer lacking a direct incentive to make premium payments, and the reinsurer lacking a direct motivation to honor a claim payment. This inherent dynamic renders these transactions susceptible to opportunistic behavior by either party. For instance, considering transaction 2f, it's noteworthy that the reinsurer could intentionally assert that the aggregate of loss has already been reached during the contract period, even if this isn't the case. If the insurer does not dispute this, the reinsurer avoids making the claim payment.

In the visualization of the operation of the smart contract design (7.2.3 Swimlane diagram), it will become apparent that certain critical transactions in Table 5 can be incorporated into the contract logic of the smart contract. For the transactions in Table 5 that can be included in the logic of the smart contract, I will discover that the smart contract can mitigate the impact of potential opportunism. Because the design will show that, for example, the payment of premium can be automated, the opportunistic behavior of the insurer will no longer affect the execution of this transaction.

A side effect of automating transactions with conflicts of interest is the elimination of monitoring costs. To illustrate, transactions 1c (monitoring premium payment) and 2h (monitoring claim payment) become redundant to the extent that the parties rely on the accurate execution of the smart contract. As the design will reveal, the premium payment is automated, and the initiation of claim payment is triggered automatically (upon the reinsurer's claim acceptance), obviating the need to monitor these transactions.

Lastly, I will provide a brief summary of chapter 6. In this chapter, I have examined the functions that must be performed concerning a reinsurance contract. The critical functions I will use for the evaluation of my design pertain to premium payment (administrative costs), claims payment (administrative costs), and dispute settlement (dispute resolution costs). For the critical functions 'premium payment' and 'claims payment,' I can conclude that not every transaction within these functions is part of the administrative costs. However, for the sake of simplicity, I will assume that transactions within a particular function are independent of each other. For example, if the smart contract proves capable of automating the premium exchange from the insurer to the reinsurer, I assume that this has no impact on other transactions within the same function.

Furthermore, I can conclude that transactions 1b, 1e, 2b, 2c, 2e, 2f, and 2g involve an inherent conflict of interest between the insurer and reinsurer. As a result, these transactions are sensitive to opportunistic behavior by one of the parties. In section 7.2.3, we will see that some of these transactions can be programmed into the smart contract logic, while others still depend on manual input by one of the parties. In section 7.2.4 Implications of delineation I will further explore the implications of this delineation.

7. Design

In this chapter, I will present a smart contract design based on an existing reinsurance contract, which can be found in appendix A. The primary objective of this design was to examine whether and how smart contracts could effectively reduce transaction costs compared to the traditional reinsurance contract. This enabled me to provide an answer to research question 2.

To this purpose, I tried to resemble the implementation of the traditional reinsurance contract as close as possible by translating the contract into pseudocode. First, I examined the extent to which the contract was translatable into pseudocode, and then reflected on the effectiveness of the design in terms of reducing transaction costs. I initially left out transaction costs analysis and evaluated this aspect after translating my design (7.4 Design evaluation).

Since I was only able to find approximate data for two specific types of transaction costs (as discussed in 5.3 Approximations of transaction costs), my evaluation primarily focused on the effectiveness of the design in relation to dispute resolution costs and administrative costs. It is important to acknowledge that due to limited available data on transaction costs, I cannot make definitive claims about the overall impact on transaction costs in general. The implications of this are further discussed in the study's limitations (8.3 Limitations).

As outlined in the research methodology, there may be certain articles of the traditional contract that cannot be seamlessly incorporated into the smart contract due to the presence of legalese. To address this, I used two approaches: (a) excluding these articles from the scope of the smart contract translation if they were not deemed of critical impact to the administrative or dispute resolution costs, or (b) devising additional mechanisms that effectively captured the purpose of the corresponding articles.

7.1 Design objective and methodology

Now, I will further specify my design objective and methodology. Utilizing this methodology, I have been able to formulate a response to sub-question 2.1. Through the institutional analysis (6. Institutional analysis) in this study, I identified critical functions, which were further subdivided into critical transactions. Further, I classified the critical transactions under the different types of transaction costs, as specified in 5.2 Transaction costs in reinsurance. For reducing costs, I specifically looked at how transactions (related to either administrative costs or dispute resolution costs), were affected by the implementation of the smart contract. I specified reducing costs related to the following transactions as the goal of the implementation. These transactions concern:

1. Exchange of premium amount (1b)
2. Pay premium pro-rate in case of cancellation (1e)
3. Exchange of proof of loss (2b)
4. Exchange of date of loss (2c)
5. Calculate claim (2e)
6. Calculate aggregate of claims (2f)
7. Exchange of claim amount (2g)
8. Notify of dispute (3a)
9. Select arbiter (3b)
10. Select umpire (3c)
11. Present case (3d)
12. Hold preliminary hearing (3e)
13. Hold hearing (3f)

14. Deliberate award (3g)
15. Enforce award (3h)

In 7.3 Translation to smart contract, I will consider these transactions one by one, and show how I translated them into the smart contract. As specified in the research methodology, I applied a reengineering approach for the smart contract design. This reengineering process involved two basic steps: reverse engineering of the traditional contract to arrive at design requirements, and forward engineering to translate the requirements into a new implementation (the smart contract). The reverse engineering also consisted of ''two consecutive steps: information extraction and information abstraction.'' (Canfora & Di Penta, 2007, p.2). First, I extracted requirements by extracting key functions from the traditional contract and translating these functions into requirements. Second, I abstracted the requirements into a swimlane diagram, which visually represents the process steps in the traditional contract and illustrates how to formalize the items in the traditional contract in pseudocode. After reverse-engineering the contract and visualizing its inner workings in a swimlane diagram, I used forward engineering to re-translate the requirements into functions to be included in the smart contract.

7.2 Reverse engineering traditional contract

The function of the XoL contract (appendix A) that I examined, is to protect the insurer against large claims of its insured (the tractor company) that exceed the retention of the insurer. The contract is a general driver liability. In such a contract, the insurer cedes part of the driver's liability of its policyholders to the reinsurer (G7: 20th June, 2023). The reinsurance contract dates back to 1974 and is a reinsurance contract originating from the US. I discuss the implications of this in the limitations of this study.

I extracted the functions of the traditional reinsurance contract, by examining the separate clauses, providing the specification and objective/function of each clause. The articles contained in the traditional reinsurance contract have been put in table 6. The first column includes the numbers of the traditional articles. In the second column, I have given a brief specification of this article, and in the third column, I have described the objective or function of this article.

Table 6: Article specification and objective of original reinsurance contract

Article	Specification	Objective/ function
1	Who the insurer (called the Company)	Express details of coverage
2	*Who is the policyholder (called the Insured)*	*Express details of coverage*
3	What is the policy number and address of policyholder	Express details of coverage
4	What is the covering period	Express details of coverage
5	Specifying liability, retention, monetary coverage, and type of reinsurance	Express details of coverage
6	Specifying premium	Express details of coverage
7	*What is the audit period*	*Express details of coverage*
8	*What is the ceding commission*	*Express details of coverage*
9	Insurer is liable for its own retention, and reinsurer liable to all terms and conditions of policy. Insurer should provide full transparency of records relating to contract or claims.	Reinsurer has complete and honest representation of risk involved
10	Insurer should provide prompt notice of claims	Reinsurer can investigate cause of loss
11	Reinsurer is liable for claims exceeding retention	Express details of coverage
12	Insurer responsible for providing proof of loss, reinsurer responsible for paying claim promptly thereafter	Reinsurer can monitor claim and must compensate if liable
13	*Reinsurer is not liable for part of claim that insurer recovered through salvage*	*Reinsurer is not liable for claims that insurer recovered*
14	*Insurer cannot claim deduction on premium when making tax returns*	*Insurer cannot claim deduction when making tax returns*
15	Insolvency of insurer or reinsurer amends the terms of certificate to law of applicable jurisdiction	To protect policyholders against loss
16	Procedure of dispute resolution in case of difference of opinion between insurer and reinsurer	Solve disputes
17	Cancellation of policy at least thirty days in advance	Ensure that the contract is terminable on a monthly basis, giving counterpart time to respond
18	Terms of certificate cannot be changed, unless by request of authorized representative of reinsurer, which the insurer accepts	Ensure that the contract is binding and cannot be changed in favor of one party

**The articles in cursive were not included in the smart contract translation*

7.2.1 Excluded articles

In table 6, the articles in cursive were not included in the smart contract translation. Here, I will briefly explain why these items were not included.

First, I excluded the specification of the policyholder (art. 2). This is because I am looking at the bilateral relationship between insurer and reinsurer, and the policyholder is not responsible for actions in the execution of this contract. Second, I excluded the audit period (art. 7). The audit period refers to a specific period of time during which the reinsurer has the right to examine the ceding company's records and accounts related to the reinsurance agreement. The purpose of a ''reinsurance audit is to determine whether the items being reviewed are in compliance with the terms and conditions of the reinsurance agreement and/or the representations made by the cedent about the subject portfolio'' (Wustrow & Hughes, 2008, p.29). Auditing can thus be seen as a form of monitoring costs incurred by the reinsurer, and I leave monitoring costs outside the scope of the analysis. In addition, two reinsurance experts in the interviews were unable to ascertain the precise meaning of this article, as it states 'none' immediately after the audit period, followed by a date. Due to the limited information provided in this article and its focus on monitoring costs, I decided not to include it in my analysis. Third, I excluded the ceding commission (art. 8), because the ceding commission is zero and it was not identified as a critical transaction. Fourth, I excluded the article relating to salvage (art. 13). Salvage refers to the repayment of (part of) the claim for when the insurer sells the damaged property, to credit a part of the damage suffered. However, salvage only relates to property insurance (Schiffer, 2019), and the contract under investigation concerned a liability contract. Finally, I excluded the article related to claim deduction when making tax returns (art.14). This article relates to legal costs and was thus excluded from the analysis. According to one of my interviewees, the introduction of a smart contract would aid in conforming to this article (G5: 13th June, 2023). The interviewee conveyed that a smart contract would enable the seamless provision of tax-related information to the tax authorities.

7.2.2 Design requirements

For the effectiveness of the proposed solution, it was important to identify the requirements of my solution. To this purpose, I used literature, the institutional analysis performed in appendix J, interviews, and the original reinsurance contract, which gave me information on what requirements the design should meet. In the table below (table 7), all requirements are numbered and specified. Column two indicates from which source the requirement was derived. Column three indicates whether this requirement was included in the scope of the design, and in which line(s) of code the requirement was included. If this requirement could not be directly translated into the smart contract, this is also indicated in column three. Possible particularities regarding the translation of the requirements are indicated in column four. All requirements from Table 7 are also visualized in appendix M.

Table 7: Design requirements smart contract

Design requirement	Derived from	Function line in contract	Note
1. Enable placement	Hoffman (2002), appendix H	N.A.: Out of scope	N.A: Out of scope
2. Comply with legislation	Williamson framework layer 2	N.A.: Unable to translate	Legal framework specified in appendix J2
3. Enable contracting functions			
3.1 Specify details of coverage	Article 1-6, Interview G1: 13th April, 2023	In code	-
3.2 Enable premium payment	Article 6	Code line: 49-63	-
3.3 Calculate reinsurance claim	Article 5	Code line: 77-90	-
3.4 Enable claim payment	Article 11	Code line: 98-112	-
3.5 Enable cancellation of contract	Article 17	Code line: 317-334	-
3.6 Enable contract termination	Article 4	Code line: 299-310	-
4. Enable dispute resolution			
4.1 Select arbiters	Article 16	Code line: 150-165 AND 193-208	For insurer and reinsurer
4.2 Select umpire	Article 16	Code line: 260	-
4.3 Provide award	Article 16	Code line: 259	-
4.4 Enforce award compliance	Article 16	N.A.: Unable to translate	Code award in smart contract
4.5 Enable discovery	Article 9	Code line: 174-187 AND 210-223	For insurer and reinsurer
5. Provide confidentiality			
5.1 Respect dispute confidentiality	Williamson framework L3	N.A.: Unable to translate	Private blockchain
5.2 Respect contract confidentiality	Williamson framework L3	N.A.: Unable to translate	Private blockchain

6. Enable trust			
6.1 Enable document transparency	Article 9	N.A.: Unable to translate	-
6.2 Enable prompt notice	Article 10	Code line: 83	Decided by arbitration
6.3 Enable proof of loss	Article 12	Code line: 84	-
6.4 Provide contract integrity	Article 18, Interview G5: 13th June, 2023	N.A.: Unable to translate	Provided by smart contract

7.2.3 Swimlane diagram

Before I started the actual translation into pseudocode, I visualized the operations that the smart contract had to go through in a swimlane diagram. This involved the second step of reverse engineering: abstraction. Here, I abstracted the items and requirements from tables 5 and 6, respectively. I represented in the swimlane diagram which actors have to perform which operations.

To enhance readability, I divided the swimlane into three sections. However, it is essential to note that the swimlane represents a continuous entity. The complete swimlane diagram is visible in appendix N. Only the function related to canceling the contract (cancell_contract) is not directly linked to the rest of the swimlane and can be invoked at any point during the contract period. The actors directly involved in the execution of the contract are: the insurer, the reinsurer, the arbiters, and the umpire. These actors are represented at the top of the swimlane. The step or activity indicated in a particular lane can only be performed by that actor. Certain actions are exactly on the dividing line between two actors, meaning that this action can be initiated by either party.

The swimlane consists of events or actions, represented by rectangles, and decisions, indicated by diamonds. Additionally, there are black dots visible in the swimlane, indicating the end of a flow where the contract logic ceases. All actions/events or decisions have been assigned specific colors to indicate whether they are automatable or not automatable by the smart contract, and whether they involve a conflict of interest or not. The corresponding legend is visible in figure 6.

a. Not automatable: Conflict of interest

Here I refer to the fact that this action/event or decision involved a conflict of interest between the insurer and reinsurer and could therefore not be automated.

b. Not automatable: out of contract logic

The processes of these actions/events or decisions took place outside the logic of the smart contract, just like they occurred outside the contractual logic of a traditional contract. However, the execution of the contract still depends on these events or the execution of these actions or decisions. With respect to these functions, the contract often depends on the input provided, and the contractual logic continues once the input is given.

c. Automatable

Certain actions/events or decisions could be automated through the smart contract. By this, I mean that these elements were included in the contractual logic of the smart contract.

d. Automatable and conflict of interest

These actions/events involved a conflict of interest between the insurer and reinsurer but could also be incorporated into the contractual logic of the smart contract.

7.2.4 Implications of delineation will elaborate on the implications of this delineation. Now I will elucidate the operations of the smart contract, utilizing the swimlane.

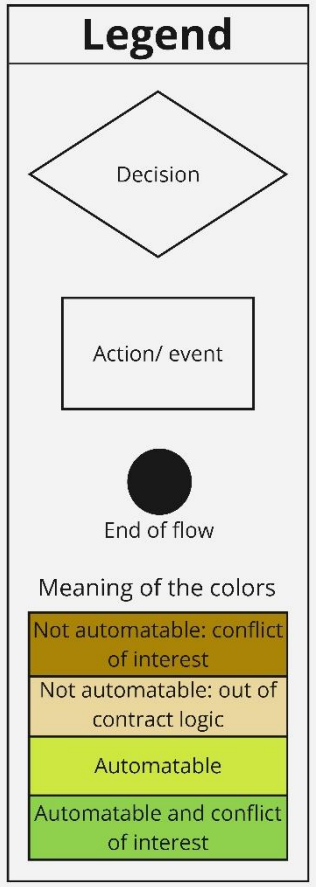

Figure 6: Legend of swimlane

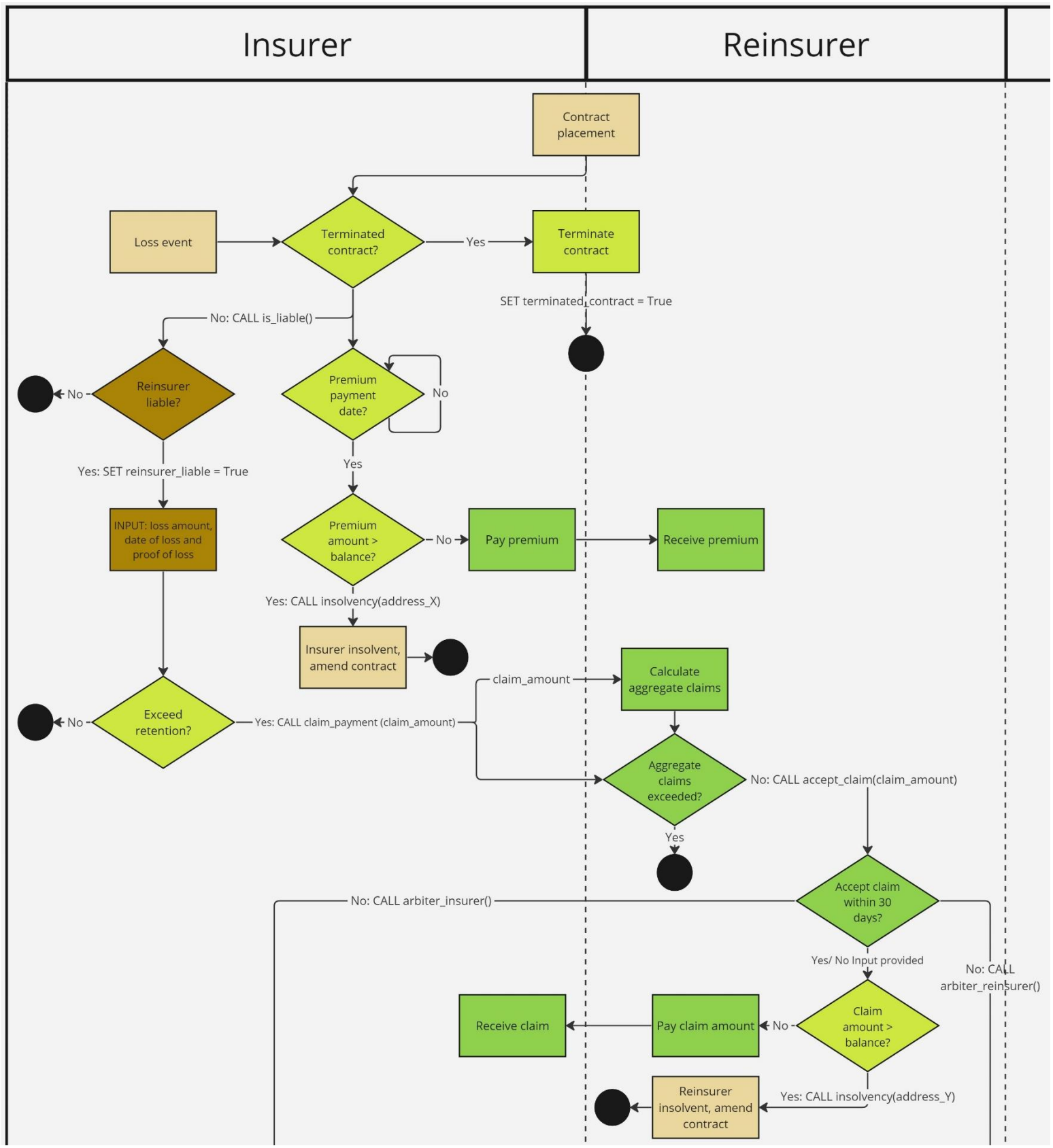

Figure 7: Swimlane part I

At the top of the swimlane (which is visible in figure 7), the contract is placed between the insurer and reinsurer. If the insurer suffers a loss (when there is a loss event), the first thing to check is whether the contract is not yet terminated (art.4). If the contract is terminated, the flow ends immediately. If the contract is not terminated, the internal logic of the smart contract checks whether the premium should be paid to the reinsurer by checking whether the premium payment date is reached. If the premium payment date is reached, and the insurer has enough balance to pay the premium, the premium is automatically transferred to the reinsurer (art.6). If the insurer does not have enough balance, the insurer is declared insolvent, and the contract is amended (art. 15).

In case of loss, the insurer calls the 'is_liable' function, checking whether the reinsurer can be held liable under the terms of the policy (art.5 section 1). If this is the case, the insurer inputs the financial loss (loss_amount), the date of the loss event (date_of_loss), and the proof of the loss (proof_of_loss_document). The date of the loss is necessary to comply with article 10 of the traditional contract, in the event that a dispute arises as to whether the loss was timely reported to the reinsurer. The proof of loss is necessary to comply with article 12 of the traditional contract. After these inputs are provided, the smart contract checks whether the loss suffered exceeds the retention (art.5 section 4), based on the input of the loss (loss_amount). If the loss amount exceeds the retention, the claim amount is automatically calculated based on the input provided by the insurer.

The 'claim_payment' function is called (using the claim_amount as input parameter), where the smart contract checks that the total amount of claims over the contract period does not exceed the $4 million aggregate (art.5 section 4). If the claim falls within the aggregate, the reinsurer has 30 days (art.12) to pay the claim. If the reinsurer does not respond to the claim within the given period, or accepts the claim within the period, the claim is transferred from the reinsurer to the insurer. Again, a check is required as to whether the reinsurer's balance sheet is sufficient to pay the claim, otherwise the reinsurer will be declared insolvent, and the contract will be amended (art.15). If the reinsurer declines the claim within the provided period, the 'arbiter_insurer' and 'arbiter_reinsurer' functions are called, giving the parties 60 days to select an arbiter. Now I zoom in on the dispute resolution process, which are the steps followed if the claim is denied. The flow of these steps is visible in figure 8 (the second part of the swimlane).

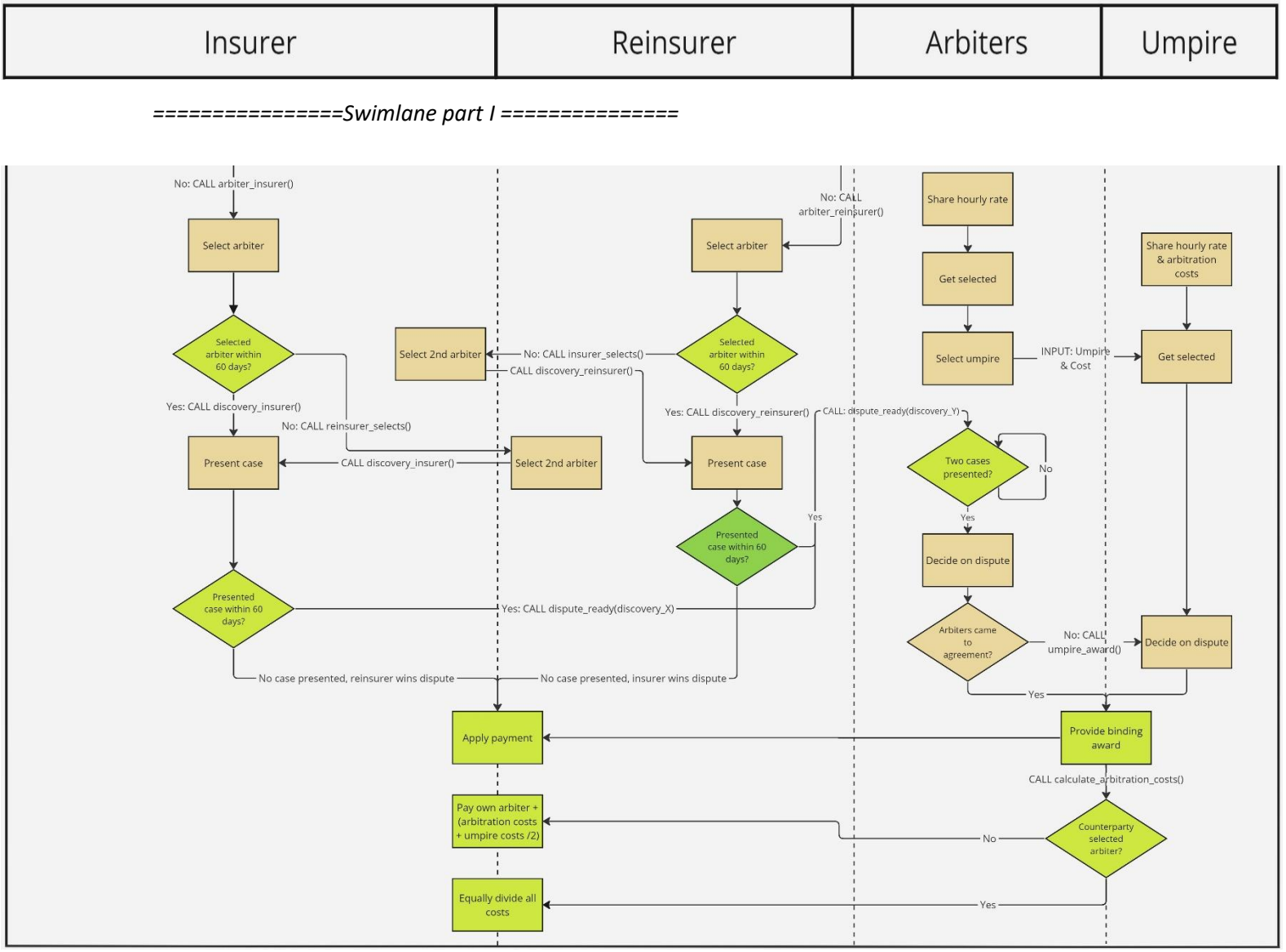

Figure 8: Swimlane part II

In the dispute resolution process, the insurer and reinsurer are given 60 days to select an arbiter (art. 16). If they fail to do so, the functions 'reinsurer_selects' and 'insurer_selects' are called respectively. In these functions, the counterparty is given the opportunity to select the second arbiter (art.16). It should be noted that I made the assumption that at least one of the parties manages to select an arbiter within the 60 days. For example, if the reinsurer refuses the claim, I assume that the insurer has an interest in resolving the dispute. If the insurer or reinsurer fails to select an arbiter, the costs of the dispute will be shared equally (art. 16). After a party has selected an arbiter (either appointed by itself or by the counterparty), the party is given 60 days to present the case to the arbiter. Here, the party presents its arguments and evidence to the arbiter.

