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EVOLUTION OR REVOLUTION? HOW SOLVENCY II WILL CHANGE THE BALANCE BETWEEN REINSURANCE AND ILS

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

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Abstract

The introduction of Solvency II has decreased regulatory frictions for insurance-linked securities (ILS) and thus redefined how insurance and reinsurance companies can use these instruments for coverage against natural catastrophe risk. We introduce a theoretical framework and run an empirical analysis to assess the potential impact of Solvency II on the market volume of ILS compared to traditional reinsurance. Our key model parameter captures all determinants of the relative attractiveness of these two risk mitigation instruments other than market prices. It is estimated by means of OLS, decomposed into a trend and cyclical component using the Hodrick-Prescott filter, and forecasted with an ARMA(3,3) model. We complement the resulting baseline prediction by a scenario analysis, the probabilities for which are based on a Gumbel distribution. Judging by our findings, we expect Solvency II to increase the volume of ILS to more than 24 percent of the global property-catastrophe reinsurance limit or approximately USD 101.14 billion by the end of 2018.

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

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1 Introduction

In recent years, insurers have increasingly employed insurance-linked securities (ILS) to cede risk to financial markets. Given its continuing rapid growth, the ILS market has the potential to disrupt the reinsurance industry. During the last four years alone, it exhibited an impressive average annual growth rate of more than 15% and, today, ILS capital of almost USD 80 billion is outstanding (see, e.g., AON Benfield, 2017). Alongside the rise of ILS, an important regulatory change took shape within the European Union. Solvency II has come into force at the beginning of 2016, redefining capital requirements for the insurance industry. As many countries are seeking Solvency II equivalence, the impact of these new standards is not limited to the EU itself, but extends far further (see, e.g., Lloyd's, 2015).

According to Swiss Re (2009), the regulatory environment has an important influence on the extent to which insurance companies use alternative risk transfer instruments.[1] The new solvency standards will force the industry to rethink its strategies for the management of catastrophe risk. So far, regulation regarding ILS has been heterogeneous and ambiguous. For a long time, the United States probably offered the most favorable regulatory environment. The National Association of Insurance Commissioners (NAIC) generally considers properly structured ILS as reinsurance. In the European Union, in contrast, the regulatory framework was less obvious. Under Solvency I, risk transfer instruments were usually disregarded for solvency capital measurement as long as no claims had been paid. In addition, it was crucial whether the risk transfer instrument qualified as reinsurance contract or not. Instruments without an indemnity trigger were generally not treated as reinsurance (see, e.g., Swiss Re, 2009).

Of course, existing rules and regulations did not prevent the strong growth of the ILS market in recent years. Nevertheless, there is untapped potential, since "*regulatory developments could lead to more adequate treatment of risk transfer and thus have a favorable impact on the use of ILS*" (see Swiss Re, 2009). More specifically, the introduction of Solvency II should be an important catalyst, as it improves the instruments' regulatory recognition and facilitates capital relief (see, e.g., Artemis, 2015*c*). 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"* (see CEIOPS, 2009). In particular, ILS are now 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 (see, e.g., Dittrich, 2010). Hence, according to both industry professionals and policymakers, the new regulatory framework could further fuel the expansion of the ILS market. A crucial question is, however, whether insurance companies are able to account for ILS through the Solvency II standard formula or whether a more complex internal model is required. In the latter case, the instrument would remain unattractive for smaller insurance companies. The fifth quantitative impact study conducted by CEIOPS (2010)

[1] Apart from the prevailing regulatory regime, insurance companies also need to consider accounting standards as well as well as the treatment of ILS by rating agencies. Under IFRS and US GAAP, most ILS are treated as reinsurance (see, e.g., Swiss Re, 2009).

mentioned that "[...] *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.*"

Against this background, we study the potential impact of Solvency II on the volume of ILS relative to traditional reinsurance. In doing so, we rely on a two-step approach. First, we develop a theoretical framework to identify the main factors that play a role in an insurance company's decision between these alternative forms of coverage. Second, we run an empirical analysis to provide a concrete forecast for the outstanding ILS capital as a percentage of the global reinsurance limit at the end of 2018. We will proceed as follows. In the next section, we lay the theoretical foundation by introducing our model economy, solving the insurer's profit maximization problem, and identifying the key drivers of the demand for ILS. The empirical analysis is presented in the third section, including a description of our data, the employed regression model, the estimation procedure for the key parameters, and the forecast of the ILS market development following the introduction of Solvency II. The fourth section contains economic implications and recommendations for investors, insurance and reinsurance companies. Finally, the paper is concluded in section five.

