Evolution or Revolution?  
How Solvency II will Change the Balance between Reinsurance and ILS

February 11, 2016

Abstract
The introduction of Solvency II will decrease regulatory frictions regarding insurance-linked securities (ILS) and thus redefine how insurance and reinsurance companies can use these instruments for coverage against natural catastrophe risk. We draw on a theoretical framework to forecast the impact of Solvency II on the relative market volume of ILS compared to traditional reinsurance. The key model parameter is estimated by means of OLS and forecasted based on an ARIMA model with Hodrick-Prescott Filter. We complement our results with scenarios for which we estimate probabilities using a Gumbel distribution. Our findings indicate that Solvency II will have a moderate positive effect on ILS markets. More specifically, market participants can expect the volume of ILS to rise to more than 26 percent of the volume of traditional reinsurance by the end of 2018.

Keywords: Insurance-Linked Securities, Reinsurance, Solvency II  
JEL classification: G11; G22; G28; G32; G38
1 Introduction

For a long time, insurance companies relied mainly on traditional reinsurance to cede risk. However, in recent years, more and more insurance companies started to use insurance linked securities (henceforth ILS) to cede risk to financial markets. In parallel to the rise of ILS, an important regulatory change within the European Union concerning the re/insurance industry started to take shape. Solvency II will, among others, redefine solvency and capital requirements for the re/insurance industry and will come into force in the beginning of 2016 (see EIOPA, 2015). Additionally, as many countries will be seeking Solvency II equivalence, the impact of Solvency II will not be limited to the EU itself, but extend far further (see, e.g., Lloyd’s, 2015). This triggers the question, how the recent rise of ILS will be affected by the introduction of Solvency II.

The motivation for raising this question is twofold. Firstly, given its recent growth, ILS could have the potential to disrupt the reinsurance industry. According to Swiss RE (2015a) the ILS market grew annually by 20% during the last three years. Today, ILS with a volume of around USD60 billion are outstanding Guy Carpenter (2015c). Additionally, the year 2014 saw with USD8.29 billion the largest volume of new cat bonds issuance since inception of the market Artemis (2015b). Research by Swiss RE (2015a) showed that the spreads of cat bonds, the most prominent asset class within ILS, and similarly rated high-yield corporate bonds converged. This suggests that investors have grown familiar with ILS as asset class, pushing it towards mainstream.

Secondly, it is expected that Solvency II will clarify how ILS can be used for reinsurance and capital relief purposes. According to Swiss RE (2009) the regulatory environment has an important influence on how and to what extend insurance companies use risk transfer instruments. Therefore, the new solvency requirements will force insurance companies to rethink their approach towards risk-management in general, and reinsurance in particular. Consequently, there exists a need for models that are able to describe how Solvency II will influence the demand for ILS relative to traditional reinsurance. The aim of this paper is to develop a framework, which enables us to forecast the impact of Solvency II on the demand for ILS relative to traditional reinsurance and deriving based on this tangible recommendations for the insurance and reinsurance industry.

Today, the regulation regarding ILS is heterogeneous and ambiguous, which is partially due to the fact that ILS was for a long time a niche product. Regulation is particularly tricky for ILS instruments without an indemnity trigger. When using ILS, insurance companies need not only to consider the regulatory framework but also national accounting rules as well as the treatment of ILS by rating agencies. These days, the United States probably offer the most favorable regulatory environment for ILS. The National Association of Insurance Commissioners, a regulatory body, generally considers properly structured ILS as reinsurance. Likewise, the common accounting standards IFRS and US GAAP treat most ILS as reinsurance (see, e.g., Swiss RE, 2009).
In the European Union the current regulatory framework is less obvious. Under Solvency I risk transfer instruments are usually disregarded for solvency capital as long as no claims have been paid. In addition, it is crucial whether the risk transfer instrument qualifies as reinsurance contract or not in order to be accountable. In general, instruments without an indemnity trigger cannot be treated as reinsurance (see, e.g., Swiss RE, 2009). Nevertheless, existing rules and regulations did not hinder insurance companies from using ILS and did not prevent the strong growth of ILS markets in recent years. However, Swiss RE (2009) notes that “regulatory developments could lead to more adequate treatment of risk transfer and thus have a favorable impact on the use of ILS”. Solvency II thus matters for ILS instruments, as it is expected that it will improve and facilitate the use of ILS as reinsurance and risk mitigation instrument Artemis (2015h). According to industry experts and EIOPA, the regulatory body, the upcoming new regulation could further fuel the expansion of ILS observed in recent years. In a report CEIOPS (2009), the Committee of European Insurance and Occupational Pensions Supervisors wrote that under the new Solvency II framework, European insurance and reinsurance undertakings can use securitization in the same way as they use reinsurance to meet their capital requirements which should have a positive effect on supply and facilitate the development of the insurance securitization market. In a more recent speech a representative of EIOPA noted that Solvency II could make ILS more interesting for insurers located in the European Union and thus bring more sponsors into the market Artemis (2015h). Specifically, ILS such as cat bonds could be incorporated into the calculation of the solvency ratio (SR) of insurance companies, thus decreasing the Solvency Capital Requirement (SCR) in the same way as traditional reinsurance Dittrich (2010). According to an industry expert, a pivotal question will be, how regulators will treat ILS for capital-relief purposes Crugnola (2014). Even though EIOPA, the regulatory body, stated that securitization will be recognized under Solvency II as risk mitigation technique potentially lowering capital requirements of insurance companies, it also pointed out that the accounting processes might be complex Artemis (2015h).

Therefore, a crucial question will be, whether insurance companies will be able to account for ILS through the standard formula or whether a more complex internal solvency model will be required. If an internal model would be necessary - which is more complex and expensive to maintain - cat bonds or other ILS instruments might become unattractive for smaller insurance companies Crugnola (2014). For instance, the fifth quantitative impact study conducted by CEIOPS (2010) mentioned that under the standard formula “[...] when a risk mitigation technique includes basis risk the insurance risk mitigation instruments should only be allowed in the calculation of the SCR with the standard formula if the undertaking can demonstrate that the basis risk is either not material compared to the mitigation effect or if the risk is material that the basis risk can be appropriately reflected in the SCR.” This example shows that given today’s information it is not yet obvious to what extend and under which conditions ILS can be used for capital relief purposes under Solvency II. Nevertheless, investors, insurance and reinsurance companies need to anticipate already today how Solvency II could affect the growth of ILS markets relative to traditional reinsurance. Therefore, it is of high interest to research and industry, how different scenarios regarding Solvency II could influence the further development of ILS markets. Will ILS grow further and therefore become a stronger competitor for traditional reinsurance? Could the market for
We will proceed as follows: in chapter two we are going to introduce a model economy, which will establish the theoretical foundation for the demand of traditional reinsurance and ILS by insurance companies\(^1\). Particularly, we will argue that insurance companies perceive ILS instruments subjectively as more or less expensive depending on their level of expertise and experience as well as the current regulatory framework. For that matter we will introduce the weighting factor $\Delta$, which captures the subjective, relative cost of ILS compared to traditional reinsurance. In chapter three we are going to look into the maximization problem of an insurance company and provide a solution for the optimal demand for ILS and traditional reinsurance. The fourth chapter is dedicated to discussing the data. Our data covers the period between end of 2002 and end of 2014. In order to obtain information about the pricing and volume of reinsurance, we had to rely on different sources and approximations. Therefore, the data situation merits careful treatment. In the fifth chapter, we will set up a regression framework based on the previously developed theoretical model and estimate $\Delta$. This will allow us in chapter six to forecast $\Delta$ based an ARMA-model and conduct a sensitivity analysis. From the different possible values for $\Delta$ we will deduce the corresponding volume of ILS market relative to traditional reinsurance. Moreover, by fitting a Gumbel distribution on the possible scenarios for the relative ILS market volumes we will be able to forecast the demand for ILS relative to traditional reinsurance after the introduction of Solvency II. Based on the forecast we will discuss the expected economic impact and derive recommendations for investors, insurance and reinsurance companies. The paper will be concluded in chapter seven.

2 Model Economy

In the following, we are going to provide an overview of our model economy. Its derivation is based on the approach proposed by Koijen and Yogo (2013), who build a model to estimate the impact of shadow insurance on the capital costs of insurance companies and thus the supply of insurance contracts. As the research question addressed in this paper is like-minded, it is justified to rely on a similar structure for the model. The model economy consists of an insurance company $I$, which offers insurance policies and optimizes its profit $\Pi$, given a set of parameters. In particular, the insurance company $I$ is able to purchase reinsurance $RE$ or sponsor $ILS$. Both instruments allow - at least in the general setting - the insurance company to reduce its risk exposure and thus the need for costly reserve capital. Both instruments have a distinctive price, namely the premium for the reinsurance contract $PR$ and the interest rate paid on the ILS instrument $R$.

\(^1\)Even though insurance companies in principal do actually issue ILS, while investors demand them, we will continue to use the term demand throughout the paper. The reason for this is that it makes it easier to treat traditional reinsurance and ILS similarly. Additionally, one might argue that insurance companies demand reinsurance by issuing ILS, which justifies the use of the term demand.
2.1 Baseline Model

The insurance company faces the following profit function at time $t$:

$$\Pi_t = P_t \times Q_t - V_t \times Q_t - R_t \times ILS_t - PR_t \times RE_t + V_t \times ILS_t + V_t \times RE_t$$ (1)

Where $P_t$ is the premium earned by the insurance company by selling quantity $Q_t$ of an insurance policy. $V_t$ is the actuarial fair value of the insurance policy and thus the expected value of the liabilities. $R_t$ is the coupon paid on the catastrophe bond $ILS_t$ issued by the insurance company. $PR_t$ is the premium paid for the reinsurance contract $RE_t$.

The insurance company is maximizing its profit given the choice variables $P_t$, $ILS_t$ and $RE_t$. Given the initial setting in the baseline model, whenever $PR > R$ or $PR < R$ it cannot be optimal to use both instruments for reinsurance purposes at the same time. This trivial solution to the problem is clearly not what can be observed in the real world and thus of little interest. Nevertheless, the baseline model shows two important things: firstly, in reality other factors besides the relative price of ILS compared to traditional reinsurance influence demand and secondly, ILS has the potential of being a strong competitor to traditional reinsurance if the only deciding factor was capital cost.

Given the fact that the proposed model is not in line with the observed reality we will adapt the model in order to make it more realistic. However, we will hold on to the main idea that theoretically ILS and traditional reinsurance could be perfect substitutes even though in reality they might as well be complements. The substitute-assumption is justified by the fact that in theory both instruments could achieve the same risk reduction and thus capital-relief Dittrich (2010).

Recent developments in the ILS market support this assumption. Munich RE (2015) for instance found that in the first two quarters of 2014 most ILS issuance had a variable rather than a fixed reset making it simpler for the cedent to adapt the reinsurance tower after the reset. This brings the characteristics of ILS closer to traditional reinsurance contracts. Nevertheless, one needs to keep the limitations of the substitute-assumption in mind, as only ILS with an indemnity trigger can be regarded as perfect substitutes to traditional reinsurance.

To incorporate this we will define a more sophisticated model, which is able to explain the currently observed ratio of reinsurance and ILS in the market.

2.2 Extended Model

In the following we are going to adjust the baseline model in a way that can explain, why insurance companies use both traditional and alternative reinsurance. Starting from the assumption that financial markets have a lower cost of capital than reinsurance companies given their higher efficiency - put forward by Cummins and Weiss (2009) as well as Gibson et al. (2014) - we have that in general $PR > R$. Given this general result, the above stated requirement that insurance companies use both instruments can
only be incorporated by either making traditional reinsurance more attractive or by making ILS less attractive, for instance by adding an uncertainty/complexity factor. As we are primordially interested in ILS, we opt for the second option and introduce the factor \( \text{Delta} \) into the model, describing broadly how cost-efficient and thus "attractive" risk mitigation through ILS is for an insurance company.

In particular, we will weight the ILS price \( PR_t \) with the parameter \( \text{Delta} \). The reasoning behind this step is that we assume that insurance companies base their decision to purchase reinsurance and/or ILS not on the relationship between objective prices \( R_t \) and \( PR_t \), but rather on the relationship between subjective prices \( \delta_t R_t \) and \( PR_t \).

\[
\Pi = P_t \cdot Q_t - V_t \cdot Q_t - \delta_t R_t \cdot ILS_t - PR_t \cdot RE_t + V_t \cdot ILS_t + V_t \cdot RE_t
\]  

The subjective price for ILS, \( \delta_t R_t \), may be different for each company and is based on the company’s experience and expertise regarding to use of ILS relative to the use of traditional reinsurance. This concept is intuitively appealing, as most insurance companies have years of experience in negotiating and using reinsurance contracts, however little when it comes to dealing with ILS instruments. Additionally, regulatory uncertainty might deter insurance companies from setting up an ILS strategy altogether. This might explain, why it took almost a decade until ILS market reached a considerable size.

Data from Guy Carpenter (2008) regarding the number and volume of first-time and repeated sponsors covering the years 1997 to 2007 provides support for our assumption of a subjective ILS price. While in the first years up to 2004 the issuance volume by first-time issuers remained often well below $800 million and was usually dominated by the issuance volume of repeated issuers, this changed between 2005 and 2007, when the issuance volume of first-time issuers grew significantly and reached $3500 million in 2007.