Arbiters who have shared their hourly rate with the party and have been selected in the dispute, will rule on the dispute. In the smart contract, I specified that if a party fails to present a case within 60 days, that party will immediately lose the dispute. Once a party has selected an arbiter and presented its case within the period, the dispute_ready function is called. The selected arbiters jointly choose a neutral middle party, the umpire. Once both parties have presented their case within the time period, the arbiters can decide on the dispute. Resolution of this dispute proceeds as usual, which is visualized

in the IDEF-0 diagram in appendix K. This part of the process was not included in the smart contract logic, because the alignment perspective of 7.3 indicated that automating the dispute resolution process would make little sense, given the complexity of the transactions involved. The cases are then presented to the arbiters, and thereafter, the preliminary hearing is held. In the hearing, the parties get the opportunity to share witness statements, and the award is deliberated.

If the arbiters cannot reach a unanimous decision, the 'umpire_award' function is called, and it is up to the umpire to make a judgement. The award is applied to the smart contract (which is illustrated in 7.3.3 Dispute settlement), and finally the arbitration costs are calculated. If the insurer or reinsurer had to choose an arbiter for their counterparty, all costs related to the arbitration process are shared equally. Otherwise, each party pays its own arbiter, while they bear the costs of the arbitration and the umpire together (art.16).

Finally, the contract also had to be cancellable by either the insurer or reinsurer. When one of the parties intends to cancel the contract, they must invoke the cancel_contract function. The process is visualized in figure 9. In this process, the party provides a cancellation date (cancellationdateX for the insurer and cancellationdateY for the reinsurer), which must be at least 30 days from the current date (art.17). If the cancellation date meets the requirement of being at least 30 days in advance, it becomes the termination date of the contract. Before the contract is terminated, the premium is shared on a pro-rata basis. For instance, if the termination date is canceled precisely at the midpoint of the contract period, then half of the premium is also transferred to the reinsurer, assuming that the premium is paid annually, and the contract period is one year.

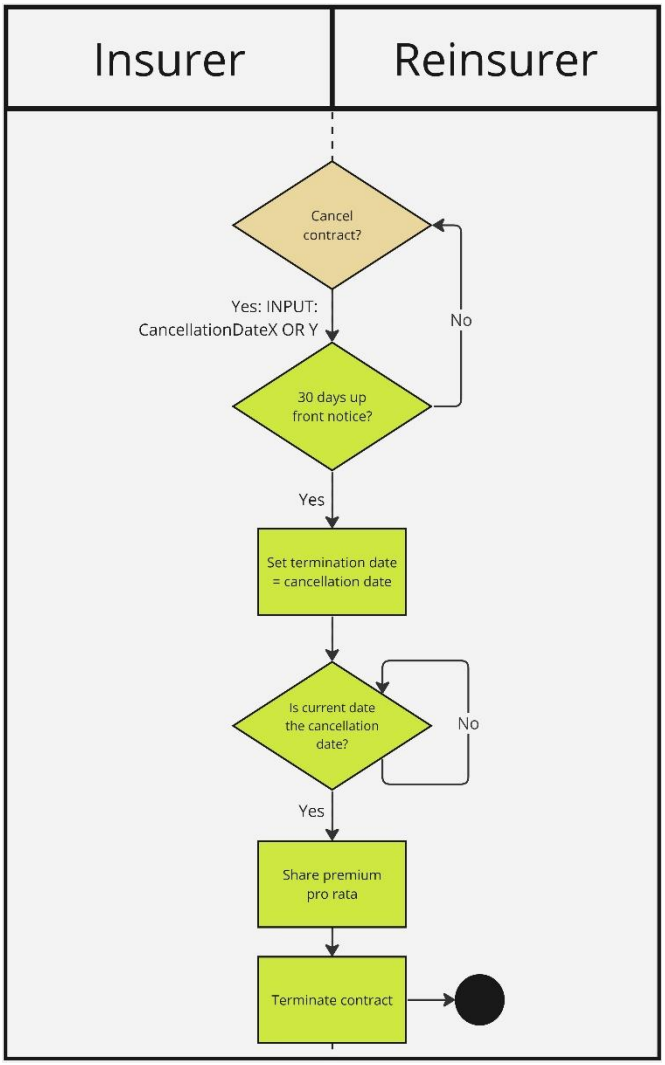

Figure 9: Swimlane part III

7.2.4 Implications of delineation

I was able to distinguish between four categories, based on two characteristics: whether the decision or action could be automated through the smart contract, and whether it contained a conflict of interest. Here I will discuss the implications of this delineation, focusing on the effectiveness of the smart contract in reducing transaction costs related to these actions/events or decisions.

(a) Not automatable: Conflict of interest

For the decisions and actions categorized as 'not automatable: conflict of interest', the smart contract did not reduce transaction costs. The reason for this is that, like a traditional contract, the smart contract still relied on the accuracy and completeness of the input it received. For example, the determination of whether the reinsurer can be held liable under the terms and conditions of the contract is a decision made by the insurer. Here, a conflict of interest arises because the insurer seeks to hold the reinsurer accountable, while the reinsurer would prefer to avoid such liability.

The same applied to the input required concerning information about the claim, which is also provided by the insurer. The insurer enters the financial loss incurred, the date of loss, and the documents providing evidence of the loss. Once again, a conflict of interest persists, and the reinsurer must still incur monitoring costs to verify the accuracy and completeness of the input provided. In conclusion, I can assert that the smart contract did not provide a solution for these decisions and actions.

(b) Not automatable: Out of contract logic

Given that the process of these decisions and actions/events were not included in the logic of the smart contract (just like the traditional contract), the smart contract did not affect them in terms of transaction costs.

(c) Automatable

These are the decisions and actions/events that did not involve a conflict of interest but were still included in the contractual logic. One consequence of this is the reduction of administrative costs related to these decisions and actions/events. The effects of the smart contract were diverse, as parties would no longer need to verify various aspects such as the termination or cancellation of the smart contract, the payment date for premiums, the selection of an arbiter within 60 days, and the allocation of costs related to the arbitration process.

(d) Automatable and conflict of interest

These are the decisions and actions/events that involved a conflict of interest and were still incorporated into the contractual logic. I argue that the added value of a smart contract is most prominent in relation to these transactions, given that processes subject to a conflict of interest are automated, eliminating opportunistic behavior in the execution of these actions or decisions. The premium payment, for instance, was automated. In this payment, the insurer has an interest in not paying the premium or paying only partially. Secondly, in calculating whether the claim exceeds the aggregate, all human input was removed, effectively eliminating the reinsurer's opportunistic influence on its execution. Thirdly, the smart contract obligates the reinsurer to respond to the claim within 30 days. Failure to do so would result in the automatic transfer of the claim amount to the insurer. This payment process reduces some of the opportunistic impact by the reinsurer.
Lastly, both the insurer and reinsurer are required to present their case within 60 days. According to the respondent of interview 8, the reinsurer benefits from taking longer to present its case, as delaying the claim payment as long as possible is financially advantageous (G8: 21st June, 2023). However, if the reinsurer fails to present its case to their arbiter, the insurer automatically wins the dispute. This forces the reinsurer to adhere to this period and partially eliminates opportunism.

7.3 Translation to smart contract

As explained in my methodology chapter (4. Research Methodology), the translation to a smart contract was done using pseudocode. In the main text, I will describe the translation related to the three critical functions identified in 6.1 Critical transactions: premium payment, claims payment and dispute settlement. Of these critical functions, I then describe the transactions related to either administrative costs or dispute settlement costs. The full pseudocode can be found in appendix B.

7.3.1 Premium payment

1b: Exchange of premium amount (line 49-63)

For the exchange of the premium amount, I specified the function 'premium payment'.
The function is visible below.

```
function premium_payment()
        require terminated_contract = False

        current_time = timestamp()
        time_elapsed = current_time - initial_time
        year_elapsed = time_elapsed / 31556866

        IF      year_elapsed > 0
                transfer (premium_amount, address_X, address_Y)
                IF      premium_amount > balance (address_X)
                        SET   insurer_insolvent = True
                        CALL: insolvency(address_X)
                ENDIF
        ELSE    return False
        ENDIF
```

As can be seen in the code, it is important for the execution of the function that the contract is not termed. The function uses a timestamp and initializes it in the variable current_time. Once 31556866 seconds have passed (60 seconds before one year has passed), the premium amount is transferred from address_X (the insurer) to address_Y (the reinsurer). If the premium amount is larger than the balance of the insurer, the insolvency clause will be called. This means that the contract will be amended. I programmed the transfer of the premium amount one minute before the end of the year, because the contract is terminated in exactly one year, thus disallowing any premium to be paid after this termination.

1e. Share premium pro-rata in case of cancellation (line 330-334)

```
        IF current_date >= termination_date AND cancelled_contract = True
                transfer (((premium_amount/365) * cancellationDate -
                current_date), addressX, addressY)
        ENDIF
```

In the cancel_Contract function, the code checks whether the current_date (which can be imported in the code) is larger than or equal to the termination date. Furthermore, cancelled_contract must be true, because the contract must be cancelled by one of the parties for this function to execute. If one of the parties cancels the contract, the termination date will be stored in the cancellation date variable. If these two conditions hold, the premium amount is divided by the number of days in a year, and multiplied by the difference between the cancellation date and the current date. This amount is transferred from the insurer to the reinsurer.

7.3.2 Claims payment

2b. Exchange of proof of loss (line 84)

```
INPUT:  proof_of_loss_document
```

In the calculate_claim function (which can only be executed by the insurer after it executed the 'is_liable' function), the insurer will have to input its proof of loss documents. Note that this did not solve anything, since the reinsurer is still fully dependent on the veracity and completeness of these inputs.

2c. Exchange of date of loss (line 83)

```
INPUT:  date_of_loss
```

The same applies to this function as transaction 2b (exchange of proof of loss).

2e. Calculate claim (line 77-90)

```
function calculate_claim()
        require terminated_contract = False
        require reinsurer_liable = True
        require type = insurer

        INPUT:  loss_amount
        INPUT:  date_of_loss
        INPUT:  proof_of_loss_document

        IF      loss_amount <= retention:
                print "loss amount too small"
        ELSE    claim_amount = MIN((loss_amount - retention), 200000)
                CALL: claim_payment(claim_amount)
        ENDIF
```

The calculate claim function first checks if the contract is not terminated, otherwise this function cannot be performed by the insurer. The insurer enters the loss_amount, date_of_loss and proof_of_loss_document, and if the loss_amount is less than or equal to the retention (of 1 million), the claim_payment function is not called. Because the reinsurer under this contract is responsible for a maximum claim of 200,000 (article 5 section 4), the claim_amount is equal to the minimum of the loss_amount minus the retention, and 200,000. If an amount is entered that exceeds 1 million (higher than the retention), the reinsurer is liable, and the claim_payment function is called with the claim_amount as input.

2f. Calculate aggregate of claims (line 101-105)

```
        total_claim_amount += claim_amount

        IF      total_claim_amount >= 4000000
                print "aggregate claims exceeded"
                return False
```

The claim amount is summed up in a variable called total_claim_amount, which cannot exceed 4 million (this is the aggregate over the contract period). If the total exceeds 4 million, the function is immediately terminated.

2g. Exchange of claim amount (line 121-140)

If the claim is found to be within the aggregate over the contract period, and the reinsurer has enough balance to pay the claim, the accept_claim function is called, using the claim_amount as input variable.

```
function accept_claim(claim_amount)
        require type = reinsurer
        INPUT:  accept claim? (Y/N)

        current_time = timestamp()
        time_elapsed = current_time - claim_time
        transfer_time = time_elapsed / 2592000        #Number of seconds in
30 days: prompt payment

        IF      INPUT = "Y":
                transfer (claim_amount, address_Y, address_X)
                SET reinsurer_liable = False
        ELSEIF  INPUT = null AND transfer_time > 0:
                transfer (claim_amount, address_Y, address_X)
                SET reinsurer_liable = False
        ELSEIF   INPUT = "N":
                start_time_arbiter = timestamp ()
                CALL: arbiter_insurer()
                CALL: arbiter_reinsurer()
        ENDIF
```

The function can only be performed by the reinsurer, otherwise the insurer could accept its own claims. The reinsurer is asked to give an input: Y/N, on whether it accepts the claim. For this, the reinsurer will have to use the input provided by the insurer, regarding the loss_amount, date_of_loss and proof_of_loss document. This function again uses a timestamp, giving the reinsurer 30 days to respond to the claim. The traditional contract states that it must make a 'prompt' payment after receiving the proof_of_loss. According to Swiss Re (n.d.b), a standard payment period is 30 days, so here I made the assumption that the reinsurer should manage to sufficiently investigate the claim within that time. If the reinsurer accepts the claim within time, or if the reinsurer does not respond within time (INPUT = null), the claim amount is transferred to the insurer. If the reinsurer selects 'N', the dispute resolution process is initiated. This starts with the selection of arbiters for the insurer and reinsurer (see 7.3.3 Dispute settlement).

7.3.3 Dispute settlement

a. Notify of dispute (line 133-140)

The dispute resolution process is initiated when the reinsurer does not accept the claim, or does not pay the claim within 30 days (as is specified in the accept_claim function above). This means that the insurer cannot initiate a dispute resolution process by itself. However, considering only 1% of the disputes concern non-monetary claims (DRD, 2023), I excluded this from the analysis.

b. Select arbiter (line 150-165 AND 193-208)

```
function arbiter_insurer ()
        require type = insurer
        arbiter_insurer_time = timestamp ()
        time_elapsed = arbiter_insurer_time - start_time_arbiter
        sixty_days_arbiter = time_elapsed / 5814000
  #Number of seconds in 60 days

        INPUT: arbiterX & cost

        IF      sixty_days_arbiter <= 0 AND INPUT != null:
        SET start_time_discovery = timestamp ()
        CALL: discovery_insurer ()

        ELSEIF  sixty_days_arbiter > 0 AND INPUT = null:
        CALL: reinsurer_selects()
        ENDIF
```

Here, I describe the insurer's arbiter selection process, which is practically the same for the reinsurer. For the reinsurer, naturally, the identical code is employed, although 'reinsurer' replaces 'insurer' in the code above, and vice versa. As one can see from the accept_claim function, the start_time_arbiter is initialized the moment the reinsurer does not accept the claim. The time elapsed from that moment (time_elapsed) is the difference between arbiter_insurer_time and start_time_arbiter. The insurer has 60 days to select an arbiter. When it succeeds in doing so, the discovery_insurer function is called. If 60 days have passed (5814000 seconds), and the insurer has not provided any input, the reinsurer may choose a 2nd arbiter. In the function reinsurer_selects, the discovery_insurer function is also called, so the insurer can still present its case to the arbiter within 60 days.

c. Select umpire (line 260)

```
INPUT2 ARBITERS: umpire & cost
```

In the dispute_ready function, the arbiters have to provide 3 inputs: (1) the award, (2) the umpire and its associated costs, and (3) the arbitration costs.

d. Present case (174-187 AND 210-223)

```
function discovery_insurer ()
        require type = insurer
        discovery_insurer_time = timestamp ()
        time_elapsed = discovery_insurer - start_time_discovery
         sixty_days_discovery = time_elapsed / 5814000        #Number of
seconds in 60 days

        INPUT: discovery_X

        IF      sixty_days_discovery <= 0 AND INPUT != null:
                CALL: dispute_ready(discovery_X)
        ELSEIF  sixty_days_discovery > 0 AND INPUT = null:
                print "no case presented, reinsurer wins dispute"
        ENDIF
```

Next, I analyze the discovery function of the insurer. Note that for the reinsurer I have again described an identical piece of code, the only difference being the reversal of the terms 'insurer' and 'reinsurer'. In the discovery_insurer function, the insurer has 60 days to present its case. The insurer has to input its documents (the discovery variable). If the insurer does not present a case within 60 days, the reinsurer is automatically the winner of the dispute. Otherwise, the dispute_ready function is called. The dispute_ready function waits until it can execute: when two arbiters are selected (either by one party 2 arbiters or by both parties 1 arbiter).

e. Hold preliminary hearing (N.A.)

This process happens outside of the smart contract logic, and was thus not specified in the smart contract.

f. Hold hearing (N.A.)

This process happens outside of the smart contract logic, and was thus not specified in the smart contract.

g. Deliberate award (N.A.)

This process happens outside of the smart contract logic, and was thus not specified in the smart contract.

h. Enforce award (line 259)

The enforcement of the award is written in the smart contract in line 259.

```
        INPUT1 ARBITERS: award
```

Note that this is a simplified representation of reality, and an actual award involves a transfer. For example, an award could look like this in practice:

```
        transfer (150000, address_Y, address_X)
```

In this example, an award is provided, with the reinsurer having to pay 150000 to the insurer. This could be the outcome of a claim that had initially been denied by the reinsurer, with the arbiters deciding that the claim did fall under the reinsurer's liability according to this contract.

i. Pay arbiters and umpire (line 276-289)

```
function calculate_arbitration_costs ()
        SET     totalcosts = arbitrationCost + arbiterXCost + arbiterYcost
                + umpireCost
        IF      insurer_selects = True OR reinsurer_selects = True :
                SET partyX_Cost = partyY_Cost = totalcosts/ 2
                transfer (PartyX_Cost, address_X, address_Z)
                transfer (PartyY_Cost, address_Y, address_Z)
        ELSE    partyX_Cost = (arbitrationCost / 2) + arbiterXCost
                (umpireCost / 2)
                partyY_Cost = (arbitrationCost / 2) + arbiterYCost +
                (umpireCost / 2)
                transfer (PartyX_Cost, address_X, address_Z)
                transfer (PartyY_Cost, address_Y, address_Z)
        ENDIF
```

The total costs consist of the cost of the arbitration, the cost of the insurer's arbiter, the cost of the reinsurer's arbiter, and the cost of the umpire. If the insurer or reinsurer has selected an arbiter for their counterparty (insurer_selects = True OR reinsurer_selects = True), the total costs are divided by two. Otherwise, each party pays its own arbiter, and the cost of arbitration and umpire is divided by two. In both cases, the amounts are transferred from the insurer and reinsurer to the escrow address (address_Z). Here, I left aside who should regulate this escrow address.

7.4 Design evaluation

In this section, I will reflect on the effectiveness and implications of this design. To this purpose, I have divided this section into 3 sub-sections, in which I used the interview input to validate the effectiveness of the design and reflect on design implications. I also compared the traditional contract with the design in terms of transaction costs. First, I investigated the impact of this design on the dispute resolution process and reflected on the potential for disputes to arise (7.4.1 Impact on dispute resolution). Second, I investigated the impact of this design on the critical transactions of the administrative processes in section 7.4.2 Impact on administrative costs (claims and premium payments). By elaborating on the effect of the smart contract implementation on these types of transaction costs, I have been able to formulate an answer to sub-question 2.2. Third, I looked at implications of this design from three different lenses in 7.4.3 Design implications: three lenses. These lenses were compiled from the patterns identified in the interviews regarding the evaluation of this design.

7.4.1 Impact on dispute resolution

The effectiveness of the smart contract design was assessed through an examination of its impact on critical transactions, as outlined in 6.1 Critical transactions. When comparing the dispute resolution process of the traditional contract with the smart contract, it can be concluded that the handling of dispute resolution remained unchanged. Both parties were still given a 60-day period to select an arbiter, another 60 days to present their case, and the dispute was resolved in the same manner, with arbiters deferring the decision to an umpire if unanimity could not be reached. However, it is overly simplistic to assume that the direct translation of the traditional contract into a smart contract has no influence on dispute resolution costs. I distinguish two factors here: the contract ambiguity, and the enforcement of the award.

Contract ambiguity

To illustrate the impact of the smart contract on contract ambiguity, I categorized disputes into two types: disputes pertaining to factual events and disputes concerning the contractual content. We see from the smart contract design that no more disputes are possible over the content of the contract. Interviewee 8 emphasized that contract certainty, embedded in the specified smart contract, had increased compared to the traditional contract (G8: 21st June, 2023). This implies a higher level of assurance regarding the contract's content, validity, and enforceability. By formalizing a smart contract, the underwriter is obligated to articulate a clear and unambiguous agreement, thereby reducing ambiguity.

For example, let's consider article 12 in the traditional contract. It states that the insurer is responsible for providing proof of loss, and the reinsurer is responsible for promptly paying the claim thereafter. However, the term "promptly" lacks a precise definition and is therefore ambiguous. In the smart contract, I defined "prompt" payment as a period of 30 days, thereby mitigating the contract's ambiguity and decreasing the likelihood of disputes.

Nevertheless, we must question the extent to which the reinsurance industry is incentivized to specify all contract terms as precisely as possible. According to one of my interviewees, reinsurance contracts often involve customized agreements, and parties prefer to retain human control and interpretation (G7: 20th June, 2023). Additionally, it can be argued that, in certain cases, the industry benefits from this ambiguous approach. Given the substantial sums involved in disputes, stakeholders in the reinsurance sector often have a need to handle disputes on a case-by-case basis, where negotiation and specialized expertise play significant roles. In

7.4.3.3 Standardization versus customization, I will dive deeper into the trade-off between automatization and standardization versus customization.

Given that most disputes center around what actually happened (late notice, atypical claims, and factual context around losses), the impact of a smart contract on this would be minimal. Indeed, interviewee 8 showed that despite the potential for a dispute about the content of a contract becoming lower, disputes will likely continue to arise over the meaning of words in the smart contract (G8: 21st June, 2023). For example, when does something fall under an automobile liability? When is a loss timely reported to the reinsurer? To what extent is the proof of loss valid and is the reinsurer liable? These are problems that the smart contract does not solve. In essence, this signifies a shift in the balance between ex ante and ex post costs. Due to the fact that pseudocode compels the contract writer to make "binary" decisions, placement costs slightly increased (as more is formalized ex ante). However, the ex post dispute resolution costs are lower as a result of this higher degree of formalization, given that the probability of a dispute becomes marginally lower.

Enforcement of award

Furthermore, the implementation of the smart contract also affected the enforcement of an award. In a traditional contract, when an arbitration decision is made, it is possible for the losing party to refuse to comply with the binding decision. In such cases, the claimant is forced to seek judicial proceedings to enforce the arbitration award. As stated by Schiffer (2006), "an arbitration award may be brought to court to be entered as a judgment and enforced if the losing party refuses to comply." (para.22). However, in this scenario, the claimant incurs additional costs, such as court registry fees and attorney fees. With the implementation of the award in the smart contract following the decision, the contract becomes binding and independent of potential opportunistic behavior regarding non-compliance by the losing party. One of my interviews revealed that non-compliance is not a common issue, with the interviewee indicating that it occurs in approximately 10% of arbitration disputes (G8: 21st June, 2023).

In conclusion, while the implementation of a smart contract design based on an existing reinsurance contract has the potential to reduce ambiguity and enhance contract certainty, its impact on dispute resolution costs in the reinsurance industry is nuanced. While certain aspects of dispute resolution may remain unaltered, the reduction in ambiguity and improved specification of contract terms can contribute to minimizing disputes related to contract content. Also, the award is completely binding, since the award given by the arbiters can be coded into the smart contract. This eliminates potential opportunism. However, the industry's preference for customization and human involvement may restrict the full realization of the potential benefits of smart contracts in terms of reducing dispute resolution costs.

7.4.2 Impact on administrative costs

The design demonstrated that certain transactions between the insurer and reinsurer can be automated. The administrative transactions were divided into transactions related to premium payment and transactions related to claim payment. First, I evaluated the impact on premium payment processes, and second, I evaluated the impact on claim payment processes.

The transactions that were automated through the implementation of the design include:

- Exchange of premium amount (1b)
- Share premium pro-rata in case of cancellation (1e)
- Calculate claim (2e)
- Calculate aggregate of claims (2f)
- Exchange of claim amount (2g)

First, I will illustrate how these transactions have been automated. In this paper, automation for specific transactions is considered as a binary situation, where the costs associated with these specific transactions were assumed to become negligibly small through automation. After addressing the impact on all specific transactions, I will discuss the implications regarding administrative costs in general, relating this back to the approximate administrative cost estimation described in 5.3.2 Approximation of administrative costs.

1b: Exchange of premium amount

The payment of the premium amount was automated, as indicated in the smart contract. The internal logic of the smart contract specifies that the premium payment is transferred annually from the insurer to the reinsurer. After 31,556,866 seconds (which is 60 seconds less than 1 year), the premium amount is transferred from the insurer to the reinsurer without any external actor input. This means that the administrative costs associated with this transaction are eliminated.

1e: Share premium pro-rata in case of cancellation

This transaction is also included in the internal contract logic. If either party cancels the contract, the cancellation date becomes the new termination date of the contract, resulting in the contract being terminated on that date. Furthermore, the internal contract logic includes a provision that allows parties to cancel the contract with a minimum of 30 days' notice, providing the counterparty an opportunity to seek a new contract partner. The portion of the premium that needs to be paid is automatically calculated by the smart contract and transferred from the insurer to the reinsurer.

What is notable about these two transactions is that the degree of dependence on opportunism is reduced. Since the transactions are executed automatically, assuming that the parties cannot modify the contract in the meantime, it means that the insurer is 100% bound by its obligations to the reinsurer after the contract is in place. This potentially reduces monitoring costs as well, given that the parties have enough faith in the proper execution of the smart contract. Next, I will consider the transactions related to claim payment.

2a: Calculate claim

This transaction is also incorporated into the internal contract logic. The insurer inputs its claim loss, and the contract calculates the claim amount based on the coverage provided by the reinsurer. It is then the reinsurer's decision whether to accept this claim or not. It should be noted here that opportunistic behavior regarding the insurer's input value cannot be avoided. In practical terms, the insurer could still enter any amount as a claim loss. Therefore, the reinsurer will still incur monitoring

costs in the form of reviewing the claim against the proof of loss, date of loss, and incurred loss amount. To summarize, the administrative costs involved in calculating the claim amount under the reinsurance contract were eliminated, but opportunistic behavior in this transaction could not be prevented with this smart contract.

2f: Calculate aggregate of claims

The claims made by the insurer against the reinsurer are automatically aggregated. The contract logic determines whether the insurer can make a claim within the terms of this contract. The administrative task of checking the total amount of claims made during the contract period is eliminated. Furthermore, opportunistic behavior from both parties no longer appears to affect this transaction, assuming that the contract cannot be altered after placement.

2g: Exchange of claim amount

The contract logic also included this transaction in the smart contract. When the reinsurer accepts the claim, the claim amount is automatically transferred to the insurer, thereby reducing some of the administrative costs associated with processing the claim. Another point to consider here is that I chose to formalize the payment period given to the reinsurer in the smart contract as well. Specifically, if the reinsurer does not respond to the claim within 30 days, the claim amount is automatically sent to the insurer. This mitigates some of the opportunistic behavior from the reinsurer in the transaction. This is because the reinsurer has no incentive to promptly pay the claim amount, and delaying claim payments positively impacts the reinsurer's cash flow (G8: 21st June, 2023).

Returning to the impact of this implementation on administrative costs, I can draw the following conclusions. In the EU (re)insurance industry, administrative costs averaged €9.2 billion annually during the period 2017-2021, as indicated by the analysis in 5.3.2 Approximation of administrative costs, encompassing both the life and non-life reinsurance sectors. Based on this analysis, I inferred that monitoring costs and legal costs related to the life reinsurance industry are negligible due to the rarity of fraud in this sector. If I assume that administrative costs related to the non-life reinsurance industry are similar to those in the life reinsurance industry, it implies that our traditional contract (which involves a non-life driver’s liability contract) entails comparable costs. According to this analysis, automating the processing of claims and premium payments could save a significant portion of the annual costs associated with claims processing in the EU. The extent to which this is the case is unclear, but given that certain administrative actions in terms of claims and premium payment processes are eliminated, there is a 0/1 situation. Administrative costs inherent in executing the traditional reinsurance contract are eliminated within the smart contract design, leading to a reduction in administrative costs.

In summary, implementing this smart contract will eliminate many of the administrative costs associated with processing of claims and premium payments. By incorporating administrative costs into the internal contract logic, these costs are effectively considered ex ante during contract specification and reduce ex post transaction costs.

7.4.3 Design implications: three lenses

Based on the interviews, several implications were drawn up regarding the design. I divided these implications into three different themes or lenses, from which I evaluated the design. The three lenses concern: (a) industry differences and market-specific considerations, (b) implications of blockchain, and (c) standardization vs. customization. I will address these three themes one by one and indicate what patterns or dilemmas I identified from the various interviews.

7.4.3.1 Industry differences and market-specific considerations

Based on interviews 3, 7, and 8, it became evident that making general statements about the reinsurance market, including the European reinsurance market, is exceedingly difficult. The interviews shed light on the disparities between Europe and the United States, discrepancies in arbitration procedures, variations in trade volumes, and disparities in specialization levels.

Interviews 3 and 7 revealed substantial distinctions between the European and American reinsurance markets. For instance, interview 7 mentioned that the US reinsurance market lacks an insurance exchange and co-insurance practices, in contrast with the EU (G7: 20th June, 2023). In addition, (re)insurers in the EU commonly employ an arbitration procedure known as ARIAS UK, aiming to establish an impartial panel for potential disputes. A similar process exists in the US, namely ARIAS US. However, in the US this process is very rarely used in practice. Because the utilization of ARIAS US clauses by (re)insurers in the US is minimal, the establishment of biased panels is a bigger problem in the US than in the EU. Furthermore, dispute resolution practices within Europe can also vary significantly, contingent upon the arbitration clause outlined in the contract. Given that there is such a wide range of dispute resolution processes, the efficiency of dispute resolution also varies considerably. When dispute resolution is very fair and relatively quick, parties are less likely to feel the urgency of using a smart contract to reduce the likelihood of disputes.

The interviews also revealed that trade volume disparities among (re)insurers, even within EU Member States, are significant. Each reinsurer operates with distinct trading volumes, leading to variations in the value proposition of implementing a smart contract. For example, as highlighted in interview 7, automating claims and premium payments may not be economically justifiable when trade volumes are exceptionally low (G7: 20th June, 2023). The level of specialization also influences the value derived from smart contracts. In cases where a (re)insurer only handles a limited number of reinsurance contracts tailored to specific counterparty needs, the incremental benefit of a smart contract is negligible considering the associated placement costs. However, European reinsurers with substantial trade volumes and a greater reliance on standardized contract types stand to gain significantly from smart contract applications. Interview 3 further indicated that translating European reinsurance contracts into smart contracts would be more feasible given the higher level of standardization under the Solvency 2 regime (G3: 25th April, 2023).

In conclusion, it is evident that no standardized statements can be made regarding the reinsurance market, including the European reinsurance market. The impact of smart contracts on transaction costs is entirely dependent on contextual factors such as market type, efficiency of dispute resolution procedures, trade volumes, and contract specialization levels.

7.4.3.2 Implications of blockchain

Based on interview 2, 4 and 5, I drew various conclusions regarding the role of blockchain in the application of smart contracts in the reinsurance industry. It is important to note that smart contracts are inherently blockchain-agnostic. They can also be implemented without blockchain. As shortly described in 3.1.1 Panel A: impact of smart contracts on transaction costs, blockchain has the potential to increase transparency and trust between players in the reinsurance market. Without delving into the precise meaning of this in the context of the reinsurance industry here, I will discuss three considerations when utilizing blockchain to deploy smart contracts: the choice of architecture, the linkage between entities and wallet addresses, and the selection of a consensus algorithm. For a more comprehensive rationale explaining why blockchain serves as a compelling infrastructure for the implementation of smart contracts, I direct the reader to appendix D.

First and foremost, it is crucial for parties to consider which blockchain architecture aligns with the needs of the reinsurance industry. Considering the requirements outlined in Table 7 and the industry's culture described in appendix C, great importance is placed on confidentiality of disputes and contracts. At the same time, compliance with the Solvency 2 Directive necessitates insurers and reinsurers to report information to regulatory authorities (appendix J2.1). Additionally, privacy requirements (GDPR) must be taken into account. These requirements inherently contradict each other, necessitating careful consideration of which information can be written and read by different parties in the network. A private permissioned blockchain, such as Corda, is likely to best meet the industry's needs, as highlighted in interview 2 (G2: 19th April, 2023). One interviewee mentioned that this design, at least in the short term, relies on a public European regulator that would become the administrator of the private permissioned blockchain (G5: 13th June, 2023). Users, including insurers, reinsurers, potential brokers, and arbiters, would then request access from this government body, which would have sole access to the network. This would make it a fully private blockchain, ‘’in which the write permission over the blockchain is given to a central organization’’ (Buterin, 2015, para. 2). Consequently, the government would serve as an intermediary between the network and the outside world. However, such an approach necessitates reflection on its implications. Are we reducing transaction costs or exposing the entire critical infrastructure of the industry to a single party, thereby incurring substantial business risks?

Second, the linkage between entities and wallet addresses is essential, as indicated in Interviews 2 and 4. Insurers and reinsurers, in compliance with the AMLD (appendix J2.5), require mandatory licenses from national supervisory institutions such as the AFM and DNB in the Netherlands. To prevent money laundering and terrorism financing, (re)insurers must be registered with these institutions. The same should apply when (re)insurers utilize smart contracts. It is crucial that all companies entering into smart reinsurance contracts are linked to the wallet address(es) they use. Otherwise, it becomes impossible for regulators to know which companies are entering into transactions, which is an unfeasible alternative from a regulatory perspective, as interview 2 revealed (G2: 19th April, 2023).

Third, according to Interview 5, when a smart contract is implemented on a blockchain, miners receive compensation for executing the functions within the smart contract. Miners, as participants in the blockchain, utilize computational power to validate transactions and create new blocks (G5: 13th June, 2023). The interviewee highlighted that for long-running functions like premium payment or contract termination, the associated costs can accumulate significantly. The miner would remain linked to these functions throughout their entire duration. In response to this, the interviewee mentioned that actors sometimes choose to exclude long-term functions from the contract or include them as a "state machine". This means the contract can exist in predefined states, and parties invoke functions when they expect the smart contract to transition to a different state. When an actor anticipates a new state

in the contract, they can call a specific function to verify it. However, the interviewee acknowledged that this approach reduces the level of automation because parties need to manually invoke functions. Additionally, this can retain the opportunistic nature of certain transactions since actors must have incentives at each step of the smart contract to proceed to the next one. This creates a potential conflict of interest, particularly concerning transactions such as premium payment and claims payment, which may pose challenges for the application of smart contracts in the reinsurance context.

7.4.3.3 Standardization versus customization

Lastly, I will delve into the trade-off between standardization and customization in the reinsurance industry, based on interviews 3 and 7. Standardizing reinsurance processes and contracts can contribute to reducing transaction costs. However, reinsurance requires a significant level of customization due to the substantial amounts at stake, as revealed in interview 7 (G7: 20th June, 2023). The agreements made in reinsurance contracts vary from client to client. The variety and complexity of certain reinsurance contracts suggest that not all reinsurance contracts can easily be standardized, which therefore may justify not investing in smart contracts for certain transactions, as indicated in interview 7. On the other hand, in somewhat contrasting the data from interview 7, the third interviewee believed that approximately 75% to 85% of contracts could be 'built' using a smart contract.

Regardless of the extent to which reinsurance contracts can generally be translated into smart contracts, it is evident that parties in the reinsurance industry benefit from flexibility and human control in certain transactions. This is desirable for industry professionals and may even contribute to the fairness of handling specific transactions. According to the interviewee from interview 7, while many agreements can be made ex ante, the way in which parties are bound by those agreements ex post may be undesirable. For instance, the question of whether three named storms occurring within three days constitute one atmospheric disturbance or three separate storms is entirely dependent on human interpretation. Although it is possible to formalize this in advance, it remains unclear whether the dispute would be resolved more fairly. Ex ante, according to the interviewee, it would be very difficult to formalize contracts in detail and at the same time assess whether the settlement of this contract is fair ex post. According to the interviewee, the "gentlemen's agreement" still prevails in the industry, where parties place significant value on maintaining long-term relationships with their counterparts. Therefore, they always have an interest in resolving disputes as fairly as possible. Related to the first identified pattern, interview 7 revealed that professionals in the sector also attach great importance to human control over negotiation processes, such as receiving written notices or engaging in phone conversations (G7: 20th June, 2023). This preference for human involvement in the negotiation process can potentially act as a barrier to the implementation of smart contracts, which aim to automate certain aspects and reduce the need for direct human intervention.

Finally, the volume of transactions plays a significant role in determining the feasibility of automating processes through smart contracts. As an example, a Dutch broker mentioned that their clients typically engage in an average of 100 transactions per year, which often require significant customization. In such a scenario, the decision to transition to a smart contract implementation would be challenging to justify. This is because the automation of claims and premium payments, which can be achieved through smart contracts, would primarily generate value in cases involving a much larger volume of transactions. Interview 8 further highlighted that associating an average number of transactions across markets and (re)insurers is illogical, as the variations can be substantial (G8: 21st June, 2023). The justification for implementing smart contracts for automation depends on the number of transactions conducted by a particular party annually, ranging from being unnecessary to cost-efficient. In summary, the suitability of adopting smart contracts for automation is heavily influenced by the transaction volume, customization requirements, and the potential value generated by streamlining processes in relation to the specific context of each market and (re)insurer.

8. Conclusion

The conclusion is structured as follows. First, in Section 8.1, the main question of this research will be addressed. Furthermore, I will discuss the relevance of the research findings in a broader context. Subsequently, in Section 8.2, I will elaborate on the various sub-questions. Section 8.3 will address some limitations of this research, and finally, in Section 8.4, I will provide suggestions for future research.

8.1 Conclusion regarding main research question

This paper has explored the potential of smart contracts to reduce ex post transaction costs in the reinsurance industry, with a focus on bilateral contracts in Europe. The main research question was: **How can the implementation of smart contracts reduce ex post transaction costs in the reinsurance industry?**

Given that I have found data for two categories of ex post transaction costs, I will specifically focus on these two types of transaction costs with regard to this question. These two categories concern administrative costs and dispute resolution costs. In answering the first sub-question, I will consider all four categories ex post transaction costs, evaluating to what extent I can make statements about the degree of reduction.

The findings of this study demonstrate that smart contracts have the ability to significantly reduce administrative costs in the reinsurance industry. By automating the processing of claims and premium payments and incorporating administrative costs into the internal contract logic, smart contracts effectively consider these costs ex ante during contract specification, resulting in a reduction of ex post transaction costs. In addition, it appeared that for transactions that contain an inherent conflict of interest and can be incorporated into the smart contract logic, opportunistic behavior related to these transactions is eliminated. However, the impact of smart contracts on dispute resolution costs in the reinsurance industry is more complex. While implementing smart contract designs based on existing reinsurance contracts has the potential to reduce ambiguity and enhance contract certainty, their effectiveness in reducing dispute resolution costs is influenced by various factors. The preference for ad hoc adjustment capacity on the interpretation of certain contract terms and the demand for customization in the reinsurance industry limit the full potential of smart contracts in reducing dispute resolution costs.

While the potential for cost reduction through smart contracts is evident in administrative processes, the impact on dispute resolution costs requires careful consideration of the industry's dynamics and the preferences of the involved parties. Striking a balance between the benefits of enhanced contract certainty and reduced ambiguity ex ante, and customization and human involvement ex post are crucial aspects. It is important for the reinsurance industry to consider technologies like smart contracts, taking into account what can be formalized ex ante to reduce potential ex post transaction costs.
Additionally, the large sums of money involved in disputes deter parties in the reinsurance industry from adopting smart contract technology. Given the significant amounts at stake, some degree of human interpretation is desirable when addressing complexities arising from disputes related to reality. Considering that disputes frequently revolve around the correlation between the contract's interpretation and the reality, or the reality itself, implies that the reduction in dispute resolution costs is marginal.

Now, let me reflect on the relevance of the findings to my main research question. It is evident that I successfully translated a very specific reinsurance contract into a smart contract. My paper has also revealed significant differences between (re)insurers, reinsurance contracts, trade volumes, sectors, and their corresponding reinsurance contracts. Consequently, the value of implementing a smart contract will be highly context-dependent, and no generalized statements can be made about the applicability of a smart contract in the reinsurance industry. Therefore, I can conclude that the direct relevance of this study to the reinsurance market as a whole is limited. However, an interesting notion that should be emphasized is that the findings of this paper might be more intriguing in an even broader context. Notably, one of my outcomes is that the implementation of a smart contract generates varying value for different types of transactions within the same contract. For example, the swimlanes of 7.3.2 Claims payment illustrate that parties can automate simple administrative tasks with a smart contract, but the added value in such cases may not be substantial.

However, for transactions that inherently involve a conflict of interest and can also be incorporated into the contract logic, the added value of a smart contract is greater. In such cases, not only are administrative costs reduced, but opportunism is also minimized, and potential monitoring costs are lowered. Parties involved in these transactions no longer need to verify ex post whether the counterparty is adhering to the agreed-upon terms, as these transactions are automated. This aspect holds significance in a broader context as I recommend that parties contemplating smart contract implementation thoroughly evaluate each transaction within their contract independently. By scrutinizing the impact of a smart contract on individual transactions within the same contract, one can attain a more comprehensive understanding of where a smart contract can offer solutions and where it may not be as effective. This insight can aid parties in making informed decisions regarding the automation of specific contract parts with a smart contract while leaving other parts untouched.

8.2 Conclusion regarding sub-questions

8.2.1 Conclusion SQ1

The first sub-question was: **How can the reduction of ex post transaction costs in the reinsurance industry due to smart contract design be evaluated?**

I will now address the four categories of ex post transaction costs one by one, evaluating to what extent I can make a statement about the potential reduction in costs facilitated by the smart contract application.

Administrative costs

Huge sums are involved in the administration of reinsurers. Many of these administrative costs are tied to legal and regulatory processes that require significant human intervention. These processes are difficult to automate. Data from EIOPA's database (2022) revealed that the average administrative costs of the non-life reinsurance sector exceed those of the life-reinsurance sector by approximately €17.6 billion per year. Interview data has indicated that the difference in the amount of administrative costs is attributed to the negligible presence of legal and regulatory processes in the life-reinsurance sector. Following the analysis of 5.3.2 Approximation of administrative costs, I found that approximately €4.6 billion is spent annually on claims and premium payment processes for both the life and non-life reinsurance sectors. This translates to an average annual cost of €9.2 billion for processing premiums and claims across the EU. For certain contracts, a smart contract application would be a logical implementation to significantly reduce these costs.

Monitoring costs

Monitoring costs were beyond the immediate scope of this research. However, based on literature data and the conducted interviews, the following conclusions can be drawn regarding the relationship between monitoring costs and smart contract application. Monitoring costs are expenses incurred by the reinsurer and insurer in overseeing their counterparty, as specified in 5.2.3 Monitoring costs. Given that a smart contract can automate transactions underlying opportunistic behavior, this, in turn, reduces monitoring costs. The exact amount of monitoring costs reduction is not quantifiable. Nevertheless, it can be asserted that monitoring costs decrease to the extent that confidence in the smart contract code increases. How trust in smart contract code could potentially be ensured with blockchain is discussed in the reflection of this research (9.2.1 SBTs to lower search costs).

Dispute resolution costs

While implementing smart contract designs based on existing reinsurance contracts has the potential to reduce ambiguity and enhance contract certainty, their effectiveness in reducing dispute resolution costs is nuanced. While smart contract formalization encourages parties to be more precise ex ante - potentially increasing placement costs in principle - it can prevent potential ex post dispute resolution costs. The extent to which parties have a need for this is unclear, given that there is a preference for ad hoc adjustment capacity regarding the interpretation of certain contract terms and the demand for customization, as also described in 8.1 Conclusion regarding main research question. The reinsurance industry is generally considered a 'gentlemen's world,' where parties are financially motivated to maintain a good reputation with their counterparts. Arbitration disputes are rare in the industry, but this does not mean that parties should not continue to seek ways to minimize disputes. Negotiations

between parties also incur costs and are considered an initial means in the industry to prevent a dispute. While the likelihood of disputes decreases, I cannot quantify this reduction in probability, thus preventing me from making statements about the amount of dispute resolution costs reduced.

Legal costs

Legal costs were excluded from the direct scope of this research due to a lack of available data regarding the amount of costs incurred in compliance with legislation. However, the analysis in appendix J2 demonstrates that 75% of reinsurers and insurers fail to comply with Solvency 2 regulations in the EU. Various scenarios can be envisioned regarding how a smart contract implementation affects legal costs. The practical application of Re, which utilizes blockchain and smart contracts to reduce legal costs, operates in the US. The EU, on the other hand, has completely different laws, preventing me from making definitive statements about the impact of smart contracts on legal costs. Data from an interview suggests that compliance with certain articles related to legislative compliance can be easily automated using smart contracts, potentially reducing costs. Nevertheless, it remains a fact that I cannot make binding statements about a reduction in legal costs through a smart contract. Based on this research, no evidence has been found to suggest that a smart contract application leads to an increase in this cost category. Assuming that the amount of legal costs and dispute resolution costs remains unchanged but that the amount of administrative costs and monitoring costs decreases, I can conclude that there is an ex post reduction in transaction costs due to smart contract implementation.

8.2.2 Conclusion SQ2

The second sub-question was: **How does a smart contract lower transaction costs?**

This sub-question specifically examines the mechanisms by which a smart contract can reduce certain transaction costs. Since I have only been able to establish a definitive link between the application of smart contracts and the reduction of administrative costs, I cannot make conclusive statements about smart contract application and transaction costs in general, given that transaction costs can be divided into the previously mentioned six categories. Nonetheless, I will delve into administrative costs and dispute resolution costs, as these categories of transaction costs were central in evaluating the effectivity of my design.

First, administrative costs decrease when the underlying transaction can be incorporated into the contract logic of the smart contract. If the transaction can be included in the contract logic, it is automated, reducing the actions parties need to take after the contract is established. For example, premium payment is fully automated, and the payment of a claim is partially automated, dependent only on manual acceptance by the reinsurer. As for dispute resolution costs, the ex ante ambiguity of the contract decreases, preventing potential disputes. Whether this also leads to a net reduction in transaction costs cannot be definitively answered because it is unclear to what extent stricter formalization increases ex ante placement costs. Therefore, I recommend that parties considering the use of smart contracts to reduce dispute resolution costs carefully weigh the increase in placement costs against the potential gains in reducing the likelihood of disputes ex post. What also emerged from this is that reducing net transaction costs involves a balancing act between different categories of transaction costs. In section 9.1 Research process and results, I will delve further into this aspect.

8.3 Limitations

Moving on to the limitations of this study, it is important to note that the impact of smart contracts on the reinsurance industry cannot be generalized. Enormous differences exist between the US and European reinsurance markets, and even within Europe, practices of reinsurers vary. Certain (re)insurers may benefit more from smart contract implementation than others. The answer to the research question is highly context-dependent due to variations in reinsurance contracts, trade volumes, levels of specialization, and type of market.

Another limitation pertains to the high level of confidentiality and closed nature of the reinsurance market, significantly impeding the research process and limiting access to meaningful information. Reinsurers are reluctant to disclose details about non-productive costs, necessitating heavy reliance on literature data concerning transaction costs. Obtaining a reinsurance contract posed challenges, leading the study to rely on a US reinsurance contract, while data related to transaction costs had to be based on the European reinsurance market. To what extent this impacts the study's results remains largely unclear.

8.4 Future research

Now, I reflect on possibilities for future research. First, future research should investigate the appropriate infrastructure for implementing smart contracts in reinsurance. Private blockchains have been suggested as a suitable infrastructure in the conducted interviews, given the reinsurance industry's emphasis on confidentiality. However, it is essential to regulate such infrastructures in compliance with EU legislation. Apart from blockchain's suitability as an infrastructure for smart contract implementation, the regulation of such an infrastructure in the reinsurance industry remains unclear. I must also conclude that when a smart contract is implemented on blockchain, costs related to the execution of the contract may increase, as miners must be paid to execute functions. The extent to which this affects costs is unclear, and should be addressed in future research.

Second, future research should investigate the extent to which critical transactions in the reinsurance industry are interdependent. While I found that the implementation of smart contracts can reduce administrative costs, its impact on placement costs remains largely unclear. It is recognized that further research is necessary to examine how the implementation of smart contracts impacts other forms of transaction costs, in order to provide a more comprehensive answer to the research questions.

Lastly, it would be interesting to explore whether there are markets for which smart contract implementation is more suitable than the reinsurance market. For example, in markets where smaller sums of money are at stake, and payment frequencies are much higher, the potential of smart contracts may be greater.

9. Reflection

I have divided the reflection of this research into two sections. In section 9.1, I will briefly reflect on the research process itself and attempt to consider the relevance of the research findings in a broader context. Then, in section 9.2, I will delve into the potential roles that blockchain can play as infrastructure if smart contracts are eventually adopted on a larger scale in the reinsurance industry. In this section, I will provide an explanation of how blockchain can play a role in certain aspects of contract execution.