One could interpret these figures as a sign that during this period more and more insurance companies were convinced that ILS offered a good deal, implying that the subjective price for ILS decreased. Guy Carpenter (2008) interpreted this development as a sign for ILS becoming mainstream. We will later see that this period coincides with a sharp decline in our estimated \( \text{Delta} \)-factor (see figure 4).

The existence of a subjective price implies that in some situations, even though in objective terms risk mitigation through ILS would be cheaper than through traditional reinsurance, insurance companies rationally decide to use traditional reinsurance.

Given the above argumentation, we build our model on the assumption, that an insurance company can only exploit the full potential of ILS as a risk mitigation instrument once it has build up the necessary knowledge and expertise and has the regulatory certainty that it will be able to use ILS as a risk mitigation instrument.

It is important to note that the two factors, regulatory framework and expertise, are inherently connected. An insurance company with extensive expertise might be better suited to account for ILS as a risk mitigation instrument.

\[ ^2 \text{Literature often refers to the provision of underwriting assistance and other technical services by the reinsurance company to the client as additional benefits of a reinsurance contract. In such a case, the price for a reinsurance contract can be understood as the cost for the whole package, including but not limited to the transfer of risk (see for example Gibson et al. (2014)).} \]

\[ ^3 \text{We will explain why the relative price for traditional reinsurance is equal to the objective price below.} \]

\[ ^4 \text{The strong growth in first-time issuance might additionally have been fueled by hurricane Katrina, which lead to a sharp increase in reinsurance rates for P/C in the US by 76\% Hartwig (2012).} \]
mitigation instrument in a given regulatory framework. Therefore, the source of regulatory uncertainty does not necessarily need to stem from the regulator itself, but can also be the result of lacking knowledge on the part of the insurance company regarding the regulatory framework in place. In consequence, we expect that the introduction of Solvency II will not only lead to a regulatory improvement, but also enhance the knowledge of insurance companies about how ILS can be used as a risk mitigation instrument.

As mentioned above, in order to account for the subjective price, we model the price for ILS such that it is a function of the objective price \( R_t \) weighted by \( \Delta \). In consequence, the factor \( \Delta \) allows us, to alter relative prices over time and thus the perceived relative risk mitigation benefit an insurance company gets by spending 1$ on either one of the two instruments. \( \Delta \) thus reflects on one hand the experience and expertise with ILS of a (potential) sponsor - the insurance company - and on the other hand the perceived complexity of ILS as a risk mitigation instrument. These factors influence at which cost ILS actually can be used by an insurance company for capital-relief purposes.

It is important to note that \( \Delta \) classifies ILS relative to traditional reinsurance. Therefore, traditional reinsurance acts similar to a numeraire good. In consequence, our model is able to represent the different characteristics of two instruments through the subjective price of ILS (modeled through \( \Delta \)).

We will describe preferences in monetary terms rather than in terms of utility, as this complies better with the line of thought proposed by the Solvency II framework, where quantitative requirements play an important role Deloitte (2010).

\section*{2.3 Convex Costs}

Our proposed model can so far explain, why both instruments exist in the market, however, not why both instruments co-exist within the same insurance company. We thus need some more assumptions regarding the cost of reinsurance contracts \( PR_t \) and the costs for ILS \( R_t \) respectively.

To justify the co-existence of ILS and traditional reinsurance instruments in an insurance company one could argue that the two instruments satisfy different needs and are thus complementing and not substituting each other.

However, several indicators contradict this argument. Firstly, if the above assumption was true, one would expect the pricing of the different issued ILS instruments to be rather homogeneous, given that they would all insure similar events, namely low-probability, high-impact events. However, when looking into the data provided by Artemis (2015), we find that pricing is quite divers, with around half of the outstanding risk capital being priced at 6% or lower and half of it above 6%. This suggests that insurance companies use ILS instruments to reinsure for all kinds of events, not only low-probability, high-impact events.

This is in line with the observations made by the panelists of the SIFMA Insurance and Risk Linked

\footnote{To offer an illustration: a company thinks about purchasing either reinsurance through financial markets (ILS) or through a reinsurance company (traditional reinsurance). We assume that both instruments have objectively the same market price and the same potential for risk mitigation. However, the insurance company has little experience with ILS and is unsure about the regulatory framework. At the same time, the insurance company has strong ties with its reinsurer and benefits from underwriting assistance. The insurance company thus perceives ILS subjectively as being more expensive than traditional reinsurance. In this case the insurance company has a \( \Delta > 1 \).

\footnote{For instance, Cummins and Weiss (2009) argue that ILS might be better suited for reinsuring low-probability, high-impact events, as financial markets offer a more efficient way to absorb such risks compared to traditional reinsurance.}
Securities (IRLS) 2015 conference, which concluded that the lines between traditional reinsurance and ILS keep blurring further Artemis (2015f), which points into the direction that traditional reinsurance and ILS are indeed substitutes rather than complements. We thus need another explanation in order to incorporate the fact that insurance companies use both instruments into our model.

Our second proposition is that at some point the cost for insuring a marginal unit through traditional reinsurance start to increase. Froot and O’Connell (1999) argue that capital market imperfections “raise the marginal costs at which reinsurers are able to offer successively greater exposure protection to insurers”. Given the above argument, we consider it justified to assume that marginal costs curve for traditional reinsurance is U shaped and thus has a positive slope after a certain contract volume Froot and Stein (1998).

This implies that, even though the marginal cost for traditional reinsurance might initially be lower than the subjective marginal cost for ILS, at some point the scale might tip in favor of ILS. This would imply that at a certain volume threshold the marginal cost curves of the two instruments cross each other. In such a scenario it would make perfectly sense for an insurance company to first reinsure through traditional reinsurance and then through ILS. Hence, by incorporating convex costs our model is able to explain why insurance companies use both types of reinsurance at the same time.

![Figure 1: Marginal Cost Curve Traditional Reinsurance and ILS](image)

It is important to note that the notion of convex costs at the level of the insurance company could be further extended by saying that it applies to every reinsurance package concluded by an insurance company. This would imply that insurance companies seeking reinsurance for a specific risk or peril would compile an optimal reinsurance package potentially containing traditional reinsurance as well as ILS. In consequence, insurance companies would not decide globally between ILS and traditional reinsurance, but rather from case to case. However, in order to make such an extension operational, data on company level would be necessary. As such data is not available so far, we will keep the simplifying assumption that insurance companies decide globally between ILS and traditional reinsurance.
3 Insurance Company’s Maximization Problem

The insurance company maximizes its profit by setting the price at which it sells insurance policies, \( P_t \), and by deciding on the quantity of reinsurance, \( RE_t \) and \( ILS_t \), it wants to purchase for given market prices.

However, the insurance company has to comply with the regulatory requirements stipulated in Solvency II, especially in terms of capital requirements European Comission (2015). Therefore, the insurance company is constraint in its choices. In order to account for these constraints, we will introduce a regulatory cost function, which is able to capture the costs associated with regulatory constraints.

The main incentive for the insurance company to purchase reinsurance is that it can cede risk at a price lying below the premium \( P_t \) it receives for taking on the risk, permitting to achieve the capital level \( K^* \) required by the regulator. In order to prevent unlimited purchase of reinsurance, we impose the condition that it is not possible for insurance companies to over-reinsure.

While the price for ILS for a given level of risk is approximately constant, assuming efficient financial markets, the marginal cost for traditional reinsurance is increasing after a certain volume purchased, given that reinsurance companies face financial constraints (see chapter 2.3).

In the following, we are first going to discuss the balance sheet dynamics within the insurance company, in order to obtain a notion on how capital reserves evolve over time. Secondly, we will introduce the regulatory cost function and derive the optimal levels for traditional reinsurance and ILS.

3.1 Balance Sheet Dynamics

As previously mentioned, one of the main purposes of reinsurance under Solvency II is capital relief, thus lowering the need for costly capital reserves. In the following we are thus going to model the respective effects of traditional reinsurance and ILS on the capital requirements of the insurance company, by describing how the balance sheet of the insurance company develops from one period to another.

The change in the liabilities \( L_t \) of the insurance company at the end of year \( t \), can be written as

\[
\Delta L_t = V_t(Q_t - RE_t - ILS_t)
\]  

Therefore, the liabilities of the insurance company grow, whenever the actuarially fair value of the written insurance business is larger than the actuarially fair value of the ceded insurance business.

Writing insurance business generates revenue, while ceding it to a reinsurance entity or to financial markets generates costs. Both effects are reflected in the change of assets \( A_t \) of the insurance company.

\[
\Delta A_t = P_t \times Q_t - \delta_t R_t \times ILS_t - PR_t \times RE_t
\]  

The above equation describes well the difference in cost that arise between traditional reinsurance and ILS given \( \delta \neq 1 \). It also shows that a high or low Delta indeed influences the net revenue of the insurance company. To see this, consider the following example: an insurance company has little experience in dealing with ILS instruments. In order to achieve the same risk mitigation result with ILS as with
traditional reinsurance more employees and resources are needed. The additional administrative and salary costs in consequence lead to higher overall costs. The insurance company in question thus has $\delta > 1$.

Given the liability and asset dynamics, we can write the capital level $K_t$ at time $t$ of the insurance company as

$$K_t = A_t - (1 + \rho)L_t$$

One can observe that the model allows both risk mitigation instruments to have a positive impact on capital $K_t$ by decreasing the liabilities $L_t$.

Important to note is that $\rho$ is the decision variable of the regulator and describes how much capital an insurance company needs to hold in excess of its liabilities. Following Koijen and Yogo (2013) $\rho$ can be understood as the "risk charge on liabilities". As Solvency II will redefine the capital requirements of insurance companies, $\rho$ will most probably also be affected by Solvency II and thus be subject to change Dittrich (2010). However, modeling its impact on the demand for reinsurance would exceed the scope of this paper. In the following we are thus going to treat $\rho$ as constant.

To recapitulate, the demand for reinsurance will be affected in two ways by Solvency II. Firstly, by how much capital insurers are required to hold relative to their liabilities - described by $\rho$ - and secondly, how ILS will be accepted by the regulator for capital relief purposes. This will in turn affect the insurers perception of the relative cost of ILS compared to traditional reinsurance - described by $\Delta$.

As mentioned above, the ability of an insurance company to employ ILS for risk mitigation purposes not only depends on the regulatory framework in place, but also on the experience and expertise of the insurance company itself in dealing with ILS.

This suggests that the amount, which can be accounted for capital relief purposes is different for every insurance company. In our model we account for this indirectly through $\Delta$ given the following reasoning: two almost identical insurance companies $i$ and $j$ with the only difference being $\delta_{t,j} > \delta_{t,i}$ have to reach the same mandatory level of capital $K^*_t$ by the means of ILS such that $K_{t,j} = K_{t,i} = K^*_t$.

Clearly, insurance company $j$ incurs higher costs for achieving the required capital level $K^*_t$, leading to $\Delta A_{t,j} < \Delta A_{t,i}$ and consequently to $\Delta L_{t,j} < \Delta L_{t,i}$.

In consequence, the insurance company with the higher $\Delta t$ has to purchase more reinsurance through ILS in order to achieve the mandatory level of capital $K^*_t$. One can easily see that if both insurance companies would purchase the same amount of ILS, the insurance company with the higher $\Delta$ could underwrite less insurance contracts. This is the same as saying that for each unit of ILS the amount, which can be used for capital relief purposes, is smaller. Therefore, even though one could argue that it would be more intuitive to weight $V_t$ - the risk mitigation effect of ILS - rather than its price $R_t$, the overall impact remains the same.

It is important to note that $\Delta$ also indirectly allows the previously stated potential advantages of traditional reinsurance (underwriting assistance, knowledge transfer) to be represented in the model.

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7 If Solvency II would indeed lead to a simplification of how ILS can be used for capital relief purposes, then evidently $\Delta$ would c.p. decrease for all concerned insurance companies. However, if Solvency II would strongly limit the ability to use ILS for capital relief purposes then $\Delta$ would c.p. increase.
This is due to the fact that if such benefits exist, then they would in some way be positively reflected in the balance sheet. One could for instance argue, that underwriting assistance would enable the insurance company to underwrite insurance contracts with a lower expected loss for a given premium. Such contracts would in return require less risk capital and thus decrease the need for reinsurance or ILS. In consequence, the subjective price of ILS would be higher compared the price of traditional reinsurance (e.g. $\Delta > 1$), as it does not offer these additional benefits.

In conclusion, even though the factor $\Delta$ influences only the subjective price of ILS it still allows to account for benefits of ILS and traditional reinsurance, which go beyond their respective actuarial value $V_t$. In our opinion, $\Delta$ is thus a quite powerful variable in terms of its modeling capacity.

3.2 Cost of regulatory capital requirements

As introduced above, the insurance company maximizes its profit under the capital constraints imposed by the regulator. Solvency II will, among others, require insurance companies to hold a high enough capital stock, in order to be able to absorb shocks.

In particular, Solvency II introduces a two level capital requirement regime European Comission (2015) with two different measures, the Solvency Capital Requirement (SCR) and the Minimum Capital Requirement (MCR), in order to trigger proportionate and timely supervisory intervention European Comission (2015). Thus, if an insurance company finds itself below the required level of capital, a costly intervention by the regulator will be triggered. Costs are particularly high for very low levels of capital (e.g. below MCR) as in this case the regulator may withdraw its authorization to operate European Comission (2015).