9.1 Research process and results

Firstly, regarding the research process, it should be noted that this investigation was challenging to conduct. The reinsurance industry is a highly closed market, making it difficult to access valuable information. Obtaining a reinsurance contract proved to be immensely challenging, and reinsurance companies were unwilling to share information concerning transaction costs. My research has primarily focused on investigating transaction costs linked to reinsurance contracts within the European Union. Fortunately, one of my interviewees generously provided me with a database containing reinsurance contracts, which enabled me to proceed with my study. Unfortunately, the database was specialized towards U.S. reinsurance contracts. Because I encountered a lack of accessible data concerning the extent of transaction costs related to U.S. reinsurance contracts, I used European data on transaction costs. It is, as outlined in 8.3 Limitations, challenging to ascertain the potential impact on my research findings. Because of this potential limitation, my analysis indicates that the evaluation of my smart contract design may not allow for an in-depth quantitative discussion regarding the reduction of transaction costs. Nonetheless, considering the binary impact of smart contract implementation, a noticeable reduction in administrative costs for reinsurance contracts becomes evident. My analysis of the design underscores the elimination of certain administrative costs associated with reinsurance contracts, as demonstrated in transactions 1b, 2f, and 2g. This finding holds true for both European and American reinsurance contracts.

Secondly, concerning the research findings, I would like to address the notion that it is not very meaningful to focus on cost reduction in one specific transaction cost category. Net transaction costs are determined by the six identified categories of transaction costs. My research clearly demonstrates that reducing transaction costs is a balancing act. Parties must evaluate whether stricter formalization ex ante is desired for each type of transaction, given the potential gains ex post. Looking at the formulated research questions, I can also conclude that considering only ex post transaction costs has limited relevance. The impact of a smart contract on net transaction costs depends not only on the extent to which it reduces ex post transaction costs but also on how it influences ex ante placement costs.

9.2 Role of blockchain

Given that certain transactions in the execution of the reinsurance contract cannot be automated using a smart contract, it is evident that certain aspects of a traditional reinsurance contract are simply not suited for smart contract automation. I will consider two examples here where a smart contract does not provide a solution in the execution of the reinsurance contract and reflect on the potential role that blockchain can play in this context.

9.2.1 SBTs to lower search costs

Firstly, the implementation of a smart contract does not provide a solution for finding an available counterparty. Logically, a (re)insurer must first search for an available counterparty before deciding to create a smart contract. In other words, a (re)insurer incurs certain ex ante search costs, as defined in 5.2.1 Search costs. For this purpose, (re)insurers rely on information provided by credit rating agencies (CRAs) to assess the financial stability and overall professionalism of potential counterparties. However, many (re)insurers express concerns about the quality and non-transparency of CRA models used to assign specific ratings (Tichy et al., 2011). Furthermore, since the subprime mortgage crisis in the US, the credibility of CRAs has significantly declined, and concerns persist regarding the conflicting interests of CRAs (Tichy et al., 2011).

Parties in the reinsurance sector may consider how blockchain could potentially offer solutions to create similar reputation systems at lower costs. When a smart contract is executed on the blockchain, certain data about the contract's execution can be stored in the form of a soulbound token (SBT). These tokens are publicly visible and non-transferable tokens (Weyl et al., 2022). Since the tokens cannot be passed on to other parties, they could be used to store reputational data of a (re)insurer. From one of my interviews, it emerged that, for instance, the solvency capital ratio, the solidity of reinsurance, the percentage of appealed reinsurance transactions, and the speed of claims payment are important reputational indicators for a (re)insurer in the search process (G3: 25th April, 2023).

If these indicators are linked to the entity (the respective wallet address) using SBTs, a reliable and publicly visible reputation can be established for every (re)insurer. Since such infrastructures do not yet exist in the reinsurance industry, I can only speculate that the use of SBTs would reduce search costs. However, what I can assert with certainty is that if these indicators are directly generated from the execution of a smart contract, the quality of this data depends entirely on the quality of the smart contract code. Because parties specifying a smart contract can decide which functions of the code are publicly visible and which are not (G5: 13th June, 2023), they also have autonomy over the level of transparency of their own reputation. Concerns about erroneous ratings from CRAs and conflicts of interest in existing reputation systems are thus reduced.

9.2.2 Decentral dispute resolution

Furthermore, smart contract design has shown that the dispute resolution process itself has remained unchanged. Although the likelihood of disputes has decreased due to stricter ex ante formalization through computer code, a dispute will still cost an average of 350 thousand euros with an average duration of 91 weeks (see 5.3.1 Approximation of dispute resolution costs).

With regard to the implementation of the dispute resolution process, I must first note that it is challenging to determine in advance to what extent an alternative process is adequate for rendering a fair judgment for both parties. Given the complexity of the dispute resolution process and the uniqueness of each dispute, there will be no one-size-fits-all dispute resolution procedure that is best suited for all types of disputes. Nevertheless, I recommend that the industry considers alternative approaches to the dispute resolution process to minimize costs associated with this process, both in terms of monetary costs and time.

A possible way to implement this process is through blockchain-based decentralized dispute resolution. To illustrate this, I will briefly discuss an existing application called Kleros (Ast, 2020). Kleros is a decentralized mechanism for dispute resolution that utilizes blockchain technology and crypto-economic principles to resolve disputes in a transparent and efficient manner. In essence, Kleros functions as a decentralized court where disputing parties agree to submit their case to a group of independent arbitrators known as "jurors" (Ast, 2020). These arbitrators are distributed across the Kleros network and possess expertise in various domains. When a dispute arises, the case is presented to a random selection of jurors from the network. These jurors evaluate the case based on evidence and arguments provided by the involved parties. They render a judgment on the outcome of the dispute, which is then recorded on the blockchain. Kleros' system incentivizes honesty and expertise among arbitrators by rewarding them for making correct decisions and penalizing them for incorrect ones. This encourages fair and effective dispute resolution without the need for a central authority or intermediary. Kleros is commonly used in decentralized applications (DApps) and blockchain projects to resolve disputes that may arise between users, such as contract breaches, payment disputes, or other legal matters. It offers a transparent, fast, and cost-effective solution for dispute resolution in a decentralized environment, as described by Ast (2020).

Decentralized blockchain applications for dispute resolution offer several potential advantages over existing arbitration processes in the reinsurance industry. Firstly, due to their decentralized nature, they minimize the risk of bias and prejudiced decisions since there is no central authority or entity overseeing the decisions. Secondly, blockchain-based dispute resolution provides a high level of transparency as all disputes and their associated decisions are recorded on the blockchain, ensuring a transparent and traceable process. Because parties can remain anonymous on the blockchain, they can satisfy their need for confidentiality while also maintaining transparency regarding dispute resolution. This could potentially lead to the development of a form of international jurisprudence that does not currently exist in the reinsurance industry (Graber & Lauterburg, 2015).

Lastly, I would like to address the fact that assessing whether such a dispute resolution mechanism for smart contracts delivers the desired results remains challenging prior to implementation. Furthermore, achieving full "on-chain" arbitration, as noted by Kasatkina (2022), is unrealistic in the short term. Therefore, I advise the industry to consider hybrid applications. For certain disputes, it may still be best to resolve them off-chain if such an application is unable to provide a fair judgment (Kasatkina, 2022). If on-chain resolution fails to deliver a suitable decision accepted by both parties, the dispute is resolved off-chain following well-established arbitration procedures.

10. Bibliography

Abramovsky, A. (2008). Reinsurance: The silent regulator. Conn. Ins. LJ, 15, 345. Retrieved from https://digitalcommons.law.buffalo.edu/journal_articles/3?utm_source=digitalcommons.law.buffalo.edu/journal_articles/3&utm_medium=PDF&utm_campaign=PDFCoverPages

Abramowicz, M. B. (2019). Blockchain-Based Insurance. Blockchain and the Constitution of a New Financial Order: Legal and Political Challenges (Ioannis Lianos et al. Eds. , 2019, Forthcoming). , GWU Law School Public Law Research Paper, (2019–12). doi:10.2139/ssrn.3366603

Ahluwalia, S., Mahto, R. V., & Guerrero, M. (2020). Blockchain technology and startup financing: A transaction cost economics perspective. Technological Forecasting and Social Change, 151, 119854. doi:10.1016/j.techfore.2019.119854

Albrecher, H., Bommier, A., Filipović, D., Koch-Medina, P., Loisel, S., & Schmeiser, H. (2019). Insurance: models, digitalization, and data science. European Actuarial Journal, 9(2), 349–360. doi:10.1007/s13385-019-00209-x

ARIAS. (n.d.). Neutral Selection Procedure. Retrieved from: https://www.arias-us.org/arias-us-dispute-resolution-process/practical-guide/neutral-selection/

Ast, F. (2020). The Kleros Handbook of Decentralized Justice. Retrieved from https://kleros.io/book.pdf

Bessire, D. (2005). Transparency: a two-way mirror? *International Journal of Social Economics*, *32*(5), 424-438.

Bieber, C. J. D. (2023). Car Accident Statistics For 2023. Retrieved from https://www.forbes.com/advisor/legal/car-accident-statistics

Blanchard, S. (2021). Contracts Without Courts or Clans: How Business Networks Govern Exchange. SSRN Electronic Journal. doi:10.2139/ssrn.3780925

Blanchard, S., Jennejohn, M. (2019). An(other) Autopsy of Cooperation: The Case of Reinsurance. Retrieved from: https://www.brooklaw.edu/-/media/Brooklaw/Centers/Block-International-Business/Sadie-Blanchard-Another-Autopsy-of-Cooperation-The-Case-of-Reinsurance.pdf

Buterin, V. (2015). On Public and Private Blockchains – Ethereum foundation blog. Retrieved from: https://blog.ethereum.org/2015/08/07/on-public-and-private-blockchains

Canfora, G., & Di Penta, M. (2007). New frontiers of reverse engineering. Future of Software Engineering (FOSE \textquotesingle07), 326–341. doi:10.1109/fose.2007.15

Canny, W. (2022). Blockchain-Powered Reinsurer Re Raises $14 Million Seed Round to Build Decentralized Market. Retrieved from: https://www.coindesk.com/business/2022/09/28/blockchain-powered-reinsurer-re-raises-14-million-seed-round-to-build-decentralized-market/

Chester, A., Johansson, S., Michel-Kerjan, E., Rachok, O., & Dong, M. (2017). Global reinsurance: Fit for the future? Retrieved from https://www.mckinsey.com/industries/financial-services/our-insights/global-reinsurance-fit-for-the-future

Coase, R. H. (1937). The Nature of the Firm. Economica, 4(16), 386–405. doi:10.1111/j.1468-0335.1937.tb00002.x

Corporate Finance Institute – CFI. (2019). Transaction Costs. Retrieved from: https://corporatefinanceinstitute.com/resources/economics/transaction-costs/

Crocker, K. J., & Reynolds, K. J. (1993). The efficiency of incomplete contracts: An empirical analysis of air force engine procurement. The RAND Journal of Economics, 24(1), 126–146. doi:10.2307/2555956

Cutler, D. M., & Zeckhauser, R. J. (1999). Reinsurance for catastrophes and cataclysms. In *The financing of catastrophe risk* (pp. 233-274). University of Chicago Press.

Dacey, J. (2023). Swiss Re said that B3i conceptually interesting,but required end-to-end view. Retrieved from https://beinsure.com/news/swiss-re-said-that-b3i-conceptually-interesting/

Da Silva, A. D., Georgarakos, D., & Weißler, M. (2023). How people want to work–preferences for remote work after the pandemic. *Economic Bulletin Boxes*, *1*.

Davidson, S., & Potts, J. (2022). Institutional cryptoeconomics. In The Economics of Blockchain and Cryptocurrency (pp. 1–12). doi:10.4337/9781800882348.00008

Deloitte Advisory. (2018). Modernizing reinsurance administration. Retrieved from: https://www2.deloitte.com/us/en/pages/financial-services/articles/reinsurance-administration.html

De Nederlandsche Bank. (2023). Solvency II: General notes. Retrieved from: https://www.dnb.nl/en/sector-information/open-book-supervision/open-book-supervision-sectors/insurers/law-and-regulations-insurers/solvency-ii-general-notes/

Dispute Resolution Data (DRD). (2023). Database on arbitration in reinsurance EU. Retrieved from: https://www.disputeresolutiondata.com/

ECB. (2023). Insurance Corporations. Retrieved from: https://www.ecb.europa.eu/stats/financial_corporations/insurance_corporations/html/index.en.html

Edmonds, C. (2019). Can blockchain smart contracts replace (re)insurance contracts? Retrieved from https://www.ledgerinsights.com/blockchain-smart-contracts-insurance/

EIOPA. (2014). Consultation Paper on the proposal for Guidelines on Solvency II relating to Pillar 1 requirements. Retrieved from: https://register.eiopa.europa.eu/Publications/Consultations/EIOPA-CP-14-036_GL-Pillar_1.pdf

EIOPA. (2022). Insurance Statistics. Retrieved from: https://www.eiopa.europa.eu/tools-and-data/insurance-statistics_en#premiums-claims-and-expenses

EIOPA. (n.d.a). Cooperation at European level. Retrieved from: https://www.eiopa.europa.eu/about/governance-structure/cooperation-european-level_en#:~:text=EIOPA%20acts%20as%20an%20independent,advice%20for%20the%20European%20Commission.

EIOPA. (n.d.b). Insurance Distribution Directive (IDD). Retrieved from: https://www.eiopa.europa.eu/browse/regulation-and-policy/insurance-distribution-directive-idd_en

ESMA. (2019). About ESMA. Retrieved from: https://www.esma.europa.eu/about-esma

European Commission (n.d.a). Derivatives/ EMIR. Retrieved from: https://finance.ec.europa.eu/capital-markets-union-and-financial-markets/financial-markets/post-trade-services/derivatives-emir_en

European Commission (n.d.b). The Report on Market Trends of Private Reinsurance in the Field of Export Credit Insurance. Retrieved from: https://ec.europa.eu/competition/state_aid/studies_reports/export_credit_insurance_report.pdf

Faems, D., Janssens, M., Madhok, A., & Looy, B. V. (2008). Toward an integrative perspective on alliance governance: Connecting contract design, trust dynamics, and contract application. *Academy of management journal*, *51*(6), 1053-1078.

Geeks for Geeks. (2023). How to write a Pseudo Code? Retrieved from: https://www.geeksforgeeks.org/how-to-write-a-pseudo-code/

Gibson, R., Habib, M. A., & Ziegler, A. (2014). Reinsurance or securitization: The case of natural catastrophe risk. *Journal of Mathematical Economics*, *53*, 79-100.

Graber, C. Lauterburg, B. (2015). Switzerland: Applicable Law And Jurisdiction In International Reinsurance Contracts From A Swiss Perspective. *Reinsurance – Switzerland.* Retrieved from: https://www.mondaq.com/reinsurance/427842/applicable-law-and-jurisdiction-in-international-reinsurance-contracts-from-a-swiss-perspective

Graillot, F. (2023). Blockchain in Insurance: What to Learn from B3i Failure. Retrieved from https://www.linkedin.com/pulse/what-learn-from-b3i-failure-blockchain-industry-florian-graillot

Hall, R. (2016). How Reinsurance Arbitrations Can Be Cheaper, Better and Faster. Retrieved from https://www.linkedin.com/pulse/how-reinsurance-arbitrations-can-cheaper-better-faster-robert-hall

Hall, R. M. (2018). When the Other Side Will not Arbitrate: Judicial Appointment of Umpires and Arbitrators. Retrieved from: https://debrahalljd.files.wordpress.com/2018/02/when-the-other-side-will-not-arbitrate-judicial-appointment-of-umpires-and-arbitrators.pdf

Hannover Re. (2022). Corporate news: Hannover Re expects further price increases next year. Retrieved from: https://www.hannover-re.com/1898998/hannover-re-expects-further-price-increases-next-year.pdf

Hannover Re. (2023). Hannover Re: The Somewhat Different Reinsurer. Retrieved from https://www.hannover-re.com/50856/company-presentation-june-2023.pdf

Hans, R., Zuber, H., Rizk, A., & Steinmetz, R. (2017). Blockchain and smart contracts: Disruptive technologies for the insurance market. Americas Conference on Information Systems. Retrieved from https://core.ac.uk/download/pdf/301371768.pdf

Heiss, H., Schauer, M., Wandt, M. (2019). Principles of Reinsurance Contract Law. University of Zurich.

Hevner, A. R. (2007). A three cycle view of design science research. *Scandinavian journal of information systems*, *19*(2), 4.

Hildebrand, P. J. (n.d.). Reinsurance Basics for the Claims Professional Relative to Bad Faith Claims. Retrieved from: https://www.cooperscully.com/uploads/seminars/Hildebrand%20-%20REINSURANCE%20BASICS%20FOR%20THE%20CLAIMS%20PROFESSIONAL%20RELATIVE%20TO%20BAD%20FAITH%20CLAIMS.pdf

Højlund, P. W., & Nielsen, L. S. (2019). Blockchain Smart Contracts For International Trade: A Transaction Cost Analysis. Scandinavian Journal of Information Systems, 19(2), 93. Retrieved from https://research.cbs.dk/en/studentProjects/blockchain-smart-contracts-for-international-trade-a-transaction-

Hoffman, W. (2002). Facultative Reinsurance Contract Formation, Documentation, and Integration. *Tort Trial & Ins. Prac. LJ*, *38*, 763.

ICCIE. (n.d.). Certificate of Facultative Reinsurance. Retrieved from: https://iccie.org/wp-content/themes/iccie/inc/html_files/Cert_2.html

Insurance Europe. (2019). Response to EC stocktaking exercise on application of GDPR. Retrieved from: https://insuranceeurope.eu/publications/1770/response-to-ec-stocktaking-exercise-on-application-of-gdpr/

Insurance Information Institute. (n.d.). How to assess the financial strength of an insurance company. Retrieved from https://www.iii.org/article/how-to-assess-the-financial-strength-of-an-insurance-company

International Risk Management Institute. (n.d.a). certificate of reinsurance. Retrieved from https://www.irmi.com/term/insurance-definitions/certificate-of-reinsurance

International Risk Management Institute. (n.d.b). contributing excess. Retrieved from https://www.irmi.com/term/insurance-definitions/contributing-excess

Jakubik, P. (2021). European insurers during the COVID crisis. Retrieved from https://www.eiopa.europa.eu/publications/european-insurers-during-covid-crisis%5Fen

Jean-Baptiste, E. L., & Santomero, A. M. (2000). The design of private reinsurance contracts. *Journal of Financial Intermediation*, *9*(3), 274-297.

Kagan, J., Brock, T. (2023). Administrative Charge: Definition and How It Works in Insurance. Retrieved from https://www.investopedia.com/terms/a/administrative-charge.asp

Kagan, J., Potters, C. (2020). Solvency Capital Requirement (SCR): Meaning and How They work. Retrieved from: https://www.investopedia.com/terms/s/solvency-capital-requirement.asp.

Kasatkina, M. (2022). Dispute Resolution Mechanism for Smart Contracts. *Masaryk University Journal of Law and Technology*, *16*(2), 143-162.

Künneke, R. (2021). Institutional Economics for Designing in Socio-Technical Systems.

Lindenberg, M., & Crosby, B. (1981). Managing Development: The Political Dimension. Retrieved from https://books.google.nl/books?id=duBRAQAAIAAJ

Lin, Y., Yu, J., & Peterson, M. O. (2015). Reinsurance networks and their impact on reinsurance decisions: Theory and empirical evidence. *Journal of Risk and Insurance*, *82*(3), 531-569.

Loukil, F., Boukadi, K., Hussain, R., & Abed, M. (2021). Ciosy: A collaborative blockchain-based insurance system. *Electronics*, *10*(11), 1343.

Lu, W., Zhang, L., & Zhang, L. (2016). Effect of contract completeness on contractors' opportunistic behavior and the moderating role of interdependence. *Journal of Construction Engineering and Management*, *142*(6), 04016004.

Marx, B. (2020). Hard Market vs. Soft Market: The Insurance Industry's Cycle and Why We're Currently in a Hard Market. Retrieved from: https://www.psafinancial.com/2013/01/hard-market-vs-soft-market-the-insurance-industrys-cycle-and-why-were-currently-in-a-hard-market/

McMinn Law Firm. (n.d.). The 7 Principles of Insurance Contracts: When You Need A Lawyer. Retrieved from: https://www.mcminnlaw.com/principles-of-insurance-contracts/

Meeusen, P. (2017). B3i – Blockchain Insurance Industry Initiative. Retrieved from https://www.swissre.com/dam/jcr:d560374e-d7ba-4472-a28c-1f53f932303b/2017_09_25_B3i_blockchain_insurance.pdf

Mendoza-Tello, J. C., & Calderón-Hinojosa, X. (2021). A blockchain-based approach to supporting reinsurance contracting. In *Advances in Emerging Trends and Technologies: Proceedings of ICAETT 2020* (pp. 252-263). Springer International Publishing.

Moody's. (2023). Reinsurers defend against rising tide of natural catastrophe losses, for now. Retrieved from https://www.moodys.com/web/en/us/about/insights/data-stories/reinsurers-mitigate-lower-profits.html

Mukhopadhyay, A. (2023). Blockchain-powered reinsurer Re backs $34 million in Q1 premiums. Retrieved from https://www.reinsurancene.ws/blockchain-powered-reinsurer-re-backs-34-million-in-q1-premiums/

Munich Re. (2016). Reinsurance Contracts – Out of the backroom and into the light of innovation.

Munich Re. (n.d.a). Information about data protection in reinsurance. Retrieved from: https://www.munichre.com/en/general/privacy/data-protection_en.html

Munich Re. (n.d.b). The Next Generation of Pricing Actuaries. Retrieved from: https://www.munichre.com/en/solutions/reinsurance-property-casualty/global-consulting/pricing-consulting/pricing-article-download.html

Niehaus, G., & Mann, S. V. (1992). The trading of underwriting risk: An analysis of insurance futures contracts and reinsurance. *Journal of Risk and Insurance*, 601-627.

Nordblom, E. (2023). Understanding the new hard reinsurance market. Retrieved from: https://www.if-insurance.com/large-enterprises/insight/understanding-the-new-hard-reinsurance-market

OECD. (2018). The Contribution of Reinsurance Markets to Managing Catastrophe Risk. Retrieved from: https://www.oecd.org/finance/the-contribution-of-reinsurance-markets-to-managing-catastrophe-risk.pdf

Pande, M., Mitchell, M. (2023). The State of the Reinsurance Property Casualty Market. Retrieved from: https://www.swissre.com/risk-knowledge/mitigating-climate-risk/state-of-reinsurance-property-cat-market.html

Pope, C. (2023). What is a policyholder? Retrieved from https://www.bankrate.com/insurance/car/policyholder/

Popovic, D., Avis, C., Byrne, M., Cheung, C., Donovan, M., Flynn, Y., … Shah, J. (2020). Understanding blockchain for insurance use cases. British Actuarial Journal, 25, e12. doi:10.1017/s1357321720000148

Potts, J., Berg, C. (2019). *Agoric + Protocol Labs // Economics of Blockchain* [Video]. Retrieved from: https://www.youtube.com/watch?v=OQMP5dmoZhs

PwC. (2012). Pillar 2 - Operational Issues of Risk Management. Retrieved from: https://www.pwc.com/gx/en/insurance/solvency-ii/countdown/pdf/pwc-pillar-2-operational-issues-of-risk-management.pdf

PwC. (n.d.a). Blockchain: The 5 billion opportunity for reinsurers. Retrieved from: https://www.pwc.com/gx/en/industries/financial-services/publications/blockchain-the-5-billion-opportunity-for-reinsurers.html

PwC. (n.d.b). Is the (re)insurance industry fit for growth? Retrieved from: https://www.pwc.com/gx/en/insurance/assets/pwc-is-the-reinsurance-industry-fit-for-growth.pdf

Raja, V., Fernandes, K. J. (2007). Reverse engineering: an industrial perspective. doi:10.1007/978-1-84628-856-2

Rubinstein, A., & Yaari, M. E. (1983). Repeated insurance contracts and moral hazard. *Journal of Economic theory*, *30*(1), 74-97.

Sayegh, K., & Desoky, M. (2019). Blockchain application in insurance and reinsurance. France: Skema Business School. Retrieved from https://www.researchgate.net/profile/Katia-Sayegh/publication/327987901_Blockchain_Application_in_Insurance_and_Reinsurance/links/5c38675d299bf12be3be7459/Blockchain-Application-in-Insurance-and-Reinsurance.pdf

Schiffer, L.P. (2005). The Late Notice Defense in Reinsurance – Updated. Retrieved from: https://www.irmi.com/articles/expert-commentary/the-late-notice-defense-in-reinsurance-updated

Schiffer, L. P. (2006). Reinsurance Arbitration -- A Primer. Retrieved from https://www.irmi.com/articles/expert-commentary/reinsurance-arbitration-a-primer

Schiffer, L. P. (2010). Mirror, Mirror on the Wall. Arias US - Federal Jurisdiction of Insurance and Reinsurance Arbitration Disputes Under the New York Convention, 17, 10–13.