We model these regulatory costs similarly to Koijen and Yogo (2013) through the cost function $C_t$, depending on the capital level $K_t$ held by the insurance company

\[ C_t = C(K_t) \quad (6) \]

with the following first and second-order derivatives:

\[ \frac{dC_t}{dK_t} < 0 \quad (7) \]
\[ \frac{d^2C_t}{dK_t^2} > 0 \quad (8) \]

That is, increasing the capital stock $K_t$ reduces regulatory costs, while very low levels of capital draw costly regulatory intervention by the supervisory body as outlined above. This is in line with the goals pursued by the regulator with the implementation of Solvency II, namely to reward insurers who have appropriate risk-management techniques in place and penalize those, who do not (European Comission, 2007, p.4). Of course, an insurance company has to consider these costs, when optimizing its profit which
leads to the following extended profit function

\[ J_t = \Pi_t - C_t + E_t [d_{t+1} \cdot J_{t+1}] \] (9)

where \( d_{t+1} \) is the stochastic discount factor.

The insurance company thus maximizes \( J_t \), taking into account regulatory cost arising through capital requirements, by deciding on the price \( P_t \), the amount of traditional reinsurance \( RE_t \) and the amount of alternative reinsurance \( ILS_t \). Obviously, the decision regarding the capital stock today has implications on the future profit, which is also taken into consideration by the insurance company.

### 3.3 Optimal Insurance Price

The first-order condition for the insurance price can be obtained by taking the first partial derivative with regards to \( P_t \) and applying the envelop theorem (Please note to avoid confusion that \( \delta \) describes in the following paragraphs partial derivatives and not the factor Delta. Whenever we make reference to Delta we will put it in bold.)

\[
\frac{\delta J_t}{\delta P_t} = \frac{\delta \Pi_t}{\delta P_t} - \frac{\delta C_t}{\delta K_t} \cdot \frac{\delta K_t}{\delta P_t} + E_t \left[ d_{t+1} \cdot \frac{\delta J_{t+1}}{\delta K_t} \cdot \frac{\delta K_t}{\delta P_t} \right] = 0
\] (10)

rearranging and dividing both sides by \( \frac{\delta K_t}{\delta P_t} \) yields to

\[
- \frac{\delta \Pi_t}{\delta P_t} \cdot \left( \frac{\delta K_t}{\delta P_t} \right)^{-1} = \frac{\delta C_t}{\delta K_t} \cdot \frac{\delta K_t}{\delta P_t} + E_t \left[ d_{t+1} \cdot \frac{\delta J_{t+1}}{\delta K_t} \right] \]

\[ c_t \] (11)

with \( c_t \) being the cost of regulatory friction. It measures the marginal reduction in profit that the insurance company is willing to accept in order to raise the capital level by one dollar (Koijen and Yogo, 2013, p.16). Taking all together we obtain

\[
\frac{\delta J_t}{\delta P_t} = \frac{\delta \Pi_t}{\delta P_t} + c_t \cdot \frac{\delta K_t}{\delta P_t} = 0
\] (12)

which is an expression describing how changes in the price influence aggregate profit \( J_t \).

### 3.4 Optimal Reinsurance through ILS

Given above considerations and using the definition for \( c_t \) we can write the first-order condition for ILS as

\[
\frac{\delta J_t}{\delta ILS_t} = \frac{\delta \Pi_t}{\delta ILS_t} + c_t \cdot \frac{\delta K_t}{\delta ILS_t} = 0
\] (13)
When calculating the respective partial derivatives explicitly we obtain the following equation

$$\frac{\delta J_t}{\delta ILS_t} = V_t - \delta R_t + c_t (\delta R_t + (1 + \rho) V_t) \quad (14)$$

From economic theory we know that an insurance company only purchases ILS in case

$$\frac{\delta J_t}{\delta ILS_t} \geq 0 \quad (15)$$

which implies that the market price for ILS \( R_t \) needs to be below a certain threshold (reservation price \( R_t^r \)), else insurance companies do not purchase reinsurance through ILS

$$R_t^r \leq \left( \frac{1 + c_t (1 + \rho)}{\delta_t (1 + c_t)} \right) V_t \quad (16)$$

Given the above formula for the reservation price for ILS, it is apparent that the willingness to pay for ILS depends not only on its actuarially fair value \( V_t \) but also on several other factors: the tightness of capital requirements, represented by \( \rho \), the cost of regulatory friction, represented by \( c_t \) and finally the subjective financial attractiveness of ILS compared to traditional reinsurance, represented by \( \delta_t \).

It is important to note that if an insurance company already purchased a sufficiently high amount of traditional reinsurance, \( c_t \) and hence willingness to pay for ILS will be low. Therefore, the reservation price for ILS depends indirectly - through \( c_t \) - on the amount of traditional reinsurance in the books and vice-versa.

If the regulator tightens capital requirements (increase in \( \rho \)) the willingness to pay for ILS increases, independently of the amount of traditional reinsurance purchased.

### 3.5 Optimal Traditional Reinsurance

We can write the first-order condition for traditional reinsurance as

$$\frac{\delta J_t}{\delta RE_t} = \frac{\delta \Pi_t}{\delta RE_t} + c_t \cdot \frac{\delta K_t}{\delta RE_t} \geq 0 \quad (17)$$

When calculating the respective partial derivatives explicitly we obtain the following equation

$$\frac{\delta J_t}{\delta RE_t} = V_t - PR_t(\text{RE}) - PR'_t(\text{RE}) \cdot RE_t + c_t \left( -PR_t(\text{RE}) - PR'_t(\text{RE}) \cdot RE_t + (1 + \rho) V_t \right) \geq 0 \quad (18)$$

rearranging yields the expression for the reservation price of traditional reinsurance

$$PR'_t(\text{RE}) \leq \left( \frac{1 + c_t (1 + \rho)}{1 + c_t} \right) V_t - PR'_t(\text{RE}) \cdot RE_t \quad (19)$$

We thus can observe that insurance companies purchase traditional reinsurance as long as the price \( PR \) is smaller or equal than \( PR'_t(\text{RE}) \). As previously stated the price of traditional reinsurance is a function of
the quantity purchased. The first-order derivative of the price with regards to the quantity can therefore be written as

\[
\frac{\delta PR_t(RE)}{\delta Q_t} = \begin{cases} 
\leq 0, & RE_t \leq RE^* \\
> 0, & RE_t > RE^*
\end{cases}
\]  

(20)

implying that marginal cost are first decreasing until quantity \( RE^* \) is reached (see chapter 2.3). From this point on, marginal costs are increasing given that reinsurers face financing constraints making reinsurance contracts more expensive (Froot and O’Connell, 1999, p.199).

Equation 19 makes apparent how the reservation price \( PR^*_t(RE) \) behaves given changes in the various variables. When the cost of regulatory friction \( c_t \) increases, then also the reservation price increases. The same holds for the capital requirements imposed by the regulator \( \rho_t \). However, other than in the ILS case, marginal costs have an influence on the reservation price. Whether the reservation price is positively or negatively affected by marginal costs depends on the quantity of traditional reinsurance purchased. This implies - as discussed in chapter 2.3 - that the reservation price for traditional reinsurance might drop below the reservation price for ILS at some quantity \( RE^* + \epsilon \), with \( \epsilon \) being some non-negative parameter.

\[
PR^*_t(RE) = \begin{cases} 
\geq R^*_t, & RE_t \leq RE^* + \epsilon \\
< R^*_t, & RE_t > RE^* + \epsilon
\end{cases}
\]  

(21)

From the equation 22 below we can observe that \( \text{Delta} \) plays a crucial role for determining the relationship between the two reservation prices and thus the demand for ILS. If \( \text{Delta} \) would be equal to 1, the only factor determining the demand structure of an insurance company for reinsurance would be the marginal cost term \( PR^*_t(RE) \) for traditional reinsurance.

\[
\left( \frac{1 + c_t(1 + \rho)}{1 + c_t} \right) V_t - PR^*_t(RE) \cdot RE_t \geq \frac{1}{\delta_t} \left( \frac{1 + c_t(1 + \rho)}{1 + c_t} \right) V_t
\]  

(22)

Starting from the assumption that the reservation price for traditional reinsurance is higher than the one for ILS (e.g. insurance companies are on average willing to pay more for traditional reinsurance than for ILS), we can observe that this relation may change, when the factor \( \text{Delta} \) decreases. It also becomes clear that for a high \( \text{Delta} \), marginal costs for traditional reinsurance need to be high as well, in order for ILS to be an attractive alternative to traditional reinsurance.

To summarize, by optimizing the profit function with regards to the volume of ILS and traditional reinsurance, while respecting the constraint for reaching a certain level of capital \( K^* \), we have identified the factors influencing the demand for reinsurance. It can conclude that next to the variables determined by the regulator, \( c_t \) and \( \rho \), which are the same for both instruments, the respective prices \( R_t, PR_t \) and the factor \( \text{Delta} \) are crucial for shaping the demand structure of insurance companies for reinsurance instruments. These findings will be the basis for building the estimation framework in chapter 5.
4 Data

In the following we are going to provide an overview of the data used in the paper. As the reader might know, data related to the reinsurance industry is often not publicly available. Moreover, as most reporting on ILS volumes and prices only started a couple of years after the inception of the market, our data set only covers the years 2002 to 2014.

In order to obtain a rich enough data set, several sources had to be used. Unfortunately, these sources do not necessarily rely on the same definitions and measurement techniques. It can thus in general not be expected that the data is fully compatible, which might lead to issues related to comparability and accuracy. We will therefore treat these issues with greatest care. In particular, we will show that the data used in this paper is sufficiently good, in order to obtain meaningful results.

As the data situation merits to be treated with full transparency, we will discuss the source of data for each of the regression variables. In particular, we will focus on the reliability of the source and the accuracy of the data. Whenever possible, we cross-checked data with a second or third source, in order to increase the viability of the information.

In order to give an overview, we first provide descriptive statistics for all relevant variables for the years 2002 to 2014. As only yearly data is available, we have 13 observations per variable. The variables ILS Multiple and RE price per unit of risk ceded are input variables for constructing the variable PriceRatio, which is later on used in the regression model. As we consider it to be important to discuss the price movements of both instruments separately, we also report them individually.

<table>
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<th>Table 1: Descriptive Statistics</th>
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<tr>
<td>ILS/RE Ratio</td>
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<tr>
<td>PriceRatio</td>
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<tr>
<td>ILS Multiple</td>
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<td>RE price per unit of risk ceded</td>
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</table>

We will discuss the descriptive statistics of each of the variables individually and in detail in the following paragraphs. However, it is worth to point out, that the mean of the variable ILS/RE Ratio is well below 1, indicating that over the whole period under investigation the volume of ILS was much smaller than the volume of traditional reinsurance. Additionally, the variable PriceRatio is on average negative, which means that the risk-adjusted objective price for ILS was lower than the risk-adjusted price for traditional reinsurance.

In a second step, we are going to discuss each of the variables, that either appear in the regression model or were used to construct a variable appearing in the regression model in detail.
**ILS/RE Ratio** describes the ratio between the the volume of outstanding ILS and the global property catastrophe reinsurance limit. It thus describes how widely used ILS is compared to traditional reinsurance. Therefore, the larger the ratio the more ILS can be considered 'mainstream'.

Looking at the variable **ILS/RE Ratio**, one can observe that on average over the 13 years, the volume of ILS instruments amounted to around 10 percent of the volume of traditional reinsurance peaking at almost 18 percent in 2014.

![Figure 2: Alternative Capital as percentage of global property catastrophe reinsurance limit](image)

By plotting the time series, it becomes apparent that the percentage of the alternative capacity in the reinsurance market increased quite steadily over the years. The only drop can be observed between end of 2007 and end of 2008 coinciding with the bankruptcy of Lehman Brothers. Given the turmoil on financial markets at that time it is not surprising that ILS took a hit regarding market share and overall volume (Swiss RE, 2009, p.38).

According to Artemis (2015b) the total volume of cat bonds measured in US-dollar fell from $17b in the end of 2007 towards $15.6b in end of 2008 and continued to fall until the end of 2011. However, the years 2012, 2013 and 2014 saw a strong recovery. In the end of 2014 cat bonds had an overall volume of $25b amounting to around 7% of the volume of traditional reinsurance at that time and comparing to around 18% for the entire alternative capital AON Benfield (2014).

The main source of data for the variable **ILS/RE Ratio** was Guy Carpenter (2015a). We cross-checked the obtained data with data extracted from a report by AON Benfield (2014). Even though the numbers do not exactly match for all years, they are close and move in the same direction. We decided to opt for the numbers provided by Guy Carpenter because they were released as raw data, whilst the numbers from AON Benfield had to be manually extracted from a graphic. Additionally, relevant publications

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8For reasons of simplicity we are henceforth using the term reinsurance volume for describing the global property catastrophe reinsurance limit.

9Lehman Brothers was an intermediary for four cat bonds, which fell out after the collapse of Lehman Brothers. At that time many experts feared that this could lead to a break-down of the ILS market, which did however not materialize, but on the contrary the ILS market recovered well AON Capital Markets (2008).

10please find the table including both data series in the Appendix
mostly refer to the numbers provided by Guy Carpenter.

The data from Guy Carpenter describes the ratio between the global catastrophe reinsurance limit to the alternative capacity (ILS) in the catastrophe reinsurance market. According to a phone call with Guy Carpenter, alternative capacity includes cat bonds, ILW, sidecars and collateralized reinsurance. Unfortunately, Guy Carpenter was not able to disclose the share of the different ILS instruments, given the sensitivity of the data.

However, the data by AON Benfield (2014) shows that until 2012 cat bonds were the largest alternative reinsurance instrument, making up more than 50 percent of the whole ILS share in a given year. Since 2012, however, collateralized reinsurance has outgrown cat bonds and become the most important ILS instrument volume-wise. ILW and sidecars are volume-wise much smaller, but grew as well.

The variable \( \text{PriceRatio} \) is the ratio between the variables \( \text{ILS Multiple} \) and \( \text{RE price per unit of risk ceded corrected by } -1 \). In the following regression in chapter 5 it will capture the effect of relative prices on the variable \( \text{ILS/RE Ratio} \). In order to be able to compare prices for ILS and traditional reinsurance, both need to be risk-adjusted such that we can express the price per unit of risk ceded. The theoretical framework developed in chapter 2 suggests that if the risk-adjusted price of ILS decreases in relative terms compared to traditional reinsurance, then insurance companies will purchase more ILS and less traditional reinsurance, leading to a lower price ratio.

When looking at the descriptive statistics it becomes apparent that the ratio was on average negative confirming the previously stated assumption (see chapter 2.2) that in general \( PR > R \).

The variable \( \text{ILS Multiple} \), describing the ratio between the spread on ILS and the expected loss, has been constructed by using data from Artemis (2015e) for the coupon and expected loss, Artemis is a portal specializing on ILS and can thus be considered to be a reliable source. In particular, we divided the average coupon paid on ILS instruments issued in the year at hand by its average expected loss. As coupon payment is adjusted to the risk-free interest rate, we can ensure that only the risky part of the remuneration is considered in the analysis of prices. Dividing through the average expected loss ensures, that the yearly average price for ILS is risk-adjusted and thus comparable over the years. The variable \( \text{ILS Multiple} \) provides thus the average price in ILS markets for ceding one unit of expected loss in a given year.

The average multiple over the whole period in question was around 3.75, meaning that expected loss of 1 percent was rewarded on average by a return of 3.75 percentage-points above the risk-free rate of return. However, one can observe that the standard deviation is rather high compared to the prices for traditional reinsurance, indicating stronger price fluctuations in the market for ILS. However, considering that financial markets were in serious turmoil in recent years, as well as the fact that markets for ILS instruments are still rather new, the volatility is not surprising.

The variable \( \text{RE price} \) reflects the price of traditional reinsurance per unit of risk ceded. As pricing data for traditional reinsurance is extremely difficult to obtain, we had to rely on approximations in order to construct the variable. A crucial ingredient for the approximation of reinsurance prices is the Rate on Line index by Guy Carpenter (2015b). The ROL index reflects indexed yearly price movements in the global property catastrophe reinsurance market for traditional reinsurance. With the ROL index we
thus have information about whether reinsurance prices increased or decreased on average as well as an indication for the magnitude of the price change. What is missing is thus a reasonable starting point, which would allow us to obtain absolute reinsurance prices. We used two different approaches to obtain such a starting value in order to approximate catastrophe reinsurance prices through the ROL index. We discuss both approaches in detail below.

In a first approach we constructed the variable \( \text{RE price} \) based on information obtained from a paper written by (Froot and O’Connell, 1999, p.200). In particular, the two authors provide in their paper catastrophe reinsurance prices in US-dollars per unit of ceded exposure for the US for the years 1990 to 1993. Given this starting point we then applied the Global Property Catastrophe ROL Index to the data in order to obtain reinsurance prices for the years 2002 to 2014. In particular, we exploited the fact that the ROL index reflects price movements in the global property catastrophe reinsurance market for traditional reinsurance relative to the year 1990, for which we have an exact price tag\(^{11}\).

Even though the obtained reinsurance prices seem to be reasonable, results should be interpreted carefully, as prices reported by Froot and O’Connell concern the US, while the price movements reflected in the ROL index consider the global reinsurance property catastrophe market. Nevertheless, we would like to present two arguments why we still consider the obtained data to be sufficient for our purposes. Firstly, the biggest share of ILS instruments concerns the US market Artemis (2015\(^c\)). Therefore, one can make the argument that US reinsurance prices were - at least in the past - the most important benchmark for ILS prices. Secondly, size-wise, the US reinsurance market is the largest single country market in the world, consistently making up for more than 20% of the global reinsurance market Standard & Poor’s (2014). One might, therefore, argue that the global reinsurance price movements reflected in the ROL index are predominantly linked to the US market. For example, after the hurricanes Katrina and Ike in 2005 and 2008 respectively, the ROL index jumped up after periods of decreasing prices Guy Carpenter (2015\(^b\)).

In order to determine the accuracy of our approximations, we made an in-sample comparison of the approximated reinsurance prices for the years 1991 until 1993 and the “true” prices reported by (Froot and O’Connell, 1999, p.200). Table 2 shows that the price approximated with the ROL for the year 1991 fits quite well the price reported by Froot and O’Connell. However, there is a larger approximation error for the price in 1992, which persists into 1993. Interestingly, the ROL index reports for the year 1992 the single largest increase in prices for traditional reinsurance for the whole period under investigation. Apparently, this global increase in reinsurance prices was less pronounced in the US (for which Froot and O’Connell report their prices) than in other parts of the world. Therefore, given that the volatility of the ROL index is much lower for the years after 1993, one might expect that it better approximates the true price fluctuations in the market. In order to account for the discrepancies, we take thus as a starting value in 1993 the average between the price approximated through the ROL index and the price reported by Froot and O’Connell. The obtained price is reported in the 6th column of table 2.

\(^{11}\)We would like to point out that the reported prices by (Froot and O’Connell, 1999, p.200) are approximations as well. The two authors state that the reported reinsurance prices are \([...based on the contract prices and exposures for four insurers that purchased reinsurance through Guy Carpenter in every year from 1975 to 1993. The series are representative of the behavior of prices and quantities for the other insurers in our database.\)
To summarize, approximation errors are inevitable, however as outlined above, one can make the argument that these errors are fairly small and thus acceptable. Hence we reason that the approximated series of prices for traditional global property catastrophe reinsurance based on starting values provided by (Froot and O’Connell, 1999, p.200) and projected by the ROL index Guy Carpenter (2015b) provides reasonable values. However, in order to confirm the obtained prices, we will compare them in a next step to prices obtained with a different approach.

To affirm the above obtained approximations, we exploit the fact that one can assume that on average the loss incurred by reinsurance companies should equal expected losses. By dividing the premium volume by the insured losses we thus get an approximation for the reinsurance price per unit of risk ceded. We took data from Swiss RE (2015b) on yearly insured global catastrophe losses and applied a 9-year moving-average to it. The obtained result is the aggregated average insured loss over a 9-years period. We thus assume that years with high insured losses and low insured losses average out over 9 years.

We then took data on the yearly global reinsurance premium volume provided by Swiss RE (2015d), and applied as well a 9-year moving average, in order to account for the difference in premium volumes over the years. We then divided the moving average for the reinsurance premium by the moving average for the insured loss, to obtain the risk-adjusted price for traditional reinsurance

\[ PR_t = \frac{RE_{t}^{ma}}{IL_{t}^{ma}} \]  

(23)

with,

- \( PR_t \): risk-adjusted price for property catastrophe reinsurance
- \( RE_{t}^{ma} \): 9-year moving average of global reinsurance premium volume
- \( IL_{t}^{ma} \): 9-year moving average of insured loss by reinsurance companies

As a consequence of applying a 9-year moving average we have to drop the last 4 observations. However, as we are mainly interested in obtaining a comparison to the price approximations based on the first approach, this is not an issue, as we still obtain a sufficient amount of data points to conduct a reasonable comparison. If the stated assumptions are correct, then the ratio in equation 23 provides an accurate approximation of the true reinsurance price.
approximation for the risk-adjusted price of a property catastrophe reinsurance contract. Figure 3 compares the prices obtained through the first (blue) and second approach (green).

![Figure 3: Comparison of risk-adjusted prices for traditional reinsurance]

The graph shows that the price series calculated with the moving average approach is smoother, but nevertheless similar to the price calculated with the ROL approach (see also table 5 in the appendix). We can thus conclude that the approximated risk-adjusted property catastrophe reinsurance price based on prices reported by Froot & O’Connell and projected by the ROL index is within a reasonable range.

5 Estimating the Model

The main goal of the paper is to forecast the potential impact of Solvency II on the demand for ILS as risk mitigation instrument by insurance companies. In particular, we are arguing that Solvency II will lead to a better understanding of ILS as an alternative to traditional reinsurance and thus increase the knowledgeableability of insurance companies on how they can use ILS for reinsurance and risk mitigation purposes.

However, it is important to note that according to industry experts and given today’s information regarding Solvency II, it is possible that Solvency II could have adverse effects on the attractiveness of ILS. One thinkable scenario with negative consequences would be, if ILS could only be used for capital relief purposes in the context of a complex internal solvency model, rather than the standard formula Crugnola (2014).\(^{13}\)

Thus, even though we expect Solvency II to have positive ramifications on the demand for ILS, we also have to consider scenarios under which demand for ILS will be negatively affected. In chapter 6.3 we will, therefore, simulate different scenarios for the effects of Solvency II on \(\Delta \text{elta} \).

In order to be able to make predictions about the impact of Solvency II on ILS and reinsurance markets,

\(^{13}\) An expert on Solvency II from the consulting practice of Deloitte Switzerland noted in a discussion that it was very difficult to make any predictions on how the ILS market will be affected by Solvency II. He pointed out that the uncertainty is especially high for less established products.
we will in the following chapter translate the theoretical model (see equation 2) developed in chapter 2.2 into a regression framework, such that we are able to estimate it.

5.1 Derivation of Structural Regression Model

In chapter 3 we found that the demand of insurance companies for ILS and traditional reinsurance depends next to the variables determined by the regulator, $c$ and $\rho$, which are the same for both instruments, on the respective prices $R_t$, $PR_t$ and the factor $\Delta$. Therefore, we conjecture that the ratio between the observed volume of ILS and the volume of traditional reinsurance in the market is a function of $\Delta$ as well as the ratio between the risk-adjusted price for ILS and the risk-adjusted price for traditional reinsurance. Therefore, the number estimated for $\Delta$ will describe the average attractiveness of ILS for insurance companies and thus be a measure of how "mainstream" ILS are.

In particular, we conjecture that the relationship between the factors can be expressed through a linear function in the following way

$$\frac{ILS}{RE} = \beta(PriceRatio_t) + \frac{1}{\delta_t} + \epsilon_t \quad (24)$$

In order to show that our conjecture is reasonable, we will look into the expected dynamics of the proposed model given changes in $PriceRatio_t$ and $\Delta$. It is important to point out that compared to the theoretical model, we $\Delta$ enters the structural regression model as a ratio. We will explain in detail in the next paragraphs why this is the case.

As previously stated, $PriceRatio_t$ is defined as the impact of the ratio between the price for ILS per unit of risk ceded in the nominator and the price of traditional reinsurance per unit of risk ceded in the denominator corrected by minus 1.\(^{14}\)

Under the assumption of a well-behaved demand function, one can expect that if the $PriceRatio$ decreases (e.g. ILS becomes cheaper relative to traditional reinsurance), the $\frac{ILS}{RE}$, the relative volume of ILS compared to traditional reinsurance, increases. The opposite applies if $PriceRatio$ increases. Therefore, in order to achieve the desired relationship between the variables $PriceRatio$ and $\frac{ILS}{RE}$ the factor $\beta$ needs to be negative.

$$\Delta\frac{ILS}{RE} > 0 \quad \text{if} \quad \Delta PriceRatio < 0 \quad \text{and} \quad \Delta \Delta = 0, \quad \text{with} \quad \beta < 0 \quad (25)$$

In case, the price of the two instruments is exactly the same, $PriceRatio$ will have a value of zero and the dependent variable $\frac{ILS}{RE}$ will only be determined by $\Delta$. This makes intuitively sense, as the difference in prices should not influence the decision-making process when it is non-existent. Now, it also becomes apparent, why we corrected the actual price ratio by minus 1.

In the following we are going to develop a similar intuition for how the dynamics of $\Delta$ influence the dependent variable. If both instruments are perfect substitutes and have the same price, then

\(^{14}\)As the relative price is reflected through a ratio, a change of price will not enter in absolute terms, but in relative terms. This means that a price increase for ILS from 100 to 101 does not have the same impact as an increase from 3 to 4.
PriceRatio = 0 and Delta = 1 by definition. This implies that ILS/RERatio = 1, meaning that both instruments will have an equal volume.

Let’s assume now that insurance companies prefer ILS instruments over traditional reinsurance given their higher liquidity Cummins and Trainar (2009). In our theoretical model this would imply that Delta < 1, as the perceived relative price of ILS would be lower than the perceived relative price of traditional reinsurance. In such a situation ILS has a larger volume than traditional reinsurance, implying that the ILS/RERatio > 1.

This explains why we included \( \frac{1}{\Delta \text{Delta}} \) and not Delta in the regression model. In this way we can ensure that when Delta increases (\( \Delta \Delta \text{Delta} > 0 \)), implying that the average insurance company perceives ILS subjectively as being more expensive than in the previous period, the volume of ILS decreases relative to the volume traditional reinsurance such that the following holds

\[
\Delta \text{ILS/RERatio} < 0 \text{ if } \Delta \text{PriceRatio} = 0 \text{ and } \Delta \text{Delta} > 0
\] (26)

In consequence, the expected dynamics in the regression model are aligned with the dynamics of the theoretical model developed in chapter 2. The above discussion showed that the conjecture made in equation 24 is reasonable and corresponds to the logic applied in the theoretical model. We will now discuss in more detail the structural regression model.