Schiffer, L. P. (2011). Reinsurance Terminology Explained: Bordereau. Retrieved from: https://www.irmi.com/articles/expert-commentary/reinsurance-terminology-explained-bordereau

Schiffer, L. P. (2015). The 'Secret' World of Reinsurance. Retrieved from https://www.irmi.com/articles/expert-commentary/the-secret-world-of-reinsurance

Schiffer, L. P. (2017). Confidentiality Agreements in Reinsurance Disputes. Retrieved from https://www.irmi.com/articles/expert-commentary/confidentiality-agreements-in-reinsurance-disputes

Schiffer, L.P. (2019). A Reinsurer's Right to Recoveries. Retrieved from: https://www.irmi.com/articles/expert-commentary/a-reinsurers-right-to-recoveries

Shetty, A., Shetty, A. D., Pai, R. Y., Rao, R. R., Bhandary, R., Shetty, J., … Dsouza, K. J. (2022). Block Chain Application in Insurance Services: A Systematic Review of the Evidence. SAGE Open, 12(1), 215824402210798. doi:10.1177/21582440221079877

Spee, P., Jarzabkowski, P., & Smets, M. (2016). The influence of routine interdependence and skillful accomplishment on the coordination of standardizing and customizing. *Organization Science*, *27*(3), 759-781.

Swan, M. (2015), Blockchain: Blueprint for a new economy. Sebastopol: O'Reilly Media.

Swiss Re. (n.d.a). Proportional and non-proportional reinsurance. Retrieved from: http://newdoc.nccu.edu.tw/teasyllabus/308002308018/Swiss%20Re%20Prop.&Non-Prop..pdf

Swiss Re. (n.d.b). Purchase Order & Invoicing standards for Swiss Reinsurance Company Ltd., Swiss Re Management Ltd., Swiss Re Investments Ltd., Swiss Re Ltd., iptiQ Group Holding Ltd., iptiQ EMEA P&C

S.A., Luxembourg, Zweigniederlassung Zürich Swiss Re Insurance-Linked Investment Management AG. Retrieved from https://www.swissre.com/dam/jcr:14377612-d3a8-48d7-a30b-8e161adf97ad/Switzerland_Invoicing_standards_for_swiss_re_en.pdf

Storm, S., Naastepad, C.W.M. (2020). Economics & Finance. Understanding Financial Derivatives – Delft University of Technology.

Szabo, N. (1994). Smart Contracts. Retrieved from https://www.fon.hum.uva.nl/rob/Courses/InformationInSpeech/CDROM/Literature/LOTwinterschool2006/szabo.best.vwh.net/smart.contracts.html

Thorpe, K. E. (2004). The Medical Malpractice `Crisis': Recent Trends And The Impact Of State Tort Reforms: Do recent events constitute a crisis or merely the workings of the insurance cycle? Health Affairs, 23(Suppl1), W4-20--w4--30. doi:10.1377/hlthaff.w4.20

Tichy, G., Lannoo, K., Ap Gwilym, O., Alsakka, R., Masciandaro, D., & Paudyn, B. (2011). Credit rating agencies: Part of the solution or part of the problem?. *Intereconomics*, *46*(5), 232-262.

Tippins, K. (2023). Smart contracts without blockchain. Retrieved from: https://contractbook.com/blog/smart-contracts-without-blockchain

Tobin, A. (2021). Cover Talk: An introduction to reinsurance. Retrieved from https://www.youtube.com/watch?v=hmvch2xdALU

Tomilson, R. (2020). A Gentlemen's Agreement Broken: Life and Annuity Reinsurance Arbitration. Retrieved from https://www.clarkhill.com/news-events/news/a-gentlemens-agreement-broken-life-and-annuity-reinsurance-arbitration/

Tonella, P., & Potrich, A. (2005). Reverse engineering of object oriented code. Proceedings. 27th International Conference on Software Engineering, 2005. ICSE 2005., 724–725. doi:10.1109/icse.2005.1553682

Traynor, P. E. (2002). Will the Historic Relationship between Cedent and Reinsurer become a Casualty of the War on Terrorism. *Conn. Ins. LJ*, *9*, 179.

Vatiero, M. (2018). Smart contracts and transaction costs. Discussion Papers, pp.2-18

Werbach, K. (2018). Trust, but verify: Why the blockchain needs the law. *Berkeley Technology Law Journal*, *33*(2), 487-550.

Weyl, E. G., Ohlhaver, P., & Buterin, V. (2022). Decentralized society: Finding Web3's soul. *Available at SSRN 4105763*.

Williamson, O. E. (1979). Transaction-Cost Economics: The Governance of Contractual Relations. The Journal of Law & Economics, 22(2), 233–261. Retrieved from http://www.jstor.org/stable/725118

Williamson, O. E. (1981). The economics of organization: The transaction cost approach. American Journal of Sociology, 87(3), 548–577. doi:10.1086/227496

Williamson, Oliver E. (1985). The Economic Institutions of Capitalism, Free Press, New York, NY.

Williamson, O. E. (1989). Transaction cost economics. *Handbook of industrial organization*, *1*, 135-182.

Williamson, O. E. (1998). Transaction cost economics: how it works; where it is headed. *De economist*, *146*, 23-58.

Wilt, W., & Zimmermann, A. (2016, November). History of Asbestos and the Insurance Industry. Retrieved from http://www.assuredresearch.com/assets/Uploads/PDF/History-of-Asbestos-and-Insurance-Nov-2016-FINAL.pdf

Wustrow, D., Hughes, R. (2008). After the reinsurance audit. *Airroc Matters.* Retrieved from: https://www.airroc.org/assets/CLIP/after%20the%20reinsurance%20audit%20winter%202008_2009%20web.pdf

Yan, Z. (2013). Testing for moral hazard in reinsurance markets. *Managerial Finance*, *39*(8), 696-713.

Zheng, Z., Xie, S., Dai, H.-N., Chen, W., Chen, X., Weng, J., & Imran, M. (2020). An overview on smart contracts: Challenges, advances and platforms. Future Generation Computer Systems, 105, 475–491. doi:10.1016/j.future.2019.12.019~~

Zou, W., Lo, D., Kochhar, P. S., Le, X. B. D., Xia, X., Feng, Y., ... & Xu, B. (2019). Smart contract development: Challenges and opportunities. *IEEE Transactions on Software Engineering*, *47*(10), 2084-2106.

Appendix A: Anonymized facultative reinsurance contract

[redacted]

[redacted]

[redacted]

CERTIFICATE OF FACULTATIVE REINSURANCE

[redacted]

(herein called the "Reinsurer")

1. Does hereby reinsure [redacted]
Name and Address of Ceding Company
(herein called the Company) in respect of the Company's policy hereinafter described, in consideration of the payment of the premium and subject to the terms, conditions and amount of liability set forth herein, as follows:

2. Name of Insured: [redacted]

3. Company Policy No.: [redacted] Address of Insured [redacted] City and State

Effective From: [redacted] To: [redacted]
(12:01 A. M. Standard Time at the Address of the Insured)

4. Reinsurance Period: From April 1, 1974 To: April 1, 1975
(12:01 A. M. Standard Time at the Address of the Insured)

5. DETAILS OF REINSURANCE AFFORDED:

SECTION 1. TYPE OF INSURANCE	SECTION 2. POLICY LIMITS AND APPLICATION	SECTION 3. COMPANY RETENTION	SECTION 4. REINSURANCE ACCEPTED	SECTION 5. BASIS OF ACCEPTANCE
Manuscript Blanket Liability and Automobile Liability	$25,000,000 occurrence/aggregate excess Deductible of $1,000,000 each occurrence $4,000,000 aggregate	Various	$200,000 part of $1,000,000 combined single limit excess Deductible of $1,000,000 each occurrence $4,000,000 aggregate	Contributing Excess

6. Reinsurance Premium Computation

Premium Basis	Estimated Exposure	Rate	Estimated Premium
Flat charge			

Deposit Premium $~~11,000.00~~ Minimum Premium $ 11,000.00

PREMIUM IF PAID IN INSTALLMENTS

EFFECTIVE DATE	1st ANNIVERSARY	2nd ANNIVERSARY	TOTAL PREMIUM →	$

7. Audit Period: none 8/21/74

8. Ceding Commission: nil

GERLING GLOBAL OFFICES INC.
U. S. Manager

9. The Company warrants to retain f[redacted] own account, subject to other Reinsurance, th[redacted]mount of liability specified in Section III of 5 above, and the liability of the Reinsurer specified in Section IV of 5 above shall follow that of the Company and except as otherwise specifically provided herein, shall be subject in all respects to all the terms and conditions of the Company's policy. The Company shall furnish the Reinsurer with a copy of its policy and all endorsements thereto which in any manner affect this certificate, and shall make available for inspection and place at the disposal of the Reinsurer at reasonable times any of its records relating to this reinsurance or claims in connection therewith.

10. Prompt notice shall be given to the Reinsurer by the Company of any occurrence or accident which appears likely to involve this reinsurance and; while the Reinsurer does not undertake to investigate or defend claims or suits it shall nevertheless have the right and be given the opportunity to associate with the Company and its representatives at its own expense in the defense and control of any claim, suit or proceeding involving this reinsurance with the full cooperation of the Company.

11. All claims involving this reinsurance, when settled by the Company, shall be binding on the Reinsurer, who shall be bound to pay its proportion of such settlements, and in addition thereto in the ratio that the Reinsurer's loss payment bears to the Company's gross loss payment, its proportion of expenses, other than Company salaries and office expenses, incurred by the Company in the investigation and settlement of claims or suits and, with the prior consent of the Reinsurer to trial court proceedings, its proportion of court costs and interest on any judgment or award.

12. Payment of its proportion of loss and expense paid by the Company will be made by the Reinsurer to the Company promptly following receipt of proof of loss.

13. The Reinsurer will be paid or credited by the Company with its proportion of salvages, i.e., reimbursement obtained or recovery made by the Company, less the actual cost (excluding Company salaries and office expenses) of obtaining such reimbursement or making such recovery. If the reinsurance afforded by this Certificate is on an excess of loss basis, salvage shall be applied in the inverse order in which liability attaches.

14. The Company undertakes not to claim any deduction in respect of the premium hereon when making tax returns, other than Income or Profits Tax returns, to any State or Territory of the United States or to the District of Columbia.

15. In the event of insolvency of the Company, the terms of this Certificate are amended to conform to the statute of any state of the United States having jurisdiction to the extent that such reinsurance as is afforded hereunder may be credited to the Company as an admitted asset or deduction from liability, it being understood that, subject to such amendment, the Reinsurer may avail itself of any other provision of any such statute applicable.

16. Should an irreconcilable difference of opinion arise as to the interpretation of this Contract, it is hereby mutually agreed that as a condition precedent to any right of action hereunder, such difference shall be submitted to arbitration, one arbiter to be chosen by the Company, one by the Reinsurer, and an umpire to be chosen by the two arbiters before they enter upon arbitration. In the event that either party should fail to choose an arbiter within sixty days following a written request by the other party to enter upon arbitration, the requesting party may choose two arbiters who shall in turn choose an umpire before entering upon arbitration. Each party shall present its case to the arbiters within sixty days following the date of their appointment. The decision of the arbiters shall be final and binding upon both parties, but failing to agree they shall call in the umpire and the decision of the majority shall be final and binding upon both parties. Each party shall bear the expense of its own arbiter, and shall jointly and equally bear with the other the expense of the umpire and of the arbitration. In the event that the two arbiters are chosen by one party, as above provided, the expense of the arbiters, the umpire, and the arbitration shall be equally divided between the two parties.
Any such arbitration shall take place at New York, N. Y., unless some other location is mutually agreed upon by the two parties in interest.

17. Cancellation of the policy of the Company shall constitute automatic cancellation of this Certificate and it may also be cancelled on a pro rata basis by either party mailing or delivering to the other written notice stating when, not less than thirty days thereafter, such cancellation shall be effective.

18. The terms of this Certificate shall not be waived or changed except by endorsement issued to form a part hereof, executed by a duly authorized representative of the Reinsurer.

In witness whereof, the Reinsurer has caused this Certificate to be signed by its authorized representative.

Appendix B: Translated smart contract

```
# initialize variables

Insurer = address_X    # Art. 1
Reinsurer = address_Y
Escrow = address_Z

Premium_amount = 11000         # Art. 6
total_claim_amount = 0  # Art. 5 Section 4
Retention = 1000000    # Art. 5 Section 4

initial_time = timestamp()
partyX_Cost = 0
partyY_Cost = 0
arbitrationPlace = 'New York, N.Y.'    # Art. 16
insurer_selects = False
reinsurer_selects = False
terminated_contract = False
cancelled_contract = False
cancellationNoticePeriod = 30  # Art. 17
insurer_insolvent = False
reinsurer_insolvent = False

reinsurer_liable = False



# Art. 5 Section 1
# Check whether the claim is liable under the reinsurance contract

function is_liable()
        require type = insurer
        require terminated_contract = False
        INPUT:  liability
        IF      INPUT = "Blanket liability"
                SET reinsurer_liable = True
        ELSEIF  INPUT = "Automobile liability"
                SET reinsurer_liable = True
        ELSE    return False
        ENDIF

# Art. 6: Premium payment
# Art. 4: First we check whether the contract is not terminated
# Second we check whether 1 year has gone by, then the premium has to
be transferred
# One year contains 31556926  seconds, but we divide it by 31556866
# Meaning: 1 minute before the contract is terminated (at exactly one
year), the premium is transferred.

function premium_payment()
        require terminated_contract = False

        current_time = timestamp()
        time_elapsed = current_time - initial_time
        year_elapsed = time_elapsed / 31556866

```

```
        IF      year_elapsed > 0
                transfer (premium_amount, address_X, address_Y)
                IF      premium_amount > balance (address_X)
                        SET   insurer_insolvent = True
                        CALL: insolvency(address_X)
                ENDIF
        ELSE    return False
        ENDIF

# Art.5 Section 4.
# Calculate claim. This is an XoL contract, in which the retention is
1.000.000, and the aggregate liability for the reinsurer is 4.000.000.
# The insurer is responsible for the first 1 million, and the
reinsurer is responsible for a maximum of 200.000 per claim, given the
claim # exceeds the retention.
# Thus: Claim amount is the minimum of the loss amount minus the
retention and 200000
# Art. 10: Promt notice clause
# For the arbiters to judge whether there is prompt notice, we need
the date of loss of the insurer

function calculate_claim()
        require terminated_contract = False
        require reinsurer_liable = True
        require type = insurer

        INPUT:  loss_amount
        INPUT:  date_of_loss
        INPUT:  proof_of_loss_document

        IF      loss_amount <= retention:
                print "loss amount too small"
        ELSE    claim_amount = MIN((loss_amount - retention), 200000)
                CALL: claim_payment(claim_amount)
        ENDIF

# Art. 12: Insurer needs to input its proof of loss document
# If the total amount of claims exceed 4.000.000, the claims exceeds
the aggregation limit
# If the total amount of claims does not exceed 4.000.000, the
accept_claim function is called

function claim_payment(claim_amount)
        require terminated_contract = False

        total_claim_amount += claim_amount

        IF      total_claim_amount >= 4000000
                print "aggregate claims exceeded"
                return False
        ELSE    SET     claim_time = timestamp ()
                IF      claim_amount > balance (address_Y):
                        SET   reinsurer_insolvent = True
                        CALL: insolvency(address_Y)
                ENDIF
                CALL: accept_claim (claim_amount)
```

```
112         ENDIF
113
114 # If claim is accepted by the reinsurer, the claim amount is
115 transferred from the reinsurer to the insurer
116 # If the claim is not accepted, the dispute_resolution function is
117 called
118 # The reinsurer has 30 days to respond to the claim, in case of no
119 response, claim amount is transferred
120
121 function accept_claim(claim_amount)
122         require type = reinsurer
123         INPUT:  accept claim? (Y/N)
124
125         current_time = timestamp()
126         time_elapsed = current_time - claim_time
127         transfer_time = time_elapsed / 2592000        #Number of
128 seconds in 30 days: prompt payment
129
130         IF      INPUT = "Y":
131                 transfer (claim_amount, address_Y, address_X)
132                 SET reinsurer_liable = False
133         ELSEIF  INPUT = null AND transfer_time > 0:
134                 transfer (claim_amount, address_Y, address_X)
135                 SET reinsurer_liable = False
136         ELSEIF  INPUT = "N":
137                 start_time_arbiter = timestamp ()
138                 CALL: arbiter_insurer()
139                 CALL: arbiter_reinsurer()
140         ENDIF
141
142 # Art. 16: dispute resolution
143 # Give insurer 60 days to select arbiter. If the insurer succeeds to
144 select an arbiter within 60 days, the discovery_insurer function is
145 started.
146 # If the insurer does not select an arbiter, the reinsurer must select
147 a second arbiter
148
149
150 function arbiter_insurer ()
151         require type = insurer
152         arbiter_insurer_time = timestamp ()
153         time_elapsed = arbiter_insurer_time - start_time_arbiter
154         sixty_days_arbiter = time_elapsed / 5814000
155 #Number of seconds in 60 days
156
157         INPUT: arbiterX & cost
158
159         IF      sixty_days_arbiter <= 0 AND INPUT != null:
160                 SET start_time_discovery = timestamp ()
161                 CALL: discovery_insurer ()
162
163         ELSEIF  sixty_days_arbiter > 0 AND INPUT = null:
164                 CALL: reinsurer_selects()
165         ENDIF
166
167 # Art. 16: dispute resolution
```

```
# Give insurer 60 days to present case. If the insurer succeeds to present case to arbiter within 60 days, call dispute_ready.
# Else, if no case is presented, the reinsurer wins the dispute (which will be decided by the arbiters)

function discovery_insurer ()
        require type = insurer
        discovery_insurer_time = timestamp ()
        time_elapsed = discovery_insurer - start_time_discovery
        sixty_days_discovery = time_elapsed / 5814000        #Number of seconds in 60 days

        INPUT: discovery_X

        IF      sixty_days_discovery <= 0 AND INPUT != null:
                CALL: dispute_ready(discovery_X)
        ELSEIF  sixty_days_discovery > 0 AND INPUT = null:
                print "no case presented, reinsurer wins dispute"
        ENDIF

# Art. 16: dispute resolution
# For the reinsurer, the arbiter selection and discovery functions are the same as those of the insurer (but contrary).

function arbiter_reinsurer ()
        require type = reinsurer
        arbiter_reinsurer_time = timestamp ()
        time_elapsed = arbiter_reinsurer_time - start_time_arbiter
        sixty_days_arbiter = time_elapsed / 5814000   #Number of seconds in 60 days

        INPUT: arbiterY & cost

        IF      sixty_days_arbiter <= 0 AND INPUT != null:
                start_time_discovery = timestamp ()
                CALL: discovery_reinsurer ()

        ELSEIF  sixty_days_arbiter > 0 AND INPUT = null:
                CALL: insurer_selects ()
        ENDIF

function discovery_reinsurer ()
        require type = reinsurer
        discovery_insurer_time = timestamp ()
        time_elapsed = discovery_reinsurer - start_time_discovery
        sixty_days_discovery = time_elapsed / 5814000
#Number of seconds in 60 days

        INPUT: discovery_Y

        IF      sixty_days_discovery <= 0 AND INPUT != null:
                CALL: dispute_ready(discovery_Y)
        ELSEIF  sixty_days_discovery > 0 AND INPUT = null:
                print "no case presented, insurer wins dispute"
        ENDIF

```

```
# Art. 16: dispute resolution
# If the insurer failed to select an arbiter, the reinsurer can select
the 2nd arbiter

function reinsurer_selects ()
        require type = reinsurer
        SET     reinsurer_selects = True
        INPUT:  arbiterX & cost
        CALL:   discovery_insurer()

# Art. 16: dispute resolution
# If the reinsurer failed to select an arbiter, the insurer can select
the 2nd arbiter

function insurer_selects ()
        require type = insurer
        SET     insurer_selects = True
        INPUT:  arbiterY & cost
        CALL:   discovery_reinsurer ()

# Art. 16: dispute resolution
# Function starts executing if both cases are presented.
# The arbiters input the umpire, umpirecosts, and arbitrationcosts.
# If the arbiters do not provide an award, the umpire has to provide
an award.
# If all input is provided, the reinsurer is no longer liable, since
the dispute is solved.

function dispute_ready ()
        IF      discovery_X AND discovery_Y != null:
                return True
        ELSE    return False

        require type = arbiter
        INPUT1 ARBITERS: award
        INPUT2 ARBITERS: umpire & cost
        INPUT3 ARBITERS: arbitrationCost

        IF      INPUT1 AND INPUT2 AND INPUT3 != null:
                SET reinsurer_liable = False
                CALL: calculate_arbitration_costs

        ELSE IF INPUT1 = null AND INPUT2 !=null AND INPUT3 != null:
                CALL: umpire_award
        ENDIF

# If two arbiters are chosen by one party, the expense of the
arbiters, the umpire and the arbitration are equally divided between
the two parties.
# The costs are transferred correspondingly.

function calculate_arbitration_costs ()
        SET     totalcosts = arbitrationCost + arbiterXCost +
arbiterYcost + umpireCost
        IF      insurer_selects = True OR reinsurer_selects = True :
                SET partyX_Cost = partyY_Cost = totalcosts/ 2
```

```
                transfer (PartyX_Cost, address_X, address_Z)
                transfer (PartyY_Cost, address_Y, address_Z)
        ELSE    partyX_Cost = (arbitrationCost / 2) + arbiterXCost +
(umpireCost / 2)
                partyY_Cost = (arbitrationCost / 2) + arbiterYCost +
(umpireCost / 2)
                transfer (PartyX_Cost, address_X, address_Z)
                transfer (PartyY_Cost, address_Y, address_Z)
        ENDIF

function umpire_award ()
        require type = umpire
        INPUT: award
        SET reinsurer_liable = False

# Art. 4: Reinsurance Coverage Period
# Terminate the contract after 1 year (31556926 seconds)

function terminate_contract()
        require cancelled_contract = False
        current_time = timestamp()
        time_elapsed = current_time - initial_time
        year_elapsed = time_elapsed / 31556926

        IF      year_elapsed >= 0
                terminated_contract = True
        ELSE    terminated_contract = False
        ENDIF

# Art. 17: Cancellation of contract.
# Parties can cancell the contract, and not less than thirty days
thereafter, cancellation is effective
# The premium is shared on a prorata basis in case of cancellation

function cancel_contract()
        INPUT INSURER: cancellationDateX
        INPUT REINSURER: cancellationDateY

        IF cancellationDateX OR cancellationDateY != null AND
cancellationDate > current_date + cancellationNoticePeriod
                SET cancelled_contract = True
                SET termination_date = cancellationDate

        ELSE    print "Cancellation date must be at least 30 days from
the current date"
        ENDIF

        IF current_date >= termination_date AND cancelled_contract =
True
                transfer (((premium_amount/365) * cancellationDate -
current_date), addressX, addressY)
        ENDIF

function insolvency ()
        IF      reinsurer_insolvent = True:

```

```
338                print "Reinsurer insolvent: this contract is amended to
339 applicable legislation"
340         ELSE    print "Insurer involvent: this contract is amended to
341 applicable legislation"
342       ENDIF
343
```

Appendix C: Process of formalization: three trends

Interestingly, the culture of the reinsurance market currently seems to be undergoing a transition. As described in 2.1 Research motivation, the market is currently characterized by a 'hard reinsurance market', as a result of an increase in both the frequency and severity of claims. A greater risk aversion among reinsurers has resulted in stricter underwriting criteria, and a high premium that insurers have to pay to reinsurers to transfer their risks. This culture of formalization is reflected in three areas: formalization of disputes, formalization of contracts, and formalization of confidentiality.

First, the formalization of the market is reflected in the increasingly formal nature of contracts, as well as in the way disputes are resolved. Schiffer (2010) argues that the "arbitration process for reinsurance became more complicated and less efficient as the amounts in dispute increased" (p.10). According to Schiffer (2010), these disputes increasingly resemble ordinary litigation, ''resulting in a detailed review of dates for discovery, motions, and exchange of evidence.'' (p.11). Compared to the pre-1970 period, the dispute resolution process based on arbitration was much less formal, in which arbiters were required to consider the contract as an 'honorable engagement' and were not required to follow strict rules or the law of evidence (Tomilson, 2020). Arbitrage prior to 1970 was characterized by an informal 'gentlemen's agreement' (Tomilson, 2020), in which mutual trust, honor, and integrity of the involved parties played a significant role in dispute resolution. However, the dispute resolution process has become increasingly formal over time (as also evidenced in 2.2 Relevance and problem statement), leading to the dissolution of the gentlemen's agreement (Tomilson, 2020). The dispute resolution process has progressively become more formalized (Schiffer, 2010), shifting much of the dispute resolution process into the governance layer (Williamson's layer 3).

Second, a formalization process is also visible in the design of contracts. Whereas contracts used to be described in a more informal way, contracts have become increasingly formal and mostly longer. Contracts are currently drawn up with lawyers, while before 1980 this was basically done by businessmen (G3: 25th April, 2023). In fact, we can say that the PRICL are increasingly formalized in contracts, forcing both parties under the contract to commit to these principles. What is striking is that the traditional contract I used for the translation to pseudocode (appendix A) is precisely a rather short contract, in which the formalization process is not very visible. A point should be clarified here that the transposed object is actually a 'certificate', and not the traditional reinsurance contract. The certificate originates from 1974, which also corresponds to the informality with which contracts used to be drawn up. Despite a certificate not being a reinsurance contract in the legal sense (ICCIE, n.d.), the certificate used to be used as a ''record of reinsurance coverage, pending its replacement by a formal reinsurance contract'' (International Risk Management Institute, n.d.a).