5.2 Structural Regression Model

The main goal of the regression exercise is to estimate a yearly value for Delta, which is our variable of interest. As previously stated, Delta reflects in some broad sense the attractiveness of ILS compared to traditional reinsurance.

Apart from the variable PriceRatio, the regression model does not include any other control variables, because other factors correlated with ILS/RE Ratio are already captured by either Delta or PriceRatio. However, relevant literature on ILS often suggests a connection between returns on similarly rated corporate bonds and cat bonds. An increase of the return on corporate bonds could indeed c.p. lead to a drop in investor appetite for ILS, leading to a lower volume of ILS in the market and thus a reduction in the volume of ILS. However, if we assume markets to be efficient an increase in the return on corporate bonds should immediately be reflected through an increase in the price for ILS and in consequence increase the variable PriceRatio, which c.p. leads to a decrease in ILS/RE Ratio and thus a lower volume for ILS compared to traditional reinsurance. When including the return on corporate bonds as a variable in the model, one would therefore run into the risk of multicollinearity.\(^{15}\) As we want Delta to reflect all variation in ILS/RE Ratio not explained by PriceRatio, we do not include an intercept in the regression model.

Next, we will take a closer look at Delta. In this setting Delta captures all the change in ILS/RE Ratio, the ratio between the property catastrophe ILS volume and the global property catastrophe reinsurance limit, not explained by the change in PriceRatio. We define the case where Solvency II has a positive

\(^{15}\)Literature also suggests that after a catastrophe intense year a hard reinsurance market follows, potentially influencing ILS/RE Ratio. Again, this would be fully explained through the variation in PriceRatio.
impact on Delta as a decrease in Delta, while a negative impact corresponds to an increase in Delta. One might think of Delta as the perceived complexity, novelty and uncertainty of ILS from the point of view of the insurance company. Therefore, the factor Delta pools several sub-forces influencing the attractiveness of ILS. Alternatively, Delta can also be understood as the relative added benefit an insurance company gets by spending one dollar on ILS compared to spending one dollar on traditional reinsurance. If Delta is equal to 1, then the insurance company perceives ILS and traditional reinsurance as perfect substitutes only differentiated through their respective prices per unit of risk. For Delta < 1 ILS offers more benefits for the same price than traditional reinsurance, for Delta > 1 the opposite applies. As Delta < 0 does not make sense economically and as Delta = 0 is mathematically not possible, Delta is defined on the set of positive real numbers excluding zero.

A decrease in Delta, thus a positive impact of Solvency II on Delta, implies a more positive perception of ILS as a reinsurance instrument. In other words, if Delta decreases, the average insurance company is willing to acquire more reinsurance through ILS for a given price. The causes for such a change in perception can be manifold. They can arise internally, for instance through learning, or externally, for example through regulatory improvements.

The estimated Delta reflects the average perception of insurance companies. This suits our purpose of forecasting market behavior after the introduction of Solvency II. We are not interested in how the individual insurance company will react, but how the behavior of the average insurance company will be affected by the regulatory changes.

However, it is reasonable to assume that in reality individual insurance companies may have distinct Deltas. This may explain, why some companies already early on started to use ILS for reinsurance purposes, while others still do not make use of it at all.

In order to be able to make predictions about how Delta will be affected by Solvency II, we first need to establish a benchmark. We will thus start by estimating how the perception of ILS (reflected in Delta) evolved in the past.

5.3 Estimation of Beta

We are going to estimate our model by pooled OLS. In order for the pooled OLS to be a useful estimator, we need some additional assumptions on top of the common OLS assumptions Wooldridge (2010),p.192. In particular, we need the variance of the error terms to be homoskedastic. We will later show that this is indeed the case.

When applying the pooled OLS estimation, the estimated Beta-coefficient represents the average effect of the relative prices on the ratio between ILS volume and the volume of traditional reinsurance. By using pooled OLS, we thus implicitly assume that this effect - and thus Beta - is constant over time. Even though this is a strong assumption, we can produce sufficient evidence to support it. To show this, we will consider cases under which the assumption might be violated and then test whether these cases can be dismissed with a high-enough certainty.

Firstly, if one assumes that insurance companies decide within the framework of profit-maximization, then one can expect the average willingness to pay to be constant over time. The reason is that holding
all other factors constant the optimal level of reinsurance for a given price remains the same, else profit-
maximization would be violated. If a company is maximizing profit today given price and quality of the
different reinsurance instruments, then the relationship between price and quality should remain the same
tomorrow. Thus, in a framework, where profit-maximization is primordial, the effect of relative prices
should remain constant over time, as else profit would not be maximized. Only a shock to the system
could lead to a shift of the demand curve for reinsurance and thus to a shift in the average willingness to
pay. Such a shock could for example happen, when a new regulatory framework is introduced.
However, one might argue that companies do not decide under the sole objective of profit maximization,
rather decisions are made by top management, which might have other decision motives. Therefore the
final decision whether and to what extend an insurance company engages in ILS for reinsurance purposes
is taken by people, who can change their attitudes and motives over time.

A non-constant price effect would imply that from year to year the average insurance top management
changes its stance towards how important the relative price is in their decision making process. Such
a change can only happen, if a significant part of top managements in the whole insurance industry
changes its attitude. Even though one can make the argument that top managers might not always decide
rationally, it is nevertheless improbable that they completely change their mind on regular basis\(^\text{16}\).
In our opinion, strong competitive pressures in the insurance market, penalizing non-economical behavior,
as well as the high importance of optimizing financial resources in the insurance industry are sufficient
to ensure that the average top management takes decisions based on market principals. Therefore, it is
safe to assume that the effect of relative prices on the decision making process in the whole insurance
industry is constant over time.

5.4 Estimation of Delta

While we argue that the effect of relative prices represented by the Beta-coefficient remains constant
over time, our model builds upon the idea that Delta, the factor capturing all other influences on the
decision-making process apart from relative prices, can change from year to year. It is quite intuitive,
why this should be the case. Firstly, Delta by definition reflects broadly speaking the experience and
aptitude of the average insurance company with alternative reinsurance and is thus an indicator for their
knowledgeability. In short, Delta summarizes how costly it is for an insurance company to use ILS for
capital relief purposes compared to using traditional reinsurance given the regulatory and internal frame-
work.

Therefore, it can for instance be argued that regulatory uncertainty implies a a higher Delta, as it im-
poses additional costs (for example through increased legal work) on insurance companies, when using
ILS instruments for reinsurance purposes.

However, experience and knowledgeability are generally not static and may change over time. Insurance
companies can obtain additional information, go through a learning process and acquire knowhow,
\(^\text{16}\)However, one can think of situations, where the top management of a single insurance company changes its attitude
towards the importance of price in the decision making process. For example, the top management of an insurance
company in financial distress might be forced by the regulator to purchase a certain amount of reinsurance, even though
it might prefer not to. In such a situation, top management might overweight the importance of the relative price, as it
is constraint to spent as little as possible.
potentially reducing the perceived relative costs of alternative reinsurance over time. In consequence, insurance companies might change their attitude towards ILS from one period to another. If many insurance companies change their attitude towards ILS, a likely scenario when for example a new regulatory framework is introduced, this may lead to a non-marginal change in the average $\Delta$. For modeling these dynamics it is thus important that we allow $\Delta$ to change from period to period.

In the case of Solvency II we will argue that the regulatory change and the accompanying in-depth treatment of ILS in industry-relevant journals, on conferences, by consultancies, think-thanks and other stakeholders, will lead to an accumulation of information and trigger a learning process within the whole insurance industry.

We will apply a two-step procedure in order to obtain an estimate for $\Delta$. It is important to note that our choice of the identification strategy was partly driven by the data situation. However, we will show that the chosen approach is valid and produces reasonable results.

In a first step, we estimate the time constant effect - represented by the $\beta$-coefficient - of the relative price on the ratio between the volume of ILS and traditional reinsurance by pooled OLS. In this regression, we include an intercept, which will by definition reflect the inverse of the average $\Delta$ over the whole period under investigation. We obtain the following results:

<table>
<thead>
<tr>
<th></th>
<th>ILS/RE Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>PriceRatio</td>
<td>-0.138*</td>
</tr>
<tr>
<td></td>
<td>(-1.86)</td>
</tr>
<tr>
<td>1/\Delta</td>
<td>0.0843***</td>
</tr>
<tr>
<td></td>
<td>(6.29)</td>
</tr>
<tr>
<td>$N$</td>
<td>13</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.238</td>
</tr>
</tbody>
</table>

White-Test: Chi-sq(2): 0.019, p-value: 0.99
$t$ statistics in parentheses

As expected, the factor $\beta$ on PriceRatio is negative and statistically significant at a 10% level, implying that an increase in PriceRatio decreases ILS/RE Ratio and thus the relative volume of ILS compared to traditional reinsurance.

The White-Test confirms that the variance of error terms is homoskedastic. The inverse of $\Delta$ is smaller than 1, which in turn implies that $\Delta$ is significantly larger than 1, namely 11.86. The high value of $\Delta$ is, however, not surprising, given the fact that over the whole period of 13 years most of the time the volume of ILS compared to traditional reinsurance was relatively small, even though prices per unit of risk were similar.

As stated above, we are not interested in the average $\Delta$ over the whole period, but in the yearly $\Delta$. As expected, the factor $\beta$ on PriceRatio is negative and statistically significant at a 10% level, implying that an increase in PriceRatio decreases ILS/RE Ratio and thus the relative volume of ILS compared to traditional reinsurance.
One way allow for these heterogeneous effects is to include time dummies into the regression model capturing the yearly effects. Unfortunately, we do not possess enough data points in order to meaningfully implement this estimation technique.

We are therefore obliged to apply a more unorthodox approach in order to obtain an estimate for the yearly $\Delta_t$. In particular, we exploit the fact that by definition in equation 24 all variation in the dependent variable not explained by the relative price is captured by $\Delta_t$. Therefore, we can argue that the inverse of the yearly $\Delta_t$ can be constructed by taking for each year $t$ the difference between the observed $ILS/RE\ Ratio$ and $PriceRatio$ multiplied by the estimated $Beta$-coefficient.

$$\frac{1}{\Delta_t} = ILS/RE\ Ratio_t - \beta(PriceRatio_t)$$ (27)

We thus obtain an estimate for our yearly $\Delta$. By plotting the obtained results (see figure 4), we can indeed observe that $\Delta$ behaves as suggested by our model in chapter 2.

![Figure 4: Yearly Delta](image-url)

$\Delta$ inhibits a decreasing trend, which can be explained through companies acquiring knowledge and experience on ILS over the years, thus decreasing their costs of using ILS instruments.

Noteworthy is the strong peak around 2004, which coincides with a drop in new issuances for cat bonds Artemis (2015b), the most important ILS instrument at that time. This sharp increase in $\Delta$ paired with the drop in new issuances could be the consequence of research findings contradicting and correcting earlier assumptions about ILS published around that time. For instance, Cummins et al. (2004) found that yields on ILS did not converge to the risk-free rate, which had been suggested by early research based on the zero beta assumption of ILS under CAPM (Cummins and Weiss, 2009, p.499). These findings supplemented earlier research that questioned the mainstream theory on ILS at that time. For example, Bantwal and Kunreuther (2000) found that investors were less willing to invest into this asset class than initially expected. It is, therefore, likely that such research findings led to an increased skepticism among insurers regarding ILS and thus a higher $\Delta$. 

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The catastrophe year 2004 was exceptionally severe Swiss RE (2005), with many high-impact, low probability events, as for example the tsunami in the Indian Ocean, which led to record losses of USD 123bn. This might explain, why in 2005 ILS again became interesting for the insurance industry and worth the resources needed for acquiring the necessary knowledge, leading to a sharp drop in $\Delta$ in 2005. Interestingly, Guy Carpenter (2008) reports that between 2005 and 2007 first-time sponsors were responsible for a substantial part of the increased issuance activity, underlying the increased attractiveness of ILS at that time.

The first wipe out of a cat bond after Hurricane Katrina marked another important cornerstone. According to (Cummins and Weiss, 2009, p.524) the wipe out of KAMP RE had rather positive implications as, "the smooth settlement of the bond established an important precedent in the market, showing that cat bonds function as designed, with minimal confusion and controversy between the sponsor and investor."

It is, therefore, not surprising that $\Delta$ decreased during this time, as insurance companies received positive feedback regarding the functioning of ILS.

It is also worth to point out that the default of Lehman Brothers and the following financial crisis only led to a slight upward movement in $\Delta$, even though Lehman Brothers acted as swap counterparty to some of the outstanding cat bonds (Cummins and Weiss, 2009, p.524). One could even say that ILS emerged stronger from this setback, as the industry was able to quickly address the issues which surfaced after the default of Lehman Brothers AON Capital Markets (2008). Again, the evolution of ILS, especially in terms of standardization and transparency, can explain why $\Delta$ decreased further in the following years and halved between 2008 and end of 2014. The small peak around 2013 can, to our knowledge, not be attributed to any particular event and might thus just be the result of uncertainty in the estimation of $\Delta$.

In conclusion, the up and down movements of $\Delta$ can in most cases be traced back to actual events affecting the re/insurance industry, legitimating the estimated values for $\Delta$. The "mainstreaming" of ILS in recent years can be attributed to the ability of the ILS market to reform itself after setbacks, which indeed led ILS to become more accepted and understood among insurance companies. It is, therefore, well possible that Solvency II will have a similar or even stronger impact on the ILS industry and thus $\Delta$.

As we now have an idea about how $\Delta$ evolved since 2002, we will proceed in the next chapter with forecasting its future development. This will enable us to form expectations about the future relative share of ILS compared to traditional reinsurance and in turn help us answering our research question.

6 Forecasting the Model

Given that we now possess an estimate for the yearly $\Delta$ we can rely on well-known time-series techniques for forecasting its future path. In order to do so, we are going to fit an ARMA-model on the series of $\Delta$. We will broadly follow the procedure suggested by (Shumway and Stoffer, 2010, pp.142).
6.1 Estimating ARMA-representation of the Model

The plot of the Delta-series (see figure 4) suggests a negative trend and thus non-stationarity. Additionally, a cyclical component might be present given the up and down movements.

To tackle non-stationarity, we need to transform the series. We accomplish this by two different approaches, as the literature does not suggest a single best solution to the issue of stationarity: our first approach is to log-transform the series and then taking first differences (see figure 5) as suggested for example in (Shumway and Stoffer, 2010, p.143). This leads us to the following equation:

$$\nabla \log(Delta_t) = \log(Delta_t) - \log(Delta_{t-1})$$

Figure 5 shows the result of the transformation, which is nothing else than the Delta growth rate from year-end to year-end. Looking at the characteristics of the plot, we find that there is no obvious trend pattern anymore, as the series is oscillating around a mean. Hence, the transformed series is stationary.

The downside of taking first differences is, that we lose one observation. However, given its simplicity, taking first-differences of the log-transformed series has its legitimization and can be used as benchmark. Therefore, we will propose a second approach - the Hodrick-Prescott-Filter - which decomposes the series into a trend and cyclical component Mathworks (2015b) and thus does not present the constraint of losing an observation. The use of the HP-Filter can be justified by the fact that it is often applied in the context of Business Cycle Analysis Hodrick and Prescott (1997). It is well-known that reinsurance markets as well are subject to cycles of hard and soft markets, which fits well with the characteristics of the HP-Filter.

We apply the HP-Filter to the log-transformed Delta-series given a smoothing parameter $\lambda$. As Delta is a yearly series we set the smoothing parameter $\lambda$ equal to 100 as commonly applied in time-series econometrics Mathworks (2015b).

Once the transformed Delta-series is stationary, which can either be seen by the plot of the differenced log series (see figure 5) or the plot of the cyclical component of the HP-Filter(see figure 6), we can proceed in fitting the optimal ARMA(p,q) model to it. In order to obtain the best ARMA(p,q) representation
for the Delta-series under both transformations, we employ the Bayesian Information Criterion (BIC) Mathworks (2015c). Another indicator for optimal values for p and q are the ACF and PACF plots, which can be found in Appendix ???. However, they remain inconclusive, which could be related to the fact that we only have few data points. Therefore, in order to prevent over-fitting, we truncate the possible values for p and q at 3 when using the BIC criterion.

For the model based on first differences, we find that the ARMA(3,2) offers the best approximation given the BIC. For the model based on the HP-Filter we find that ARMA(3,3) fits best our purpose of approximating the Delta-series.

It is important to note that we include a constant in our ARMA-representation of the Delta-series. The reason for doing so, is that if we would not include a constant, we would assume that the average yearly growth rate of Delta is equal to zero, whereas there clearly exists a negative trend (and thus a non-zero, negative growth rate) in our model in the period under investigation (see figure 4).

In a next step we estimate both proposed ARMA-models for the Delta-series and analyze the residuals of the estimated models. (Shumway and Stoffer, 2010, p.148) suggest that a model fits well, when the residuals are independent and approximately normally distributed. We will thus present diagnostics of the residuals as well as the model fit. The corresponding figures can be found in the Appendix in section B.

For both models we plot the autocorrelation function of the residuals (see figure ?? and figure ???) and find that while the ACF of the residuals of the ARMA model based on the HP-Filter does not exhibit any statistically significant correlation under robust standard errors, the ACF of the residuals of the ARMA model based on first differences has a spike at lag 4. We also perform a Ljung-Box test to consider the magnitude of the sample autocorrelation of residuals as a group. For both models we cannot reject the null hypothesis no autocorrelation, which confirms the findings from the ACF plots.

The QQ-plot of residuals (see figures ?? and ?? in appendix B) for both models indicates that the residuals are almost normally distributed with the exception of some extreme values. In conclusion, the analysis of the residuals supports both model assumptions.
6.2 Forecasting Delta

In a next step, we forecast values for Delta two periods into the future. As we have so far employed two different transformations for modeling the ARMA(p,q) model, we will also make use of both for forecasting Delta.

In a first step, we will forecast the expected Delta value at year-end 2015 based on the two ARMA models. We will then use the forecast for 2015 to estimate the ARMA model again and forecast the expected Delta value at year-end 2016. The reason for doing so is, that we are only interested in the forecast for 2016, because this is when we expect the effects of Solvency II to have kicked in. By treating the forecast for 2015 as if it would be a given value, we underline this aim. However, it is important to note that the forecast value for 2016 will represent the expected Delta value in the absence of Solvency II and therefore only serve as starting point for the sensitivity analysis.

The forecast resulting from the ARMA(3,2) model based on first differences of the log transformed series yields the expected growth rate of Delta for 2016, from which we can easily obtain the Delta forecast for 2016. The model forecasts that in the absence of Solvency II the downward course of Delta will continue and reach a value of 6.52 in 2016 down from 7.05 in 2014. Our model predicts that given the decrease in Delta and assuming no changes in relative prices the ILS/RE Ratio will increase to 19.2 percent up from 17.95 in 2014.

For forecasting the ARMA(3,3) model based on the HP-Filter, we forecast the cyclical and the trend component separately. The forecast of the cyclical component relies on the ARMA(3,3) representation, while we assume for the trend component that it will pursue the same linear trajectory as in the previous periods.

In the past, the trend component decreased on average between 2002 and 2015 each year by -0.094 points. We could describe this as the natural learning process of insurance companies and the steady amelioration of industry standards, for instance the improvement of transparency standards. Every year more research on ILS is conducted and more experience gained, which leads to a natural decrease in Delta. On the other hand, the cyclical component can be understood as particular events temporarily influencing the attractiveness of ILS instruments for reinsurance purposes, as for example the default of Lehman Brothers as swap counterparty. In conclusion, the trend component captures the steady industry advancement and learning effect, while the cyclical component incorporates positive or negative effects of specific events.

In a next step we back-transformed the forecasts for the cyclical and trend component into a non-logarithmic representation in order to obtain the one-step ahead forecast of Delta, representing the expected Delta value for the year 2015. Based on the forecast for 2015, we reestimated the ARMA(3,3) model and forecast the Delta value for 2016. In particular, we find that the downward course of Delta is slightly more pronounced as compared to the forecast based on first differences, leading to an expected value of 5.49 for Delta in 2016. Ceteris paribus this would represent an increase of the ILS/RE Ratio by around 4 percentage points to 22 percent compared to 2014.

The forecast of a continued decrease in Delta seems to be reasonable given recent observations in the ILS market, which saw a record ILS issuance of $2.1 billion in the first quarter of 2015 Artemis (2015g) even

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17 We employed an algorithm, where we used the first 8 observations for forecasting the future value of Delta, while keeping the remaining observations in order to be able to compare the in-sample forecasts with the true values.
though prices for ILS rebounded Artemis (2015a) and prices for traditional reinsurance further decreased Artemis (2014).

Given that both approaches led to reasonable and similar results, we will now focus solely on the ARMA(3,3) model based on the HP-Filter. The reasons for doing so are twofold: firstly, we can exploit one more observation, which we consider to be crucial given that we only have few data points available. Secondly, given the decomposition of the Delta series into a cyclical and trend component, we have two parameters which we can adjust in the sensitivity analysis, compared to only one parameter for the ARMA(3,2) model based on first differences.

6.3 Sensitivity Analysis for Delta

The main assumption of the paper is that Solvency II will have an impact on Delta, a variable adjusting the subjective price for ILS relative to the price of traditional reinsurance according to the prevailing market sentiment regarding ILS. However, the magnitude of the impact and the final consequences for the ILS/reinsurance market remained indeterminate so far. We will, therefore, present different scenarios and conduct a sensitivity analysis to obtain a range for the magnitude of the impact. Therefore, the sensitivity analysis will provide us with an idea, by how much Delta will change under different scenarios.

In particular, the sensitivity analysis will allow us to model positive or negative consequences of Solvency II on Delta. As previously defined, a positive impact on Delta is defined by Solvency II simplifying the use of ILS instruments for reinsurance purposes and thus decreasing Delta, for example by making it easier to account for ILS instruments. A negative impact would render the use of ILS instruments for reinsurance purposes more difficult, thus increasing Delta, for example by requiring a complex internal solvency model Crugnola (2014).

The starting point for the sensitivity analysis will be the 2016 forecast for Delta, which represents the conditional expected value of Delta under the status quo assumption that Solvency II does not have any tangible impact on Delta.

As stated in chapter 6.2, we have two parameters - the cyclical and the trend component - which we can modify within the framework of the sensitivity analysis. We propose the following idea: as Solvency II will bring a major transformation to the re/insurance industry particularly in the European Union and change the rules for a considerable number of players in the market it will act as a shock, disrupting the current pattern of Delta. However, as we understand the introduction of Solvency II as a regime change rather than a temporary disruption, we will model its expected long-term effect through a shock on the trend. Nevertheless, we will in the following sensitivity analysis also allow the cyclical component to depart from its expected value in order to present a broader picture and allow for overreactions of the markets.

In particular, the impact of Solvency II will pronounce itself through a structural break in the trend pattern, shifting the currently existing trend up (negative impact) or down (positive impact). We assume, that it is a one time shock and that after the shift, the slope of the trend will pursue its initial trajectory at least in the short term (see figure 7).

For conducting the sensitivity analysis we need to make some assumptions on the size and direction of
the change in parameters. As there are no similar precedents to Solvency II in the history of ILS, which could help to quantify the potential impact of such a regulatory change, we have to base the inference solely on information from industry experts and the regulator itself.

Given current information the chances that Solvency II will have negative regulatory percussions for ILS are rather low. In particular, industry experts are confident that ILS with indemnity trigger will be fully accountable under the Solvency II standard formula Crugnola (2014). This view is supported by the 5th Quantitative Impact Study (QIS5) made by CEIOPS (2010), which states under SCR 12.14 that financial mitigation instruments, which do not present basis risk or for which it can be shown that the basis risk is not material, may be used under the standard formula.

Combined with recent developments in the ILS market, which saw a strong increase of ILS instruments with indemnity triggers, which until July 2014 made up 70% of newly issued property cat bonds AON Benfield (2014), this makes a strong case for assuming a non-negative impact of Solvency II on the ILS market.

Nevertheless, according to Artemis (2015d) still 40% of outstanding ILS are not based on an indemnity trigger only, but other kinds of triggers or combination of triggers. For instance, cat bonds making up for more than 20% of the outstanding cat bond volume have an industry loss trigger Artemis (2015d). Also, when looking at the cat bonds released in the first quarter of 2015 3 out of 8 did not have an indemnity trigger AON Benfield (2015a).

Hence, there exists arguably a market for non-indemnity trigger ILS instruments. Given current information on Solvency II, these instruments have a chance to be negatively affected or at least not favored by the introduction of Solvency II. Taking all these factors into account and matching them with information from people active in the industry, we assume that there is a 10% chance that Solvency II will have a
negative impact on \( \Delta \). We will build the sensitivity analysis on the above reasoning.

For defining the respective values for the trend component, we revert to its previously stated definition, which defines the trend as the steady, yearly industry advancement and learning effect, amounting on average to around \(-0.094\) points. Therefore, we can use this number as a scale for defining the different impact magnitudes by saying that a shift of the trend by \(3 \times -0.094\) represents a triplication of the learning effect in the given year.

Given the above argumentation regarding the potential impact of Solvency II we assume that its introduction could in the best case have the same effect on \( \Delta \) as 5 years of learning under normal circumstances\(^{18}\), while at worst it could move \( \Delta \) back to where it has been in 2013, thus undoing the (forecast) progress achieved between 2013 and 2016.

For each trend-scenario in the sensitivity analysis we consider 5 sub-scenarios depending on the value of the cyclical component. In particular, we consider next to the estimated value for the cyclical component values lying at 50% and 100% on both sides of the estimated value. With this rather conservative approach we account for potential inaccuracies in the forecast of the cyclical component as well as over-reactions of the markets in the light of Solvency II.

The sensitivity analysis provides a range of possible values for \( \Delta \) between 3.17 and 7.88 points, which would ceteris paribus result in an \( \text{ILS/RE ratio} \) of 16.5% and 35.4% respectively. Under the status quo (Solvency II has no impact) our model predicts a value of 5.49 for \( \Delta \) corresponding to an \( \text{ILS/RE ratio} \) of 22.1%. In a next step, we will attach probabilities to the different scenarios in order to be able to make a quantitative statement about the effect of Solvency II on \( \Delta \).

### 6.4 Probability distribution for Delta and ILS/RE Ratio

Given the different scenarios obtained from the sensitivity analysis and the resulting values for possible \( \Delta \)s, we will now fit a probability distribution to the scenarios, based on the assumption of their likelihood derived in the previous subchapter. The probability distribution for \( \Delta \) will then be translated into a distribution for the ILS/RE ratio allowing us to make statements about the future relative volume of ILS compared to traditional reinsurance.