A final informal institution that seems to have been formalized relates to confidentiality. Confidentiality in reinsurance stems from two interests in the industry. First, parties in dispute do not want to suffer reputational damage (Schiffer, 2015). Indeed, if parties are known as a 'difficult claims payer', this will have a negative impact on the company. In addition, parties in the industry value confidentiality so as not to make their way of doing business public (Schiffer, 2015). When all information related to risk diversification (premiums and underwriting strategy) is publicly available, parties lose their competitive advantage. Nowadays, in principle, all reinsurance contracts contain a confidentiality clause, thus incorporating this institution into layer 3 (governance). Schiffer (2017) goes on to describe that traditional reinsurance contracts do not contain a confidentiality clause, as ''it was industry practice to treat reinsurance arbitrations and contracts as confidential and most parties went along with that informal understanding'' (p.31).

Appendix D: An argument for blockchain-based smart contracts

As highlighted in the introduction, trust between parties is crucial for conducting transactions. Establishing trust is essential to minimize the probability of opportunistic behavior from the counterparty (Lin et al., 2015). Opportunistic behavior refers to self-interested actions taken by one party to exploit or take advantage of the other party's vulnerabilities or lack of information in a transaction (see appendix I). In the reinsurance industry, such behavior can result in mistrust, higher administrative costs, and potentially disrupt the smooth functioning of the risk allocation process (Bessire, 2005). Thus, insurers not only seek reinsurance at the lowest price but also demand assurance of adequate coverage and the absence of opportunistic behavior from reinsurers (Spee et al., 2016). According to Spee and colleagues (2016), ‘’this necessitates the establishment of a trust relationship, typically developed over multiple years.’’ (p. 501).

Prior to 1970, trust between insurers and reinsurers primarily relied on informal mechanisms and qualitative information, as noted by Blanchard (2021). She writes that business partners would go on joint vacations with their families to gather qualitative information and foster trust (Blanchard, 2021, pp. 49-51). However, with an increase in market participants and the amounts in dispute, the industry has undergone formalization, transitioning from a close-knit business network to a loosely-connected one (Blanchard, 2021). The previously amicable reputation-based relationships have evolved into more business-oriented relationships, where parties increasingly rely on quantitative information about their counterparts (Blanchard, 2021). Over time, the availability of quantitative information has grown, aided by sophisticated models used by actuaries to analyze claims severity and frequency (Munich Re, n.d.b).

Despite the increased availability of data, many market participants express concerns about its quality. Deloitte advisory (2018), for instance, identifies the quality of timely and informative data as a significant pain point in the reinsurance industry. Consequently, establishing trust, whether through qualitative information or quantitative data, incurs some form of cost, what Potts and Berg (2019) delineate as the "cost of trust".

This is where blockchain presents a potential solution. Blockchain is a decentralized digital ledger technology that facilitates secure and transparent record-keeping of transactions. It operates through a network of computers, or nodes, which collectively validate and store each transaction in a series of blocks, forming a chain. Miners play a critical role in verifying transactions by solving cryptographic puzzles (Davidson & Potts, 2022). The value of blockchain lies in the fact that industry participants no longer need to rely on trust between each other, as transactions can be verified through the ledger (Werbach, 2018). This verification process is distributed and relies on a consensus mechanism, wherein the majority of participants agree on the validity of transactions and their inclusion in the blockchain. Swan (2015) describes distributed ledger technology as "trustless" for this reason. Because every transaction is agreed upon by ‘’consensus and transparency, blockchain-based smart contracts have the ability to partially eliminate opportunism” (David & Potts, 2022, p.10).

In summary, the application of blockchain-based smart contracts in the reinsurance context is intriguing for two reasons. Firstly, such contracts have the potential to partially eliminate opportunism. By automating the execution of contractual relationships through immutable smart contracts, the potential for opportunistic behavior influencing these relationships is reduced. Secondly, smart contracts based on blockchain technology have the potential to lower the costs of trust (Potts & Berg, 2019). Costs associated with acquiring qualitative or quantitative data could be reduced ''allowing professionals to allocate less time to gathering data and running reports, and more time to analyzing data and drawing deeper, more meaningful business insights and performance analytics.'' (Deloitte Advisory, 2018, p. 9).

With regard to the available amount of time for conducting this research, I will largely set aside the discussion of blockchain. My focus is specifically on the contractual relationship between insurers and reinsurers, with the objective of investigating whether smart contracts can enhance efficiency in this context. I consider blockchain as a potential infrastructure on which smart contracts can be implemented, assuming that its utilization reduces opportunism and trust-related costs. In the evaluation of my design, I will briefly reflect on the implications of utilizing blockchain as an infrastructure.

Appendix E: Types of reinsurance contracts

Reinsurance can be categorized into two primary types: treaty and facultative. Treaty contracts refer to agreements that encompass groups of policies. In that case, all, or part of business of the primary insurer relating to a class of insurance is reinsured under the treaty. For example, a primary insurer can cede an entire portfolio of auto insurance to a reinsurer under a treaty contract. For risks that are too big, for example an expensive skyscraper or a hospital, facultative reinsurance is commonly used. In facultative contracts, a specific single asset (or a small set of assets) is fully or partially ceded to a reinsurer. Thus, each transaction is individually negotiated in a facultative contract. I will also dive in the differences between proportional and non-proportional reinsurance. Another distinction that can be made is regarding the risk profile of reinsurance contracts. To illustrate, I will compare a treaty contract of car insurance, to a treaty with catastrophic event reinsurance. The reinsurance treaty of a car insurance policy can be considered low risk, as car accidents happen on a daily basis (Bieber, 2023), and these risks are practically uncorrelated. A catastrophic risk treaty, on the other hand, financially protects insurers from natural disasters such as earthquakes, floods, fires, diseases, etc. The risk profile here is substantially different, as the frequency of claims is much lower, but the impact on the reinsurer's financial stability much higher.

Treaty contract

A treaty contract is a portfolio of risks covered, often over a longer period of time, compared to a facultative contract. Usually, the treaty is ‘’renewable on a fairly automatic basis unless one of the parties seeks a new term.’’ (Abramovsky, 2008, p.358). Unlike facultative reinsurance, treaty reinsurance provides broader and ongoing coverage for a range of risks under a single agreement. Crucially, reinsurance treaties provide coverage for all risks underwritten by the ceding insurer that align with the treaty's terms, unless expressly excluded. Consequently, treaty reinsurers typically do not assess the individual risks covered by the treaty or conduct their own underwriting for those risks. Instead, they depend on the ceding insurer's underwriting expertise, while exercising prudence by investigating the insurer's underwriting philosophy, loss history, approach to claims management, and other business practices. In fact, investigating the other party is a way of lowering information asymmetry.

Facultative contract

As explained, facultative reinsurance is a method in which an insurer cedes a specific, one-off risk to a reinsurer. The reinsurer assesses the individual risk and is under no circumstances obliged to accept any particular risk. That is what makes the agreement facultative. The reinsurer and insurer negotiate on the specific risk covered and negotiate on whether the contract terms and conditions, including the premium is satisfactory for both parties (Abramovsky, 2008). Although the reinsurer in both types of contracts has the ability to accept or reject an offer of an insurance company, the flexibility in a treaty contract is generally much lower. The obligation to accept risks within the predefined parameters is higher than in facultative reinsurance.

Pro rata (proportional) reinsurance

In proportional reinsurance, the premium and risks are shared in the same predefined proportion. For example, ‘’the insurer keeps the same standard retention on each risk (e.g. 70%) and consequently cedes to reinsurance a percentage which is always the same (e.g. 30%).’’ (Swiss Re, n.d.a, p.8). The two common forms of proportional reinsurance are quota share and surplus rate. Simply put, with quota share reinsurance, the proportion of risk ceded to the reinsurer is ‘’a fixed, invariable percentage which is generally applied to the entire portfolio of risks.’’ (Swiss Re, n.d.a, p.7). Using the example above, that would mean that for each specific risk in the portfolio, the reinsurer would be responsible for 30% of the losses, while the insurer would have to cover 70% of each loss. However, the quota share often includes a quota share limit, indicating a maximum liability for the reinsurer. Next, with surplus rate reinsurance, variable percentages for the business ceded to reinsurance are used, depending on the size of the individual risk. The portfolio is then divided into certain size classes, and the percentage reinsured is dependent on the specific class. For example, an insurer may choose to cede a larger percentage to the reinsurer for peak liabilities. These are risks with a low probability, but with a high economic impact. According to Swiss Re (n.d.a), compared to quota share reinsurance the system of surplus reinsurance is more complex and the administration more expensive. One of the aims of this study is to reduce the administrative costs, by translating a reinsurance contract into a smart contract. Keeping this goal in mind, the added value of translating a quota share contract is potentially smaller than translating a surplus reinsurance contract, as the quota share contract is simple to administer anyway (Tobin, 2021).

Excess-of-loss (non-proportional) reinsurance

Excess of loss reinsurance is a form of reinsurance where the reinsurer agrees to cover losses exceeding a specified threshold, known as the "excess" or "retention" amount. In this arrangement, the primary insurer (ceding insurer) retains a portion of the risk and transfers the remaining portion to the reinsurer. The excess of loss reinsurance contract provides protection to the ceding insurer against large or catastrophic losses that exceed its risk appetite or financial capacity. By transferring a portion of the risk to the reinsurer, the ceding insurer can reduce its exposure to potential losses and protect its financial stability. The excess of loss reinsurance arrangement is often utilized in sectors or lines of business that are exposed to significant risks, such as property insurance, liability insurance, or catastrophe insurance. It enables the ceding insurer to mitigate its risk exposure by offloading losses that exceed a certain threshold to the reinsurer. Under this arrangement, the ceding insurer retains responsibility for losses up to the specified threshold, while the reinsurer assumes liability for losses exceeding that threshold. The ceding insurer typically pays a premium to the reinsurer in exchange for this coverage, which is based on factors such as the level of coverage provided, the underlying risks, and the reinsurer's assessment of the ceding insurer's claims experience and financial stability. Overall, excess of loss reinsurance serves as a risk management tool for insurers, allowing them to limit their potential losses and ensure their ability to fulfill policyholder obligations in the face of significant or catastrophic events.

Appendix F: Ex ante and ex post transaction costs combined with research scope

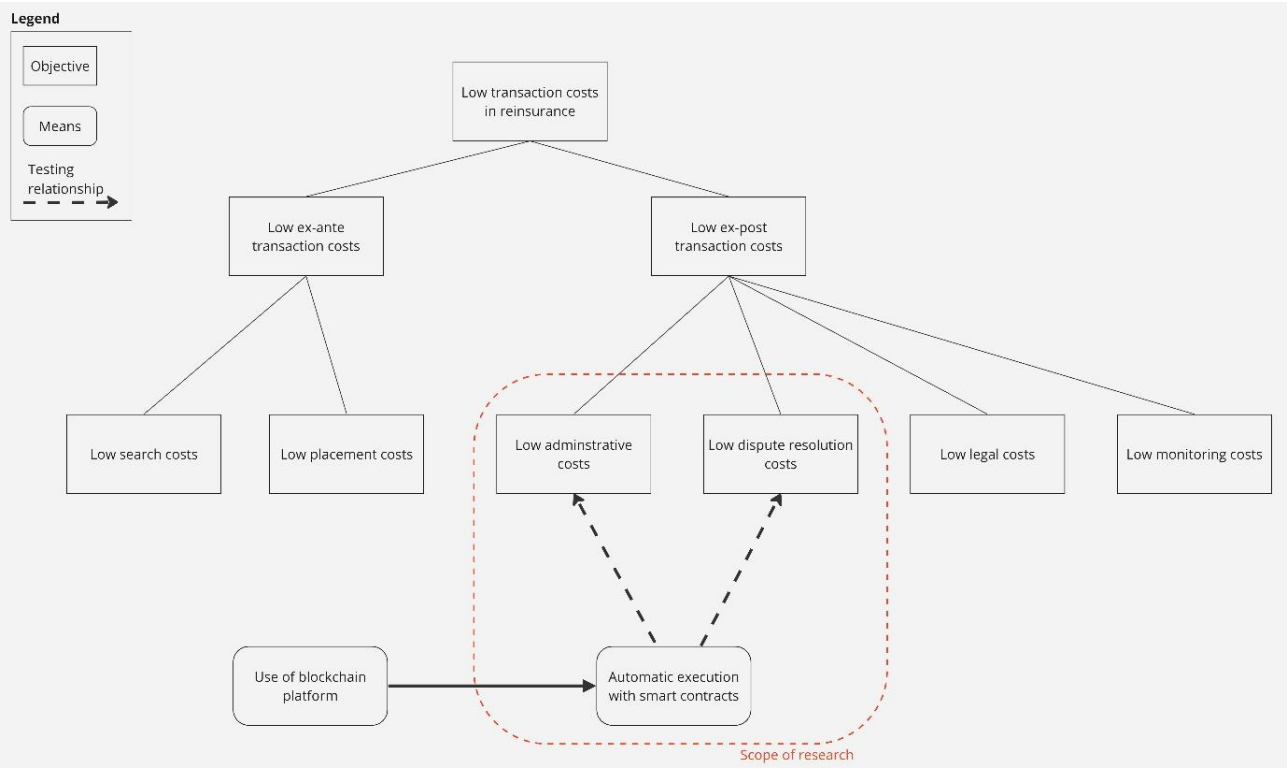

Figure 10: Visualization of transactions costs and research scope

Appendix G: Interviews

G1: 13th April, 2023

Interview topic	Critical insight	Implication for design	Incorporate in
Dispute resolution and contract terms	Disputes occur over what is meant by certain terms, such as what an 'event' is. Example regarding storm that rages over twice within a short period of time, is this one event or two events? If it was two events, it fell under the deductible twice.	You can formalize these kinds of agreements in a smart contract, but it is smart contract independent. You can also formalize this kind of agreement in traditional contracts.	Design evaluation
	Arbitration is still the most used method to resolve disputes in the reinsurance industry	Focus design on arbitration procedure	Research scope
	Litigation more common in facultative than in treaty reinsurance	N.A.: litigation out of scope	N.A. litigation out of scope
	Reinsurance contracts are set up so there is a lot of room for negotiation what they mean	Unclear whether this is desirable, given that dispute resolution costs are increasing	Design evaluation
Transaction costs in reinsurance	Cedents today are less dependent on informalities, because there is a lot more data available about suitable counterparts.	Search costs have become lower over time in the reinsurance industry.	Problem description
	Large part of the transaction costs in the reinsurance industry are not related to the formalization and drafting of contracts, but in what you don't know about your counterparty.	Contrasting claim in Munich Re (2016), which argues that formalizing contracts has become much more expensive over time, and that the industry needs to think about ways to formalize contracts in a more efficient way.	N.A.
Smart contracts	Facultative contracts better translatable into if-then statements than treaty contracts	I will translate a facultative contract into a smart contract	Methodology
	Smart contracts might be better suitable for markets where the obligations are simpler. For example, lending, and very risky markets.	A potential lender might think that the risk or cost of performing the payment obligation against a party who does not decide to pay is too high, and so they simply do not enter the market. But if they could have the payment obligation executed automatically, they might be more inclined to enter that market.	Future research

G2: 19th April, 2023

Interview topic	Critical insight	Implication for design	Incorporate in
(Legal) implications of smart contract design	Insurers and reinsurers need a license from the DNB or AFM in the Netherlands. Furthermore, you need to consider money laundering and terrorism financing. Parties are not allowed to provide services to each other otherwise.	Addresses should be verified by these bodies, and the addresses should be linked to the parties. This could potentially be done with a whitelist smart contract, but this is beyond the scope of this study.	Design evaluation
	Smaller parties are more likely to use a contract like this when smaller amounts are at stake. For example, Stella who sells bicycles and wants to reinsure a risk. Volkswagen does the same, they carry the small risks themselves and tuck it away in a subscription in the lease price. Only the extreme outliers they insure, they earn much more from that.	Future research should address to what extent such a design is applicable to markets with smaller amounts at stake.	Future research
Role of blockchain in smart contract design	The input regarding the claim amount can be better verified if the insurer also uses a blockchain ledger. It starts with the insurer having an accountable system	Future research should address whether the implementation of a blockchain could resolve these 'trust' issues in reinsurance.	Future research
	Whether these smart contracts can best be implemented on a public or private blockchain depends on how much the parties value confidentiality.	A private blockchain is better suited to the reinsurance industry than a public blockchain.	Design evaluation
	You could solve many of the privacy issues in this draft with a Corda blockchain.	N.A.: Out of scope	N.A.: Out of scope
Transaction costs	If you want to bring down transaction costs, you need to standardize.	Standardizing reinsurance processes would reduce transaction costs, however, reinsurance involves a lot of customization	Design evaluation
	Cost reduction will become especially important for reinsurers when competition becomes high enough.	Since competition in the reinsurance industry in the 'hard reinsurance market' is not very strong, reinsurers will not be forced to seek cost reductions now.	Design evaluation
Dispute resolution	If the terms are clear, then no dispute is possible. With transparency and simplicity, the chances of a dispute are low.	Limitation of design: the question of what the words in the contract mean remains subject to human interpretation, and thus potential dispute.	Design evaluation

G3: 25th April, 2023

Interview topic	Critical insight	Implication for design	Incorporate in
Smart contracts	Smart contracts and blockchain technology are expected to primarily find application in standardized and commoditized transactions, rather than in complex and customized transactions.	Complexity of reinsurance contracts varies	Design evaluation
	Believes that you can build 75% to 85% of the contracts with a smart contract, using basic clauses	This means that 15-25% of contracts cannot be built by a smart contract, and cannot be automated.	N.A.
Transaction costs	Manual placement of traditional contracts into smart contracts is now highly inefficient.	Placement costs of smart contracts are high and potentially outweigh the added value.	Future research
	Solvency 2 requirements are a major burden for (re)insurance companies in the EU, and giving (re)insurers 'headache'.	Would imply large legal costs, that future research should address.	Future research
	Key reputational information that (re)insurers are interested in concern: solvency capital ratio, stability of the reinsurance, percentage of disputed reinsurance transactions, and the speed of claims payments.	Search costs are made for and by (re)insurers to identify a suitable counterparty.	Reflection
US market comparison	Businessmen underwrote the contracts in the 1940s and 1950s, but due to a huge increase in number and severity of claims related to asbestos and the environment, lawyers were increasingly involved in drafting the contracts. The 'gentleman's agreement was broken'.	Confirmation of problem situation in the US, less of a problem in the EU.	Design evaluation
	A market reformed contract specified numerous requirements to insure or reinsure in the EU (Lloyd's model). European reinsurance contracts are better suited to smart contract applications because these contracts are more standardized.	Limitation of design: translation of US reinsurance contract.	Limitation of research
	Unable to share EU reinsurance contract	Limitation of study: The reinsurance industry is a very closed market	Limitation of research

G4: 9th May, 2023

Interview topic	Critical insight	Implication for design	Incorporate in
(Legal) implications for smart contract design	From a regulatory standpoint, you need to consider that the account is bound to a particular (re)insurer	You need a static connection from a company to a wallet address. Possible to implement with an on-chain whitelist	Design evaluation
	Fundamentally, smart contracts cannot replace legal contracts	Limitation of design: legal framework currently not yet aligned around smart contracts	Design evaluation
	The reinsurance industry is very 'unwieldy', change process is extremely slow	In the short term, a transition to an on-chain dispute resolution mechanism in the reinsurance industry is unthinkable	N.A.
	The Kleros design contains a perverse incentive through the staking mechanism	Future research should reveal whether an incentive system is an effective way to deliver an award in the reinsurance industry. Unclear whether 'strategic voting' rather than fully objective voting has a negative effect on the quality of dispute resolution.	N.A.
Smart contract design	A timestamp of the smart contract design should be initialized at the beginning of your smart contract.	Initialize timestamp at beginning of code	Smart contract pseudocode

G5: 13th June, 2023

Interview topic	Critical insight	Implication for design	Incorporate in
Smart contract design	Documents can be implemented in a smart contract (but in a compressed form, a hash).	Possible to implement a proof_of_loss document, discovery_X and discovery_Y, but in compressed form	Smart contract pseudocode
	Claim payment and premium payment is automated through smart contract implementation	The administrative costs involved would be around 20-30 euro over the entire duration of the contract	Design evaluation
	Oracle problem	One problem you do not solve with your smart contract is that the veracity and completeness of the information entered in a smart contract, is not necessarily increased.	Design evaluation
	Insolvency clause (art. 15) is in practice an amendment to applicable legislation, and a termination of the actual contract	Change insolvency clause in smart contract	Smart contract pseudocode
	Rephrase the arbitration procedure so that you do not make use of the while loop, highly unusual in drafting smart contracts	Change arbitration clause in smart contract	Smart contract pseudocode
Smart contract design (from blockchain perspective)	Using while-loops is inefficient, because there would be a miner that remains linked to your function during the while-loop. You pay per operation, so using a while-loop would cost a lot of money. The same goes for the functions that use a timestamp, but it really depends on the specific implementation.	Further research is needed to investigate the impact of this factor. Unclear to what extent the costs related to the execution of such a contract are negatively affected.	Design evaluation
	Functions in blockchain smart contracts are often called externally in practice, as full automation leads to inefficiencies regarding 'gas fees'.	In that case, for every new action, there must be a party that benefits, and chooses to execute the function. At every state transition, there should then be a party with incentive to go through the next step or make payment.	Design evaluation
	In this practice, smart contracts are often deployed to perform only the simplest and most critical transactions	From this perspective, only premium payment, claim payment and termination would be in the smart contract. The more complex transactions would then be left out of the smart contract.	Design evaluation
	Using private blockchain will meet both your requirements regarding confidentiality, and your legal requirements.	Reflect on in the discussion, potentially creating a single point of failure, making platform regulation an essential component	Design evaluation
	Immutability of contract (art. 18) is secured by the nature of a smart contract.	That is, information stored on blockchain is immutable	Design requirements

G6: 14th June, 2023

Interview topic	Critical insight	Implication for design	Incorporate in
Implementing challenges	It is very difficult to get a good adoption rate	Especially the smaller parties are difficult to get into this process. Large parties are more open to it and also have enough clout to implement it properly	Design evaluation
	The completeness and veracity of claims starts from the individual claims of policyholders, and this is very difficult to establish. The same applies between the relationship of the insurer and reinsurer	N.A. Out of scope, but essential for the validity of data on blockchain	Future research
Transaction costs	It would cost around €25,000 to implement this smart contract	Given there is already a traditional contract in place. Whether this means that the actual placement costs would go up, and to what extent standardization of contracts affects placement costs is unclear.	N.A.: placement costs out of scope
	The value creation of the smart contract is mainly in a single point of truth, there is no discussion about the contract content itself.	This lowers the chance of disputes. Reflect on fact that meaning of the words in the contract could still be subject to dispute.	Design evaluation
Smart contract design	Claims payments and premium payments are largely automated, eliminating much of the human input and actions in these processes.	Reducing administrative costs	Design evaluation

G7: 20th June, 2023

Interview topic	Critical insight	Implication for design	Incorporate in
Dispute resolution	Nearly any disputes noted by Aon as broker, only 2 disputes since 2006 in the facultative reinsurance line	Would mean that the added value of designing an alternative form of dispute resolution is negligible. However, information from another interview shows that number of disputes in other markets can vary enormously.	Design evaluation
	Example of three storms last year: Dudley, Eunice and Franklin. Much wrangling between parties on the question of what constitutes one storm. Is that one atmospheric disturbance or is that one named storm?	You could formalize this in a smart contract, but this is smart contract independent: it is about what agreements you make with your counterparty.	Design evaluation
	Example of three storms last year: not every reinsurer paid in this. However, no one went to arbitration. Everyone tries to come out among themselves, visiting, explaining the position, corresponding, and one legal negotiating with another legal.	Implies that the 'gentleman's agreement' is still alive. Explaining the position, corresponding about the negotiation, and negotiating between the legals is also considered a form of dispute resolution costs in this study.	Design evaluation
Dispute resolution costs	There are very few disputes, but it starts with negotiations where you engage in conversation in good faith, then mediation, then arbitration, then court.	Although few negotiations result in a dispute, negotiation is more common, and also a form of dispute resolution costs.	Design evaluation
	People in industry like to have human control over negotiation processes: receive a written note, can call someone, etc.	Could be a barrier to implementation of a smart contract, in which some of the human action is reduced.	Design evaluation
Administrative costs	As a Dutch broker, we see on average only 100 transactions a year, which also require a lot of customization.	Would not justify automating this process.	Design evaluation
	With certain companies with whom they do a lot of business, the design could create efficiencies in the claims and premium payment processes.	Implies a reduction in administrative costs	Design evaluation
General remarks	Reinsurer prepares contract at facultative XoL, and there must be a risk transfer in it otherwise it is a money swap.	N.A.	N.A.
	Everyone is in it for the long-run and to maintain long-term relationships. You build relationships because it's about a lot of money.	Gentlemen's agreement still exists	Design evaluation
	You have translated a very old contract, and much has changed in the meantime. For example, for	Limitations of translating an outdated contract.	Limitations

	the selection of arbiters, we use ARIAS UK procedures.		
	The Dutch reinsurance market is completely different from the US one. For example, the US does not have stock exchange nor co-insurance. But even the differences between EU member states in terms of market are significant.	This implies that it is very difficult to make statements about the reinsurance market in general, or the reinsurance market in Europe, because the differences are significant, in terms of volume, types of contracts, degree of specialisation and markets.	Limitations

G8: 21st June, 2023

Interview topic	Critical insight	Implication for design	Incorporate in
Dispute resolution	The arbitration procedures differ significantly in the US, the EU, and Asia, with the EU having a wide range of specific to vague arbitration clauses, some of which invoke arbitration institutions but lack a standard clause, while most arbitral regimes worldwide require a neutral arbitration panel, and in UK reinsurance disputes, parties still have the ability to appoint their own arbiter with input from counsel and clients rather than leaving it solely to the arbiters.	Arbitration procedures are very different, also in terms of efficiency. Limitation of draft is that it focuses on the arbitration procedure described in the 1974 contract.	Limitation
	If the parties are allowed to communicate with their arbiter prior to the hearing, other than presenting their case, this is inevitably leading to a biased panel;	This would mean that the panel is most unbiased when no communication is possible before the hearing.	N.A.
	Today, there are far fewer disputes surrounding COVID 19 claims than was the case with asbestos and environmental claims in the 1980s and 1990s. This does not mean there are no disputes, you simply cannot know.	Limitation: limited information available on reinsurance disputes	Limitations
	Kick to litigation in case of non-compliance is infrequent: less then 10% of the cases	Added value of an award written bindingly into the smart contract is minimal but present.	Design evaluation
Impact smart contract on dispute resolution costs	Smart contracts with contract certainty resolve disputes related to signing, entering into contracts, and specific terms, but disagreements may arise over the interpretation of contract language, particularly in determining the intended coverage or meaning of specific terms.	Implies a reduction in disputes, opportunistic behavior to interpret contract rules in one party's favor is minimized.	Design evaluation
	Disputes in contracts and insurance claims often stem from unforeseen circumstances, like late notices, significant or atypical claims, and the factual context surrounding the loss, rather than disagreements over the explicit language and comprehension of the contract, which are embedded in the smart contract design	Would mean only a marginal reduction in the number of disputes.	Design evaluation
	The highest administrative costs are caused by acquisition: the	Administrative costs mainly become high when many parties	N.A.