As stated before, we expect it to be rather unlikely that the introduction of Solvency II will have a negative effect on \( \Delta \). In case a negative effect materializes, it would be limited in magnitude. Hence, we regard it as highly improbable that Solvency II will wipe out the market for ILS completely. Rather, we expect Solvency II to have a moderate positive impact on \( \Delta \). Furthermore, we assume that events, which would lead to a decrease of \( \Delta \) by more than 25% of the expected status quo value - thus below 4.12 - are as well rather improbable and happen only in 10% of the cases. Nevertheless, there remains a small possibility that Solvency II will have a large scale positive impact on \( \Delta \) and thus the ILS market. All in all, we need a probability distribution for the possible values of \( \Delta \), which is negatively skewed, with a mean well below the status quo value for \( \Delta \) of 5.49 and with 10% of the cases being above the status quo value and 10% of the cases being below a \( \Delta \) of 4.12. We find that the Gumbel distribution, even though usually used in extreme value theory, does fulfill all these requirements Mathworks (2015a).

\(^{18}\)This corresponds to a shift in the trend of minus \(5 \times -0.094\) points.
We thus fit a Gumbel distribution to the data generated by the sensitivity analysis and adjust its location parameters \( \mu \) and \( \sigma \) such that the fitted distribution satisfies the above stated requirements. We find that a Gumbel with \( \mu = 5.17 \) and \( \sigma = 0.47 \) matches the desired shape quite well (see figure 8). Given these location parameters we find that the resulting distribution for \( \Delta \) has a mean of approximately 4.9, compared to an expected value of 5.49 for \( \Delta \) under the status quo. The obtained distribution for \( \Delta \) allows us to attach a probability to the different possible values for the \( ILS/RE \) ratio obtained through the sensitivity analysis. The mean-value for \( \Delta \) of 4.9 translates into a mean-value of 24.3% for the \( ILS/RE \) Ratio (see figure 9), compared to the status-quo value of approximately 22.1%. Therefore, the relative volume of ILS compared to traditional reinsurance will grow by an additional 10% due to Solvency II\(^{19}\). If we want to translate the relative figures of the \( ILS/RE \) ratio into absolute figures, we have to consider that the absolute volume of ILS depends on the development of absolute volume of traditional reinsurance. It is, therefore, quite difficult to provide an exact forecast for the total volume of ILS by the end of 2016. However, we can make some approximations by considering today’s numbers for the variable \( PriceRatio \)\(^{20}\) and for the volume of traditional reinsurance. Given these numbers, the expected \( ILS/RE \) ratio of 24.3% in the year 2016 would correspond to an ILS volume of around $80.9 billion\(^{21}\), which is approximately $7 billion higher than the status quo scenario and corresponds to an increase of approximately $20 billion compared to the end of 2014. Even though these numbers seem impressive on first sight, they reflect the fact that ILS grew since 2002 on average by around $5 billion each year\(^{22}\).

\(^{19}\)The following calculation applies: \( \frac{24.3}{22.1} = 1.1 \)

\(^{20}\)Given recent comments of re/insurance experts (see for example Artemis (2014) or Artemis (2015a)) on the pricing of traditional reinsurance as well as ILS it seems as if pricing for both instruments has reached a floor and could stay there for some time. Therefore, the assumption that relative prices between ILS and traditional reinsurance could remain stable in the coming years does not seem to be far fetched.

\(^{21}\)The following calculation applies: $Global Property Catastrophe Reinsurance Limit 2014*ILS/RE Ratio 2016= $333bn*0.2427=$80.9 billion. The Global Property Catastrophe Reinsurance Limit has been approximated by numbers provided by Guy Carpenter (2015c).

\(^{22}\)Own calculation based on numbers provided by AON Benfield (2014) and Guy Carpenter (2015a).
Figure 8: Probability Density Function and Cumulative Distribution Function for Delta
As previously stated, we fitted the Gumbel distribution such that only 10 percent of events are above the status quo scenario for $\Delta$ and only 10 percent below status quo+25%. This translates into 80 percent of the cases being located between an ILS/RE ratio of 22.1% and 28.1%, which would amount to a range of absolute ILS volume between $73.5 and $93.8 billion at the end of 2016 given today’s figures for the total volume of traditional reinsurance.

Our model forecasts a moderate impact of Solvency II on the ILS market on average and thus a moderate increase of ILS relative to traditional reinsurance. However, it is worth remembering that only part of the increase can be attributed to Solvency II, as the industry advancement and learning effect would by itself contribute each year -0.094 points to the trend component. For the mean, the additional effect on $\Delta$ coming from Solvency II under the assumption of a cyclical effect of -0.079 amounts to approximately -0.115 points, which implies that Solvency II will lead on average increase the industry advancement and learning effect by factor 2.2 in the year 2016. In the extreme case of an ILS/RE Ratio of 28.1% the industry advancement and learning effect would be factored by approximately 4 in 2016.

When considering cases where Solvency II would have a negative impact on the ILS market (e.g. push...

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\[ \text{Following calculation applies: Trend(\text{Status Quo Delta})-Trend(\text{Mean Delta}) = 1.78-(log(4.89)-(-0.079))= -0.115} \]

\[ \text{Following calculation applies: } (-0.115)-(-0.094))/-0.094=2.2 \]
Delta above its forecast status quo value of 5.49), our model suggests that events leading to a Delta above 5.95 points are highly improbable with a cumulative probability of less than 1 percent. Therefore, a contraction of the ILS market relative to the market for traditional reinsurance, which would require a Delta > 6.37 holding all other factors constant, is almost impossible. However, this is less of a surprise, when taking into account that the ILS industry is constantly making progress adapting the instruments further and making them more cedent and investor friendly, which is exemplified for example by the introduction of annual variable resets Munich RE (2014a) and improved disclosure standards Munich RE (2015).

![Figure 10](image)

**Figure 10: Forecast: alternative capital as percentage of global property catastrophe reinsurance limit**

Guy Carpenter (2015a)

For illustrative purposes in figure 10 four different scenarios are pictured. The status quo scenario describes the development of ILS markets if Solvency II would not have no impact on ILS markets, the optimistic scenario describes what would happen if Solvency II would have a strong positive impact (90% of cumulative probability below this scenario), while the pessimistic scenario describes a negative impact (10% percent of cumulative probability below this scenario). The mean scenario depicts the average expected development of ILS markets volumes relative to traditional reinsurance under Solvency II.

To summarize, Solvency II is expected to affect the ILS market positively and moderately by boosting the industry advancement and learning effect on average by a factor of 2.2, decreasing Delta to 4.9 and increasing the ILS/RE ratio to 24.3 percent. When quantifying the average expected effect of Solvency II on the volume of ILS using today’s numbers we find that Solvency II will increase the ILS volume by $7.4 billion by the end of 2016.

As a decrease in Delta can be interpreted as a decline in subjective costs for using ILS for reinsurance purposes relative to traditional reinsurance, the expected lower Delta should positively influence profits.
of insurance companies. In the next subchapter we take a closer look on the expected economic impacts linked to the forecast development of ILS markets.

6.5 Expected economic impact

The expected strong increase in ILS volume compared to the volume of traditional reinsurance after the introduction of Solvency II will have consequences for investors, insurance companies as well as reinsurance companies. In the following we are going to provide some thoughts on how these actors might be touched by the development of ILS markets and how they can act and react in order to be best prepared to benefit form the changes.

For investors, the expected boost in the growth of ILS markets will have the primary consequence that more investment opportunities are going to exist, which in turn will drag more investors into this asset class. In particular, a growing ILS market will most certainly increase the diversity of perils and geographies, as well as offer a higher variety of spreads available to investors, allowing them to better diversify their portfolios. Hence, they will be able to offer on their part better investments opportunities to their clients (see (AON Benfield, 2015a, p.7)).

A larger ILS market with a bigger and more diversified investor base will probably also lead to a more liquid secondary market, which again might have an amplifying effect on the attractiveness of ILS instruments.

An often cited advantage of ILS instruments over traditional reinsurance is the theoretical pricing advantage, due to the lower cost of capital compared to reinsurance companies Cummins and Trainar (2009). However, Moody’s Investor Services (2014) argues that similar to traditional reinsurers, who are fast approaching technical minimum pricing, also ILS investors are on the course of reaching the lower pricing bound, which reduces their ability to chip away market share through price declines. However, we have shown in this paper that a decrease in \( \Delta \), corresponding to a decrease in the relative subjective price of ILS, can have the same effect as a decrease in objective prices\(^{25} \). Given the high \( \Delta \) values in the past, it is, however, possible that the difference in objective prices, which favors ILS, did not actually kick in yet. This is due to the fact that so far the subjective price dominated the objective price, rendering changes in the objective price for ILS marginal. Given that \( \Delta \) is forecast to decrease substantially in coming years, the objective price of ILS could gain in importance, thus amplifying the advantage of lower cost of capital of ILS investors compared to traditional reinsurers. Therefore, in the future ILS investors might be able to steal market share from traditional reinsurers at an even faster pace.

In conclusion, for ILS investors the expected amplified growth of ILS markets due to Solvency II will have mostly positive consequences, with the most important being the increased variety of perils, geographies and spreads on offer.

Our forecasts show that ILS are here to stay and therefore it is for insurance companies definitely worth, to build up the necessary knowledge in order to be able to be present on ILS markets as sponsor. Further standardization, likely to follow from the adjustment of ILS instruments to Solvency II

\(^{25}\)Remember that we defined the difference in objective prices between ILS and traditional reinsurance as the difference in market prices for the two instruments. The subjective price refers to the objective price for ILS weighted by \( \Delta \) and accounts for the fact that using ILS instead of traditional reinsurance might come with higher regulatory or internal costs.
requirements, could lead to lower costs for sponsors and thus attract more insurance companies into the market. Additionally, as ILS markets grow further and issuing ILS becomes easier, insurance companies with advanced experience and expertise in using ILS might be able to outperform their rivals, who do not possess the same level of expertise. Additionally, as reinsurance companies increasingly incorporate ILS into their proposed reinsurance solutions to better fit the needs of their clients, insurance companies without the necessary expertise and experience might fall behind their peers.

Furthermore, the expected rise of ILS also enhances the bargaining power of insurance companies over reinsurance companies, meaning that they can demand more services or put pressure on the price. However, it is worth to point out that as mentioned before, pricing for traditional reinsurance as well as ILS might already have reached a lower bound Artemis (2014). This, combined with the assumption that real interest rates are going to increase, suggests that an increase in prices at least for ILS instruments might follow in the medium term irrelevant of the overall volume of ILS markets. Therefore, insurance companies should not expect reinsurance prices to decrease much more in the coming years. Nevertheless, insurance companies can expect to find better reinsurance solutions on offer, both in terms of alternative reinsurance as well as traditional reinsurance. This might in turn enable insurance companies to offer their clients more attractive contracts and services.

In conclusion, it is likely that the forecast growth of ILS markets due to the introduction of Solvency II will have a positive impact on the bottom line of insurance companies. In particular, insurance companies, who are able to adapt sufficiently fast to the new reinsurance world, will profit most from the growth of ILS markets.

The forecast boost of the ILS markets due to Solvency II will put additional pressure on the market share of traditional reinsurance, especially in the light of Moody’s newest report, that indicates that the number of traditional reinsurance contracts is in decline Moody’s Investor Services (2014). Additionally, (AON Benfield, 2015b, p.19) has found that already today ILS are making their way into the higher-margin areas, the main profit pool for traditional reinsurance. Given the growth prospects of ILS this tendency will most certainly continue or even increase.

These trends are forcing reinsurance companies to reevaluate their value propositions and business models, in order to keep their relevance in the market. (AON Benfield, 2015b, p.20) notes that one way to address the increasing influence of ILS is by offering better services and conditions to clients, not replicable by ILS. This would put an upward pressure on Delta as ILS would be perceived more expensive relative to traditional reinsurance, given that it offers less. According to Moody’s Investor Services (2014) larger reinsurance companies might be better suited to offer a larger line sizes and a full product suite. As a consequence, some reinsurers might decide to opt for a growth strategy, while others scale back their business. Therefore, we could see further consolidation in the traditional reinsurance market on top of what we have seen in the years 2014 and 2015 A. M. Best (2015).

However, in our opinion the best solution for reinsurance companies to cope with the growing influence of alternative capital is not to fight it but to embrace it.

Again (AON Benfield, 2015b, p.19) suggest that companies, which are successful in incorporating ILS into their value proposition and business model could be able to flourish in the new environment despite the
increased concurrence. For example, (Munich RE, 2014b, p.4) offers a bridge cover to insurance companies with expiring cat bond expires, but who wish to delay the issuance of a new cat bond. Many reinsurers, as for instance Swiss RE (2015c), use their resources and knowledge in order to support and advice sponsors in structuring and issuing ILS. Therefore, with a growing interest in alternative reinsurance products, reinsurer might increasingly take the role of the intermediary between insurance companies and markets. To conclude this section, reinsurance companies willing to innovate and adapt their business model to the new environment will continue to occupy an important place within the reinsurance market. Our paper has shown that by leveraging characteristics of traditional reinsurance not present in ILS instruments, traditional reinsurance can remain interesting to insurance companies, despite apparent capital cost disadvantages. The reason is that these differences drive up Delta and thus the relative subjective price of ILS. Similarly, by incorporating ILS into their reinsurance solutions or by acting as an intermediary, reinsurance companies can use the rise of ILS to their advantage.