Impact of smart contract on administrative costs	more hands touch the policy, the higher the administrative cost. You often see a ceding commission (what is used for internal administration) of almost 30%.	are involved in the same policy, through acquisition and ceding commission.	
	Life reinsurance is much less complex than non-life reinsurance: you die, they pay. Death certificate, money comes out. Disputes are very uncommon, and involve fraud.	Allows me to estimate the administrative costs used to process claims and premium payments.	Research scope, approximation of administrative costs

Appendix H: Business flow facultative contract placement

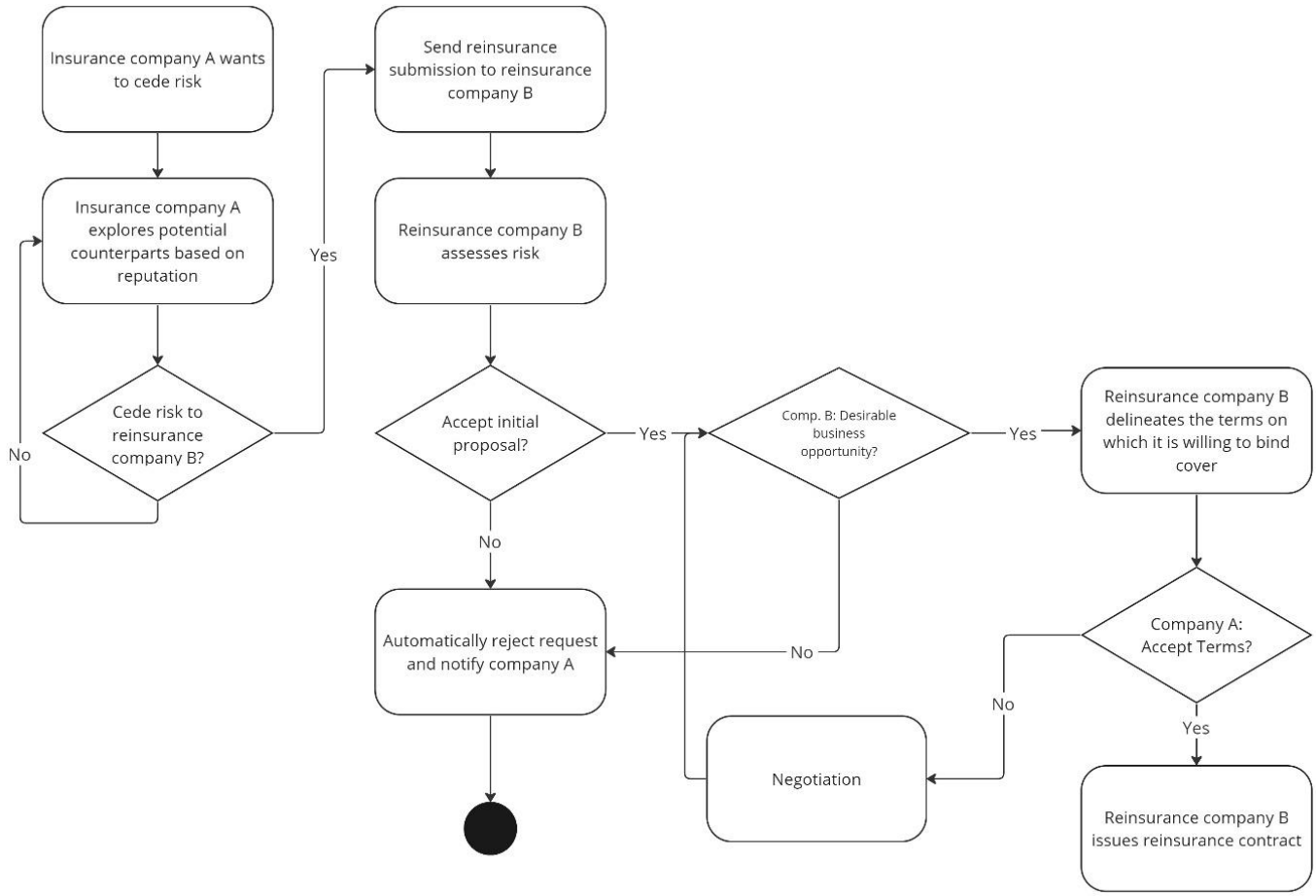

Figure 11: Process diagram of facultative placement reinsurance based on Hoffman (2002)

Appendix I: Informational asymmetry

An informational asymmetry in the reinsurance market occurs when one party, typically the primary insurer, has more information about the risk being insured than the other party, typically the reinsurer. Since moral hazard and adverse selection are both caused by information asymmetry, information asymmetry can be seen as the root of the problem.

Jean-Baptiste and Santomero (2000) argue that information asymmetry between recipients and providers of capital will increase the cost of capital in the presence of incentive conflicts between the two parties. Obviously, this is the case in the relationship between cedent (=insurer) and reinsurer. As a result, the premium the reinsurer will demand from the cedent will be higher given the information asymmetry.

I1: Adverse selection

Adverse selection is a first case in which asymmetric information is exploited. In the (re)insurance market, the buyer of the insurance (cedent) typically possesses more information on the insured product(s) than the seller (the reinsurer). Therefore, it is essential that reinsurers are careful in selecting what policies they cover, else they might end up covering mostly high-risk policies, and potentially more losses. Adverse selection is mitigated through a variety of mechanisms, under which: long-term and focused cedent-reinsurer relationships, strict underwriting criteria, extensive risk models, etc.

Still, ‘’the primary insurer is likely to know much more about the true loss distribution than will the reinsurer.’’ (Cutler & Zeckhauser, 1999, p.233). The optimal policies for reinsurance in the presence of adverse selection depend on the nature of the information asymmetry, according to Cutler and Zeckhauser (1999). If the asymmetry is on the probability of a loss but not its magnitude, the optimal reinsurance contract is an "excess-of-loss" policy, where the primary insurer is responsible for small risks, and the reinsurer is responsible for large risks. If the asymmetry is over the magnitude of the loss, the optimal reinsurance policy covers smaller losses as well as large losses but leaves the primary insurer exposed for some large losses. Thus, it is difficult to make broad statements about the optimal form of reinsurance policies.

Cutler and Zeckhauser (1999) argue that in the event of a cataclysm – which they arbitrarily define as a loss of €5 billion or more of insured losses – the reinsurance industry turns out the be inadequately prepared. Reinsurers that are overly exposed to these particular aggregate risks, ‘’may risk the insurer’s bankruptcy, putting recovery for its insureds at risk.’’ (Cutler & Zeckhauser, 1999, p.235). According to Cutler and Zeckhauser (1999), the reinsurance market is unable to provide insurance for cataclysms, which mean the reinsurance of these risks require new institutional forms.

Traynor (2002) argues that the most effective way to mitigate adverse selection, is through long-term and focused cedent-insurer relationships. However, as explained in the introduction, the reinsurance industry is making a shift to more short-term relationships in a competitive landscape ever since the 1970s. As a result, adverse selection is a persistent problem in the reinsurance market, which calls for new governance mechanisms, that potentially better address reducing adverse selection.

I2: Moral hazard

Moral hazard is a second case in which asymmetric information is exploited and refers to a disincentive to beware of risk when one is protected from its consequences. Trivially, this is a typical coordination issue in the (re)insurance market, as with (re)insurance, the cedent protects itself from certain losses. One subsequently speaks of a moral hazard, if coverage against a loss induces the insured to take riskier or less cautious actions, resulting in higher probability of loss (Yan, 2013). This goes against the purpose of reinsurance. Indeed, despite lowering the probability of a large payout claim, it increases the probability of a risk event. In order to mitigate the issue of moral hazard, the reinsurance market uses some governance mechanisms, such as the use of retention limits, coinsurance and monitoring.

Retention limits refer to the amount of risk that the primary insurer is required to retain before they can pass it on to the reinsurer. This means that the primary insurer must bear some of the risk themselves, which can reduce the likelihood of moral hazard. This creates an incentive for primary insurers to manage risk and ensure they have sufficient capital to absorb losses.

According to Rubinstein and Yaari (1983), ''offering repeated insurance contracts featuring discounts to insureds with a favorable record of past claims, enable both insurer and insured to counteract the inefficiency that arises from moral hazard.'' (p.74). This notion is supported by the literature of Blanchard (2021), who argues that reinsurance companies in the US aimed at establishing long-term relationships with each other before 1970. However, according to Blanchard (2021), the industry is changing ever since 1970, into a more competitive landscape, in which parties in the reinsurance industry increasingly enter into short-term relationships. Logically, the transactions costs of one-year shopping for the cheapest alternative to cede risk are currently much lower than before 1970.

Appendix J: Four layer scheme of Williamson (1998): the reinsurance market

To analyze the institutional context, I will use a helpful categorization by Williamson (1998). Williamson distinguishes four layers of institutions, based on two criteria: the frequency of change, and the chances of changing these institutions with the aim of increasing economic efficiency. The four levels of institutions are informal rules and culture (L1), institutional environment (L2), governance (L3), and resource allocation (L4). Here, L1 is the least subject to change, while L4 has continuous change. This implies that opportunities to make change at L4 are ubiquitous, while deliberately changing L1 is basically not possible. In the subsequent sections, I will systematically examine each of the four levels by elucidating how these levels are structured within the reinsurance industry.

J1: Culture and informal rules (L1)

L1 consists of informal institutions, which have evolved over time and become part of the culture of the reinsurance industry. First, I will reflect on the Principles of Reinsurance Contract Law (PRICL). While drafting a reinsurance contract, these PRICL served as a reference and guide, helping to identify relevant legal considerations, and ensuring a balanced distribution of rights and obligation between the reinsurer and cedent.

J1.1: PRICL

Seven principles of Reinsurance Contract Law (PRICL) are used by underwriters when drafting a contract (Heiss et al., 2019). These principles are utmost good faith, insurable interest, proximate cause, indemnity, subrogation, contribution and loss minimization (McMinn Law Firm, n.d.). I will now proceed to provide a concise overview of each of these principles.

- Utmost good faith: This principle dictates that both parties involved in a reinsurance contract should act in good faith with each other. Specifically, this means that they should share all data relating to the terms and conditions of the contract.
- Insurable interest: This principle stimulates that the cedent must have an interest in the subject matter being (re)insured.
- Proximate cause: Subjects can be insured against certain causes of loss, but not against all causes. In the event of a loss, the insured party must find out what the 'nearest' cause of loss is. If this proximate cause is insured, the (re)insurer must pay for compensation.
- Indemnity: This principle emphasizes that the insured party should be indemnified for any loss it has suffered, to the financial position they were in before the claim occurred. Here, the insurer promises to indemnify the insured for the amount specified in the (re)insurance contract.
- Subrogation: This principle involves moving property rights to the insurer if an insured has been compensated for their damages. We see this clearly in scenarios such as salvage. For example, if a policyholder causes car damage, and the insurer has to pay for it, the car wreck is hereafter owned by the insurer. The money the insurer earns from selling the car wreck is then used to compensate the policyholder.
- Contribution: This principle refers to proportional liability in case an insured subject is covered by multiple insurance contracts.
- Loss minimization: According to this principle, it is the responsibility of the insured to take precautionary measures to minimize loss.

J2: Legal framework (L2)

The institutional framework (L2) for reinsurers in the European Union (EU) is based on a series of regulatory and supervisory measures aimed at ensuring the stability, integrity, and security of the reinsurance market. These formal institutions are designed to protect the interests of policyholders, strengthen the confidence of market participants, and promote competition in the reinsurance market. Despite keeping legal costs outside the scope of this study, it is important for the validity of the smart contract to reflect on what these institutions mean for the smart contract design. Therefore, I will provide brief feedback on L2 in the design evaluation (7.4 Design evaluation).

The five most crucial formal laws in Europe regarding the reinsurance market include: Solvency II, Insurance Distribution Directive, European Market Infrastructure Regulation, General Data Protection Regulation, and Anti-Money Laundering Directive. Now I will proceed to elucidate each of these laws individually.

J2.1: Solvency II

First, the Solvency II Directive is the most important regulation of (re)insurance companies in the EU, providing a comprehensive framework for the regulation and supervision of (re)insurance companies operating in the EU. By establishing common rules for capital requirements, risk management, supervision, and disclosure, the Directive aims to ensure that (re)insurance companies are financially sound and able to meet their obligations to policyholders. The Directive is based on three pillars, namely (1) solvency capital requirement, (2) governance and risk management requirements, and (3) supervisory reporting and public disclosure.

The three pillars of the Solvency II Directive will be discussed below.

Pillar 1: Solvency Capital Requirement (SCR). The SCR indicates the total amount of funds that (re)insurance companies in the EU are required to hold. The SCR is calculated by multiplying the correlation of different risk-modules, such as property-casualty reinsurance, life reinsurance, health reinsurance, market reinsurance, and counterparty reinsurance (EIOPA, 2014). The higher the risk assumed by the (re)insurance company, the higher its SCR.

Pillar 2: Governance and risk management. (Re)insurance companies are required to have robust risk management systems in place to identify, assess, and manage the risks they face (PwC, 2012). According to PwC (2012), (re)insurance companies are under this second pillar obliged to (a) gradually merge risk and control functions, (b) define the operational risk, and (c) model the operational risk. Whether (re)insurance companies comply sufficiently to these guidelines is constantly monitored and regulated by national supervisory authorities in each EU member state. For example, in the Netherlands, this supervisory authority is De Nederlandsche Bank (DNB).

Pillar 3: Supervisory reporting and public disclosure. According to De Nederlandsche bank (2023), pillar 3 consists of four elements: (a) reports on solvency and financial condition, including quantitative reporting forms; (b) supervisory reports, including quantitative reporting forms; (c) reports on predefined events; and (d) the policy on information to be publicly disclosed and the policy on reporting to the supervisory authority. All (re)insurance companies and brokers are obliged to deliver all these reports to their supervisory authority, which can be a demanding task. Notably, the rigorous requirements of Solvency II have garnered substantial criticism and are causing considerable challenges for (re)insurance companies (G3: 25th April, 2023). According to Kagan and Potters (2020), ‘’75% of firms in 2011 reported that they were not in a position to comply with Pillar 3 reporting requirements’’ (para. 5).

J2.2: IDD

The Insurance Distribution Directive (IDD) sets out rules for the distribution of (re)insurance products in the EU. The directive requires that all distributors of insurance and reinsurance products are registered with their national supervisory authority and meet certain professional standards (EIOPA, n.d.b). According to EIOPA (n.d.b), ''the IDD aims to ensure that distributors take responsibility for consumer outcomes and that the products sold meet consumers' needs'' (para. 1). To this purpose, each member of the EU has its own regulating authority. In the Netherlands, this is the Dutch Authority for the financial markets (AFM).

J2.3: EMIR

The European Market Infrastructure Regulation (EMIR) is implemented to enhance the stability and transparency of the over-the-counter (OTC) derivatives market in the EU. Just like in the financial industry, derivates transactions are practiced in the reinsurance industry as well. As the European Commission (n.d.a) stipulates, derivatives play an important role in the economy, but they also bring certain risks. Especially OTC derivates, ''contracts that are traded (and privately negotiated) directly between two parties'' (Storm & Naastepad, 2020, para.3), can pose significant risks for the financial stability of the financial markets. This became evident in the 2008 financial crisis, in which these OTC derivatives were primarily used by financial institutions to speculate. In this study I focus on traditional reinsurance, that is, with the primary objective of risk transfer. This excludes EMIR, which primarily targets the financial reinsurance sector and is centered around capital management, from the scope of the study.

J2.4: GDPR

The General Data Protection Regulation (GDPR) plays an important role in ensuring the protection of personal data involved in reinsurance transactions. Reinsurance transactions may involve the exchange of personal data, such as names, addresses, and medical information, particularly in the case of life or health insurance. According to Munich Re (n.d.a), the data they receive from the (re)insurance company is often anonymized. Nevertheless, under particular circumstances, they may opt to conduct the risk and claims assessment internally (Munich Re, n.d.a), implying that they would seek access to personal data. They do this when the sum insured is extraordinarily high. Interestingly, the national laws and regulations regarding privacy protection of policyholders in the EU Member States differ. According to Insurance Europe (2019), the insurance and reinsurance federation, some Member States allow transfer of personal data from the insurer to the reinsurer ''without obtaining the consent of the insured person (policyholder)'' (p.8), while other Member States do not.

J2.5: AMLD

The Anti-Money Laundering Directive (AMLD) sets out rules for the prevention of money laundering and terrorist financing in the EU. Reinsurance companies are required to have systems and controls in place to prevent money laundering and terrorist financing, and to report suspicious transactions to their national financial intelligence unit (FIU). Similar to the Solvency II and IDD directives, Member States have the flexibility to implement EU laws in their own manner, provided that they comply with the directives. In the Netherlands, the national FIU falls within the Ministry of Justice and Security.

J3: Governance: a traditional contract (L3)

Williamson's governance layer (L3) pertains to the control, decision-making, and enforcement of contracts and agreements. In the context of this study, I am specifically examining the control, decision-making, and enforcement aspects of a reinsurance contract. To prevent redundancy, I will not reiterate the transactions involved in the execution of a reinsurance contract. 6.1 Critical transactions provides a comprehensive overview of the critical transactions associated with the execution of reinsurance contracts concerning administrative costs and dispute resolution costs. For the sake of completeness, I will allocate this section to describing all parties involved in the 'consumption' of a reinsurance contract.

First of all, a reinsurance contract consists of at least one reinsurer and one insurer. In fact, an insurer can spread its risk over an unlimited number of reinsurers, with each reinsurer responsible for a proportion of the claims incurred. In that case, we speak of a 'contributing excess' (International Risk Management Institute, n.d.b). However, for the sake of simplicity, I exclude this from the analysis. Furthermore, mainly facultative contracts also mention the policyholder, which is the party insured under the original insurance policy. As indicated in 5.2.1 Search costs, actuaries are involved in preparing reinsurance contracts. They calculate the probability of future outcomes and use statistical models to determine an appropriate premium and coverage for the reinsurance product.

Should a dispute arise, arbitration is the most commonly used form to resolve these disputes, as described in 5.2.6 Dispute resolution costs. According to DRD (2023), 74 percent of disputes are resolved by arbitration. Arbitration resolution may involve different parties, as not all arbitration processes are the same. As described in 5.3.1 Approximation of dispute resolution costs, both parties usually choose their own arbiter, and it is up to the arbiters to select an umpire. The umpire gives a final decision, should the arbiters together be unable to reach a decision.

For setting up the arbitration procedure, such as scheduling the preliminary hearing and the hearing itself, the parties in dispute can resolve this (a) ad hoc, or (b) through an arbitration institute. Often, arbitration institutes provide other services besides scheduling the arbitration proceedings, including putting together a neutral panel of arbiters (ARIAS, n.d.). Once the award is made, it is up to the parties to comply with the award. In certain cases, it happens that the losing party does not comply with the award, forcing the parties to enforce the award in court. In that case, lawyers may also be involved in the dispute, and a judge will have to rule.

J4: Resource allocation (L4)

The final layer of the Williamson framework concerns layer 4: resource allocation. Resource allocation in the reinsurance industry involves dynamic allocation of financial, human, and technological resources across sectors, driven by factors like market conditions, regulations, and customer demands. Striking a balance between maintaining capital reserves and maximizing profitability is a key challenge for reinsurers, requiring effective risk management, technological investments, and streamlined operational processes for long-term viability. The goal is to achieve economic efficiency and ensure the industry's sustainability. In the context of my study, I can say that the implementation of a smart contract in the reinsurance industry is partly related to layer 4. The justification for implementing a smart contract depends on the extent to which it can have a positive impact on the profitability of (re)insurers. Indeed, since the implementation of a smart contract also involves a dynamic reallocation of resources (reallocation of financial, technological, and human resources), I can also consider the implementation of a smart contract as part of Layer 4.

Appendix K: Arbitration process reinsurance

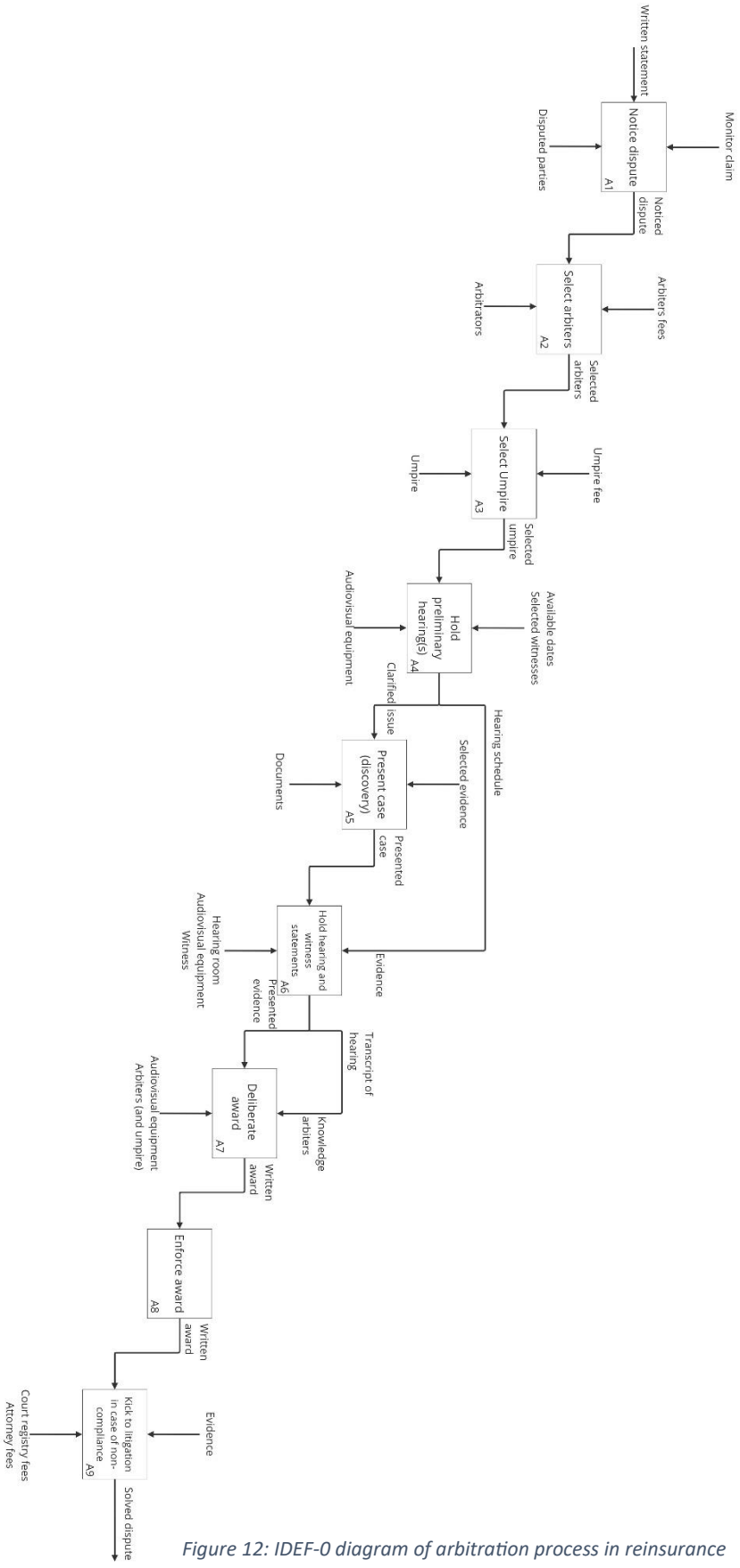

Figure 12: IDEF-0 diagram of arbitration process in reinsurance

Appendix L: Stakeholder Analysis

In the development of any design, it is essential to understand the political dimension of the particular industry, because these actors benefit from the outcome, and can also exercise power over the outcome. The steps in conducting stakeholder analysis include: making an inventory of the actors who might have a role in decision-making and collecting information about them to gauge their importance (Lindenberg & Crosby, 1981). For this purpose, I will first compile an inventory of all actors present in the reinsurance industry, and then apply a power-interest analysis to assess the importance of all actors. In addition, I will include a formal chart.