To summarize, the expected rise of the importance if ILS instruments for reinsurance purposes due to Solvency II, will require investors, insurers and particularly reinsurers to reconsider and adapt their business model. Those, who master the transition best, will see their competitiveness rise and be able to reap the benefits of a more diverse reinsurance industry. Interestingly, if traditional reinsurance will become more specialized while ILS more standardized in the course of these adjustments in the reinsurance industry, the two instruments will shift from being substitutes to being complements.

7 Conclusion

The starting point of the paper was the soon to be introduced Solvency II regulatory reform and its potential impact on the growth of ILS markets. Solvency II is expected to impose a new set of rules about how ILS can be used for risk mitigation and capital relief purposes by insurance companies located within the European Union. Hence, ILS markets as well as the dynamics between ILS and traditional reinsurance are likely to change.

Based on these grounds the paper pursued two goals in order to answer the question whether Solvency II will further fuel the recent rise in ILS volumes relative to the global property catastrophe reinsurance limit26: our first goal was to develop a theoretical framework based on economic principals and capable of explaining how insurance companies decide what quantity of traditional and alternative reinsurance to purchase. We proposed the concept that insurance companies do not compare objective prices of ILS and traditional reinsurance, but rather subjective prices. Specifically, we modeled the subjective price of ILS by introducing a weighting term called Delta in the insurance company’s profit function. By the means of empirical data on prices and volumes of traditional reinsurance and ILS respectively, we were able to quantify the yearly Delta for the period between year-end 2002 and year-end 2014. Our calculations showed that insurance companies on average considered ILS to be subjectively more expensive compared to traditional reinsurance, which answers the question why for a long time ILS has remained a niche product in the market for reinsurance solutions even though ILS offered in general the

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26 For simplicity and comparability called volume of traditional reinsurance throughout the paper.
lower objective price per unit of risk ceded.

Furthermore, we were able to demonstrate that the rise of ILS in recent years is reflected in the decline of the weighting term $\Delta$. Structural and regulatory advancements within the ILS industry, as well as to the accumulation of knowledge and experience by insurance companies reduced the subjective price of ILS compared to traditional reinsurance.

Given these results, our second goal was to estimate and forecast based on the theoretical framework and information from industry experts the impact of Solvency II on relative volumes of ILS and traditional reinsurance. Our results suggest that Solvency II will have a positive effect on the growth of ILS markets, thus further accelerating their rise and increase their importance within the reinsurance industry. In particular, our ARMA(3,3)-model for the $\Delta$-series predicts that the introduction of Solvency II will lead the ILS volume to grow to 24.3% of the volume of traditional reinsurance by year-end 2016. Therefore, Solvency II will increase the growth rate by 10% compared to the status quo without Solvency II. Holding today’s numbers for the volume and price of ILS and traditional reinsurance constant, this would imply a growth of the ILS volume to $80.9 billion compared to the forecast status quo scenario of $73.5 billion.

Given these findings, investors, insurers and particularly reinsurers need to adapt their strategy to the evolving reinsurance industry. Insurance and reinsurance companies should consider incorporating ILS into their business model, in order to be able to combine and reap the benefits of both reinsurance instruments to their and their clients’ advantage and needs. Those companies, who master this transition well, will see their competitiveness and profitability rise. Investors on the other hand should further push for structural advancements in ILS markets, in order to meet the needs of sponsors and support growth.

Nevertheless, our research design has its limitations. Firstly, we had to deal with a small dataset, which only consisted of yearly macro data. In order to obtain a measure for reinsurance prices we had to rely on approximations, potentially causing measurement errors. Additionally, due to the lack of data, we had to limit our model to insurance companies, even though countries and organizations also issue ILS instruments. Therefore, the quantitative results reported in this paper should be interpreted with the necessary caution and by considering an appropriate margin of error.

We see our paper as a first step to better understanding how regulatory change can affect the dynamics between ILS and traditional reinsurance. Therefore, an important task for future research will be to collect further empirical evidence. For instance, once Solvency II has come into force it could be insightful to look at whether EU-based insurance companies reinsure themselves differently than their peers not affected by Solvency II.

Additionally, future research could extend the concepts developed in this paper to the micro level, in particular to the level of individual insurance companies. It would be especially interesting to find more evidence on how $\Delta$ evolves within the individual insurance companies over time and why it diverges. Such studies are likely to provide further insights into the various factors affecting and influencing $\Delta$. Additionally, we also see potential for qualitative research in the form of case studies on the level of insurance companies. Specifically, one could focus on the question why and how the management addresses the rise of ILS. This could help defining best practices and strategies for the industry in order to be able to deal with future regulatory change.
Appendices

A Alternative Capacity according to AON Benfield and Guy Carpenter

<table>
<thead>
<tr>
<th>Year</th>
<th>Guy Carpenter</th>
<th>AON Benfield</th>
<th>Difference</th>
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<tr>
<td>2002</td>
<td>4.5%</td>
<td>5.5%</td>
<td>-1.0%</td>
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<tr>
<td>2003</td>
<td>5.5%</td>
<td>6.0%</td>
<td>-0.5%</td>
</tr>
<tr>
<td>2004</td>
<td>6.0%</td>
<td>7.0%</td>
<td>-1.0%</td>
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<tr>
<td>2005</td>
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<td>-1.0%</td>
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<tr>
<td>2006</td>
<td>9.0%</td>
<td>11.8%</td>
<td>-2.8%</td>
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<tr>
<td>2007</td>
<td>13.0%</td>
<td>14.0%</td>
<td>-1.0%</td>
</tr>
<tr>
<td>2008</td>
<td>8.0%</td>
<td>11.0%</td>
<td>-3.0%</td>
</tr>
<tr>
<td>2009</td>
<td>8.9%</td>
<td>12.0%</td>
<td>-3.1%</td>
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<tr>
<td>2010</td>
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<td>12.0%</td>
<td>-1.1%</td>
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<tr>
<td>2011</td>
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<td>12.5%</td>
<td>-0.6%</td>
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<tr>
<td>2012</td>
<td>13.9%</td>
<td>16.8%</td>
<td>-2.9%</td>
</tr>
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<td>2013</td>
<td>14.9%</td>
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<tr>
<td>2014</td>
<td>18.0%</td>
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<td>-1.0%</td>
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Table 5: Comparision of risk-adjusted Reinsurance Prices

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<tr>
<th>Year</th>
<th>Prices ROL($)</th>
<th>Prices Mov.Average($)</th>
<th>Difference($)</th>
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<tr>
<td>2002</td>
<td>4.24</td>
<td>3.28</td>
<td>0.96</td>
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<td>2003</td>
<td>4.45</td>
<td>3.34</td>
<td>1.11</td>
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<tr>
<td>2004</td>
<td>4.06</td>
<td>3.34</td>
<td>0.72</td>
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<tr>
<td>2005</td>
<td>3.75</td>
<td>3.34</td>
<td>0.41</td>
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<tr>
<td>2006</td>
<td>5.12</td>
<td>3.33</td>
<td>1.80</td>
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<tr>
<td>2007</td>
<td>4.67</td>
<td>2.67</td>
<td>2.00</td>
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<tr>
<td>2008</td>
<td>4.19</td>
<td>2.46</td>
<td>1.73</td>
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<tr>
<td>2009</td>
<td>4.53</td>
<td>2.58</td>
<td>1.95</td>
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<td>2010</td>
<td>4.26</td>
<td>3.14</td>
<td>1.12</td>
</tr>
<tr>
<td>Mean</td>
<td>4.37</td>
<td>3.05</td>
<td>1.31</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>0.37</td>
<td>0.35</td>
<td>0.54</td>
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B Diagnostics

B.1 First Differences

Table 6: Results of ARMA(3,2) model estimation based on first differences

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<tr>
<th>Parameters</th>
<th>Estimate</th>
<th>std.err</th>
<th>t-stat</th>
<th>p-value</th>
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<td>Constant</td>
<td>-16.869814</td>
<td>0.000005</td>
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<td>0</td>
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<td>AR(1)</td>
<td>-0.394461</td>
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<td>-104989708</td>
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<tr>
<td>AR(2)</td>
<td>0.121778</td>
<td>0</td>
<td>920869.202</td>
<td>0</td>
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<td>AR(3)</td>
<td>-0.323257</td>
<td>0</td>
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<tr>
<td>MA(1)</td>
<td>4.629177</td>
<td>0.000001</td>
<td>4760869.06</td>
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<td>MA(2)</td>
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<tr>
<td>R-squared</td>
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<td>-9.566607</td>
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<td>Rbar-squared</td>
<td>0.978914</td>
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<td>Std. Deviation(y)</td>
<td>24.923457</td>
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<tr>
<td>SE of regression</td>
<td>3.619176</td>
<td></td>
<td>AIC</td>
<td>2.193048</td>
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<td>Sum of Squared Errors</td>
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<td>BIC</td>
<td>2.435501</td>
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<td>Log-likelihood</td>
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<td>HQC</td>
<td>2.103283</td>
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<td>F-statistic</td>
<td>75.278206</td>
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<td>Pr(F-statistic)</td>
<td>0.00237</td>
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Mean(y) = -9.566607
Std. Deviation(y) = 24.923457
AIC = 2.193048
BIC = 2.435501
HQC = 2.103283
Pr(F-statistic) = 0.00237
### B.2 HP-Filter

Table 7: Results of ARMA(3,3) model estimation based on HP-Filter

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<th>Parameters</th>
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<th>t-stat</th>
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<tr>
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<td>AR(1)</td>
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<td>AR(2)</td>
<td>0.278541</td>
<td>0.00283</td>
<td>98.439562</td>
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<td>AR(3)</td>
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<td>R-squared</td>
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<td>SE of regression</td>
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<td>Sum of Squared Errors</td>
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<td>Log-likelihood</td>
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<td>F-statistic</td>
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<table>
<thead>
<tr>
<th></th>
<th>Mean(y)</th>
<th>Std. Deviation(y)</th>
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<th>BIC</th>
<th>HQC</th>
<th>Pr(F-statistic)</th>
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<td>HQC</td>
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<td>Pr(F-statistic)</td>
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B.3 Sensitivity Analysis

Table 8: Sensitivity Analysis Delta

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<td>7.178</td>
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<td>-0.119</td>
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<td>5.802</td>
<td>6.373</td>
<td>7.002</td>
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References


   URL: http://www.aon.com/reinsurance/capital-markets.jsp

   URL: http://www.artemis.bm/blog/2014/12/08

   URL: http://www.artemis.bm/blog/2015/05/14

Artemis (2015b), ‘Catastrophe Bonds & ILS Issued and Outstanding by Year’.
   URL: http://www.artemis.bm/deal_directory/cat_bonds_ils_issued_outstanding.html

Artemis (2015c), ‘Catastrophe Bonds & ILS Outstanding by Risk or Peril’.
   URL: http://www.artemis.bm/deal_directory/cat_bonds_ils_by_risk_or_peril.html

Artemis (2015d), ‘Catastrophe Bonds & ILS Outstanding by Trigger Type’.
   URL: http://www.artemis.bm/deal_directory/cat_bonds_ils_by_trigger.html

Artemis (2015e), ‘Catastrophe Bonds and ILS Outstanding by Coupon Pricing’.
   URL: http://www.artemis.bm/deal_directory/cat_bonds_ils_by_coupon_pricing.html

Artemis (2015f), ‘Distinction between ILS and Reinsurance to Keep Blurring’.
   URL: http://www.artemis.bm/blog/2015/03/05

Artemis (2015g), ‘Record Q1 2015 Catastrophe Bond & ILS Issuance of $2.1 Billion’.
   URL: http://www.artemis.bm/blog/2015/04/01

Artemis (2015h), ‘Solvency II Likely to be Major Development for ILS market: EIOPA’.
   URL: http://www.artemis.bm/blog/2015/06/25


   URL: https://eiopa.europa.eu/fileadmin/files/publications/reports

46
CEIOPS (2010), *Quantitative Impact Study 5.*


Dittrich, J. (2010), ‘The impact of reinsurance on capital requirements under solvency ii’.


EUropean Comission (2015), ‘Solvency ll overview - frequently asked questions’.


Guy Carpenter (2015a), ‘Alternative capital as percentage of global p&c reinsurance limit’.


Guy Carpenter (2015c), ‘January 1, 2015 renewals see lower pricing and broader coverage for clients, reports guy carpenter’.


URL: [https://eiopa.europa.eu/regulation-supervision/insurance/solvency-ii](https://eiopa.europa.eu/regulation-supervision/insurance/solvency-ii)


URL: [http://www.gccapitalideas.com/2015/01/08](http://www.gccapitalideas.com/2015/01/08)

URL: [http://www.gccapitalideas.com/2015/01/08](http://www.gccapitalideas.com/2015/01/08)


Moody’s Inverstor Services (2014), ‘Global reinsurance negative outlook: Buyers wield strong bargaining power and continue to explore cheaper alternatives to traditional reinsurance’.


Swiss RE (2005), ‘Natural catastrophes and man-made disasters in 2004: More than 300 000 fatalities, record insured losses’, *Sigma 1*.

Swiss RE (2009), ‘The role of indices in transferring insurance risk to the capital markets’, *Sigma 4*.


Swiss RE (2015b), ‘Natural catastrophes and man-made disasters in 2014: Convective and winter storms generate most losses’, *Sigma 2*.

Swiss RE (2015c), ‘Swiss re capital markets insurance-linked securities’.

Swiss RE (2015d), Total p&c reinsurance premiums.