I divided the stakeholders in three separate groups, namely the actors economically active in the reinsurance industry, the regulatory institutions from the EU, and the regulatory institutions from the member states of the EU. To give an indication of how legislation from the EU permeates its member states, I have chosen the Netherlands as an example here.

L1: Economically incentivized actors

In this context, I refer to the economic actors as the actors having a financial incentive in the reinsurance industry. Thus, these are the parties that derive their profits from providing or receiving insurance, reinsurance, retrocession, or act as intermediaries between the insured and the insurer. The economic actors in the reinsurance industry are visible in figure 13.

Starting from the bottom, the policyholder is the owner of the policy that is ensuring a particular risk. This is usually an individual, but can also be a business or organization. Policyholders can insure risk directly at an insurance company, or via an insurance broker. In this way, they financially protect themselves from any type of risk such as accidents, illnesses, natural disasters or other unforeseen events. The policyholder pays a (often) monthly premium, and can receive a claim if the claim falls within the terms and conditions of the policy. The policyholders are responsible for buying and managing their policy, adjusting their coverage as needed (Pope, 2023). In the property and casualty insurance industry, for example, the policyholder of a car insurance policy is usually the owner of the car. Whenever they become owner of the vehicle, they are legally obliged to have minimum insurance coverage. In most counties this includes that vehicle owners can financially compensate others for damages or injuries caused by their vehicle.

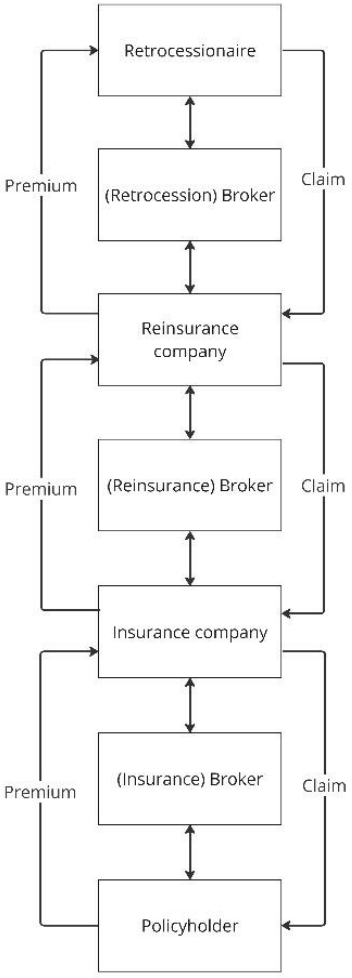

Figure 13: Economic actors reinsurance industry

Just as a policyholder transfers part of its risk to an insurer, an insurer transfers part of its risk to a reinsurer. Again, they can choose to reinsure directly to a reinsurance company, or transact via the reinsurance broker. Lastly, a reinsurance company might choose to retrocede (a part of their) risk via a broker to a retrocessionaire, or directly to the retrocessionaire. What is important to consider is that the distinction between the actors is often not at all as sharp as shown in figure 13. For example, a reinsurer can offer primary insurance and reinsurance, simultaneously to different parties. According to a Chester and colleagues (2017), the lines between primary insurance and reinsurance have blurred over the last decade. To illustrate, the written premiums of Munich Re comprise about 60% reinsurance, while the remainder is primary insurance.

L2: Regulatory institutions: European Union

Unlike the US, the same legislation on reinsurance applies to every EU member state. The European Union consists of multiple bodies regulating the reinsurance industry. These include the European Central Bank (ECB), European Securities and Markets Authority (ESMA), the European Commission (EC) and the European Insurance and Occupational Pensions Authority (EIOPA).

1. ECB

Although the ECB is not directly tied to the reinsurance industry, it is still responsible for the overall economic stability of Europe. According to the ECB (2023), the insurance market ''plays an important role in financial markets as institutional investors and investment targets.'' (para.6). In order to keep an eye on the financial stability of the European Economic Area (EEA), the ECB collects data of insurers and reinsurers of their balance sheet, premiums and claims. Further, the ECB collaborates with EIOPA, in developing and implementing regulatory frameworks for the insurance sector.

2. ESMA

The mission of European Securities and Markets Authority is to ''enhance investor protection, promote orderly financial markets and safeguard financial stability.'' (ESMA, 2019, para.2). The, ESMA was established in response to the recommendations outlined in the 2009 de Larosière report. This report was prepared immediately after the global crisis (2008-2011) to analyze its causes. One of the catalysts appeared to be the intransparency of the financial market, especially with regard to over-the-counter (OTC) derivatives. These financial (or insurance) transactions were entirely between two parties, i.e. without the ability of regulators to monitor them. Initially used to spread risk, however, these financial instruments were used to speculate in the run-up to the crisis. ESMA was set up to oversee this type of financial market risk, under the EMIR (see institutional analysis). Importantly, therefore, ESMA is not primarily responsible for regulating the reinsurance market, but rather for regulating the financial market. The insurance industry and financial sector are closely related however, as in some cases reinsurers are active in the financial sector as well, for instance through securitization of insurance risks. As indicated in the introduction, the financial reinsurance sector falls outside the scope of this study.

3. EC

The role of the European Commission (EC) in the reinsurance industry in Europe is to provide regulatory oversight and ensure the proper functioning of the market. The EC plays a significant role in shaping and implementing policies and regulations that impact the reinsurance sector. The EC has the power to propose legislation and coordinate policies across member states. Interestingly, a report of the EC examined the impact of reinsurance market consolidation as it raised concerns about the availability of reinsurance. According to the report, insurers have no difficulty

reinsuring, ''but it is sometimes difficult to find reinsurance at a good price.'' (European Commission, n.d.b, p.58)

4. EIOPA

Lastly, the EIOPA is at the heart of insurance and occupational pensions supervision in the EU. The EIOPA is an ''independent advisory body to the European Commission, the European Parliament and the Council of the European Union.'' (EIOPA, n.d.a, para.2).

The relationships between the regulatory institutions, is visible in figure 14. This figure provides a formal chart, illustrating what European bodies are responsible for what legislation, and how it feeds back into its member states. To illustrate how the regulatory institutions impact its member states, I provided the framework with the Netherlands as an example.

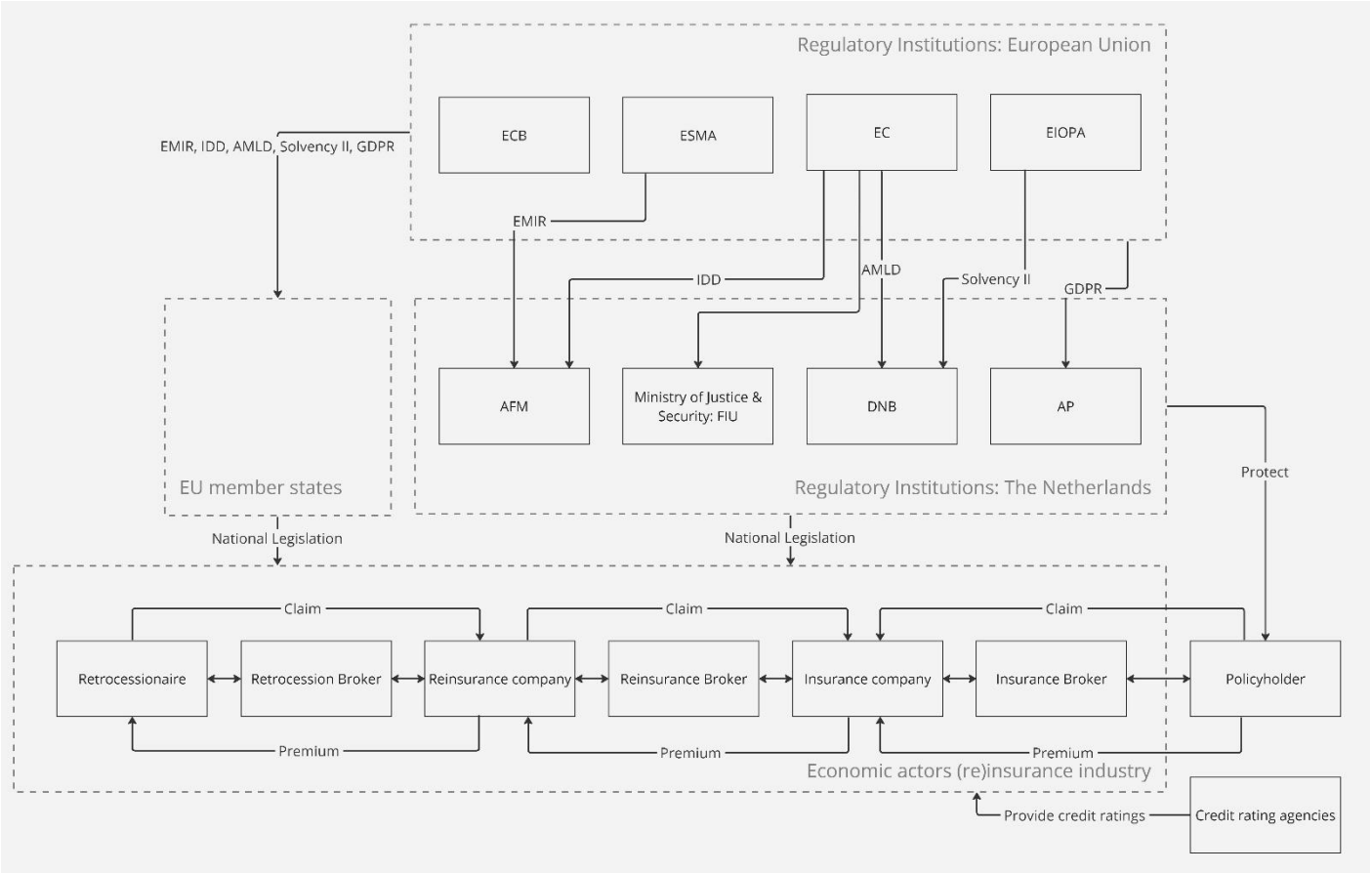

Figure 14: Formal chart reinsurance industry Europe

Appendix M: Design requirements

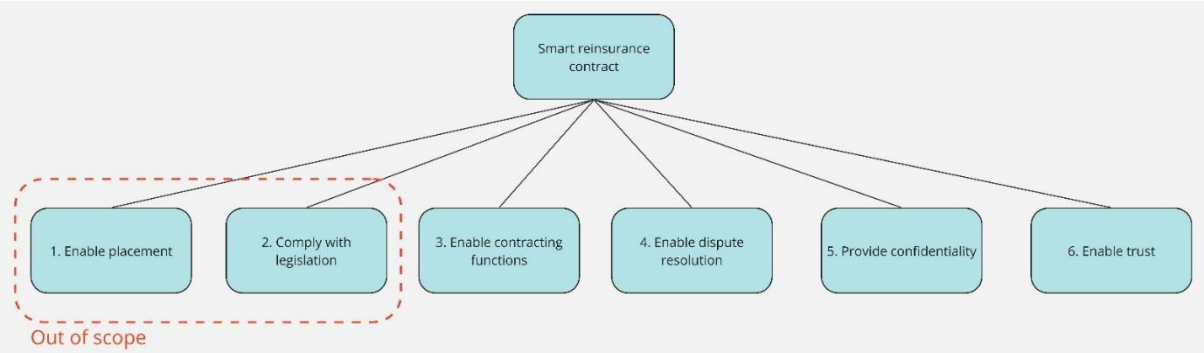

Figure 15: Design requirements

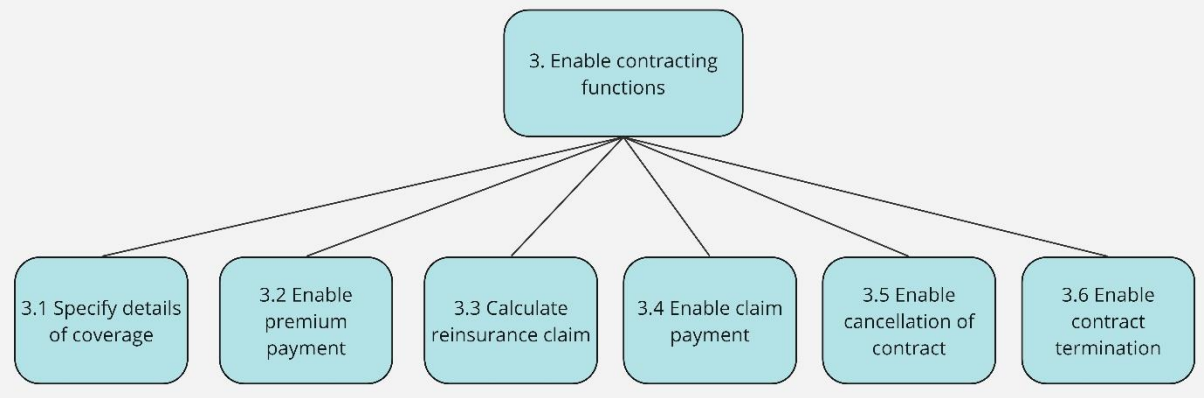

Figure 16: Design requirements (enable contracting functions)

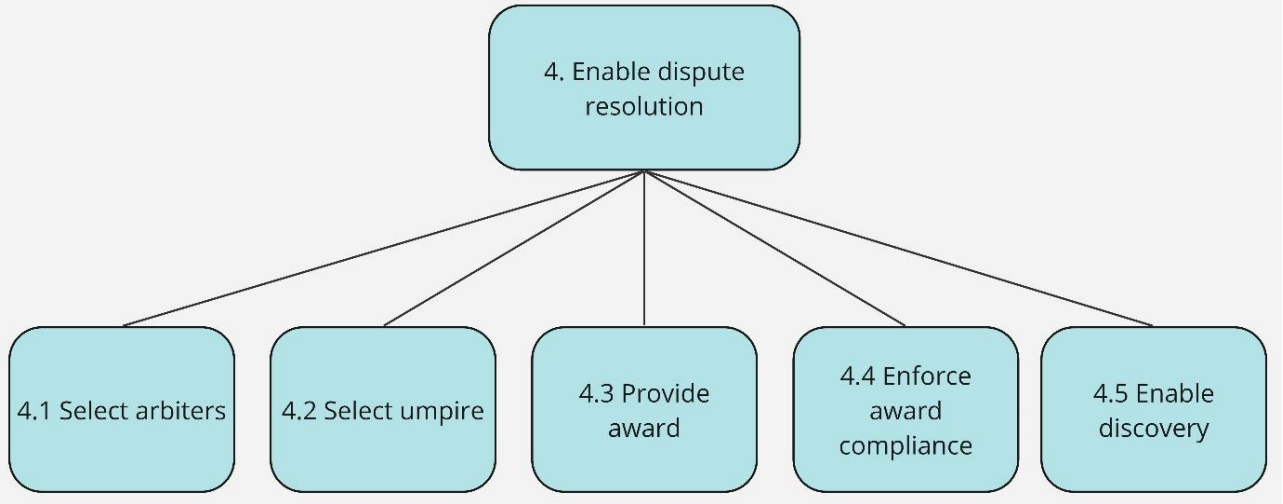

Figure 17: Design requirements (enable dispute resolution)

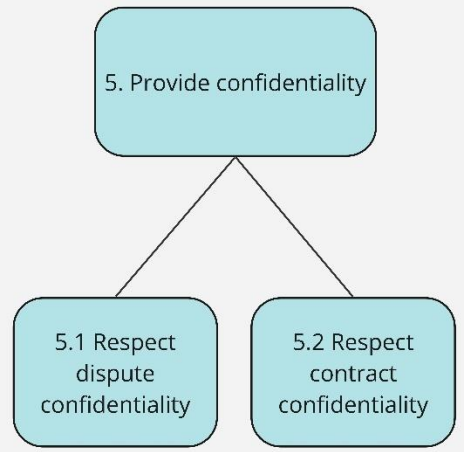

Figure 18: Design requirements (provide confidentiality)

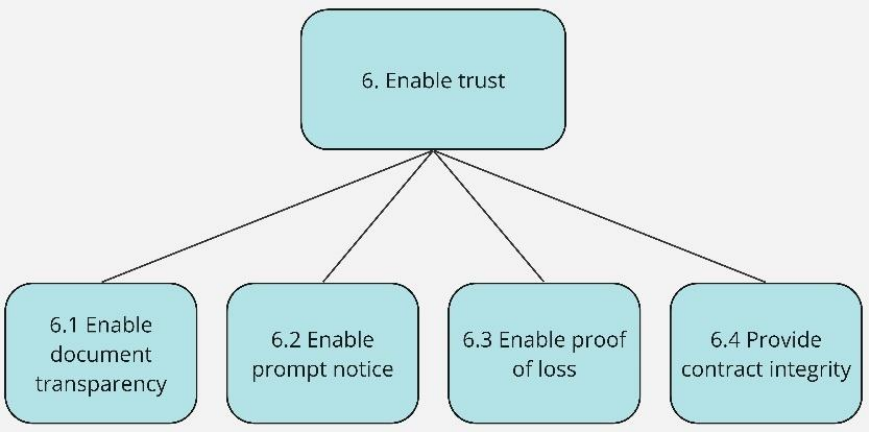

Figure 19: Design requirements (enable trust)

Appendix N: Full swimlane diagram

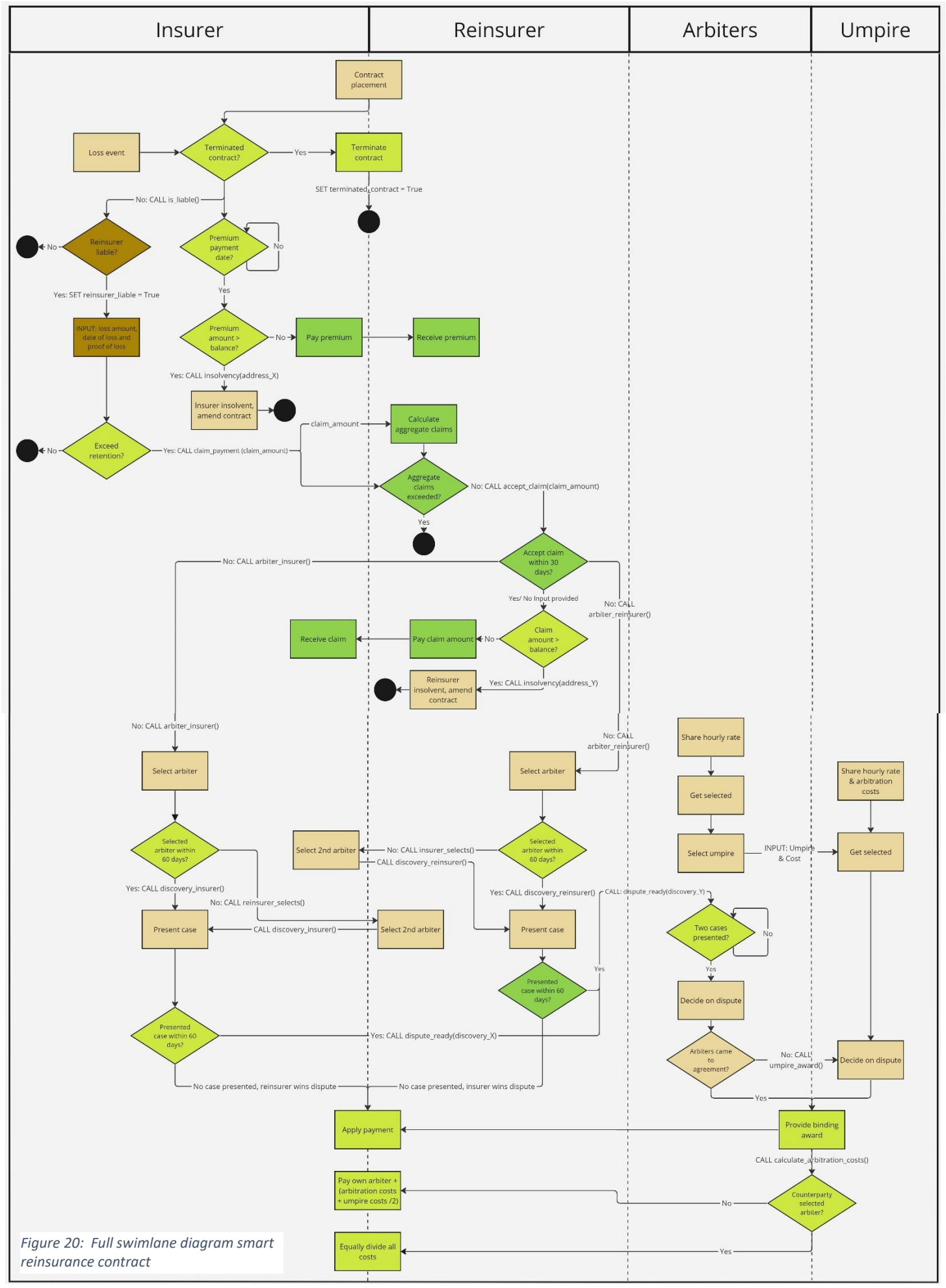

Figure 20: Full swimlane diagram smart reinsurance contract

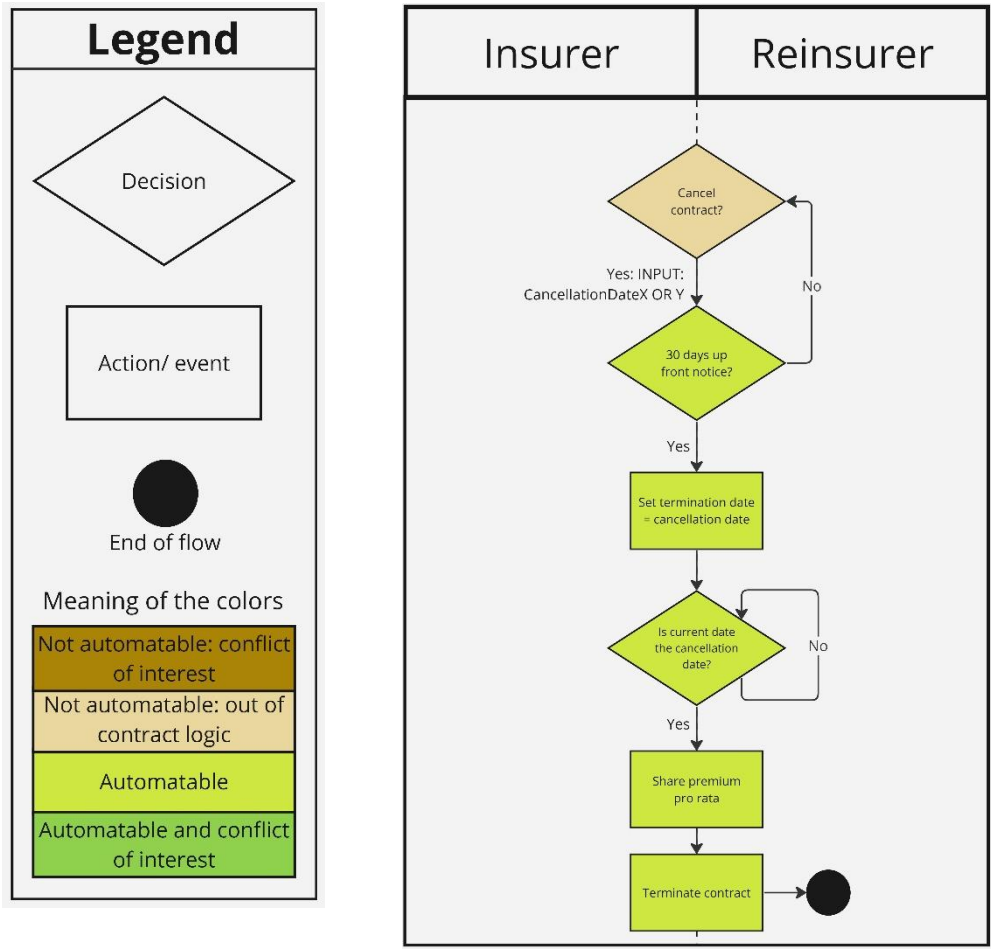

Figure 21: Swimlane diagram: Cancellation of smart reinsurance contract