2 Theoretical Analysis

2.1 The Model Economy

Profit Function

Our model economy is inspired by the work of Koijen and Yogo (2016). It consists of a representative property-casualty insurance company I, which sells a quantity Q_t of an insurance policy for a premium P_t in period t and may purchase reinsurance coverage of volume RE_t or transfer a risk amount ILS_t to the capital markets. Both instruments allow it to reduce its exposure and thus the need for costly reserve capital. Their respective prices (per unit of risk) are the reinsurance premium, PR_t, and the risk spread on the ILS instrument, R_t. Hence, the insurer exhibits the following period-t profit function Π_t:

$$\Pi_t = P_t \cdot Q_t - V_t \cdot Q_t - \delta_t R_t \cdot ILS_t - PR_t \cdot RE_t + V_t \cdot ILS_t + V_t \cdot RE_t, \tag{1}$$

where V_t is the actuarial fair value of the insurance policy (expected value of the liabilities).[2] The insurance company can influence its profit through the decision variables P_t, ILS_t and RE_t. However, it bases its decisions on a subjective ILS price $\delta_t R_t$ instead of the market price R_t. The coefficient $\delta_t \geq 1$ represents the insurer's individual assessment of risk mitigation through ILS relative to traditional reinsurance.[3] It captures the ILS experience of the firm as well as the regulatory recognition of such coverage. At the same time, it indirectly allows potential advantages of traditional reinsurance such as underwrit-

[2]For the sake of simplicity, we abstain from modeling operating costs of the insurance company.
[3]In other words, traditional reinsurance acts as a numraire good.

ing assistance and advisory services to enter the model. For $\delta_t = 1$, ILS and traditional reinsurance are perfect substitutes.[4] For $\delta_t > 1$, in contrast, spending one dollar on ILS coverage is less attractive than spending one dollar on traditional reinsurance. As an example, consider an insurance company that aims to transfer some of its natural catastrophe risk to the capital markets or to a reinsurance company. Assume that the insurance company has little experience with ILS and is unsure about their regulatory treatment. In contrast, it has strong ties with its reinsurer and heavily relies on the advisory services of the latter. The insurance company thus subjectively perceives ILS to be more expensive than reinsurance, even if both instruments have the same objective price. It exhibits a $\delta_t > 1$.[5]

The Subjective ILS Price Coefficient δ_t

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 early years up to 2004, the issuance volume by first-time issuers remained often well below USD 800 million and the market was dominated by repeat issuers, this changed between 2005 and 2007. In 2007, the issuance volume of first-time issuers grew significantly and reached USD 3500 million.[6] This development indicates that, over time, more and more insurance companies became familiar with ILS, implying that the subjective price of the instrument decreased. In the empirical analysis we will see that this period coincides with a sharp decline in our estimates for δ_t (see Figure 2). Consequentially, Guy Carpenter (2008) highlighted that ILS were becoming mainstream. For the sake of completeness, it should be noted that the learning process associated with ILS was not limited to the sponsor side. In the early days of the market, investors were also reluctant to engage in the ILS market. Their skepticism led to the emergence of a novelty premium in returns (see Bantwal and Kunreuther, 2000).[7]

Convex Marginal Costs for Traditional Reinsurance

Under the current setup, either reinsurance coverage strictly dominates ILS ($PR_t < \delta_t R_t$) or vice versa ($PR_t > \delta_t R_t$). Hence, it can never be optimal to use both instruments at the same time. This is clearly not what we observe in reality. To allow for coexistence of reinsurance and ILS within a single insurance company, we thus assume that the marginal cost curve for traditional reinsurance is convex. In other words, the price (PR_t) is a function of the quantity purchased (RE_t) and the first-order derivative of the price function can be expressed as:

$$\frac{\delta PR_t(RE_t)}{\delta RE_t} = \begin{cases} \leq 0, & RE_t \leq RE_t^* \\ > 0, & RE_t > RE_t^*. \end{cases} \tag{2}$$

[4] This implies that both instruments are equally well understood by the insurer and lead to exactly the same capital relief.

[5] The provision of underwriting assistance and other technical services by reinsurance companies are often seen as additional benefits of a reinsurance contract. The price of the latter can thus be understood as the cost for the whole package, including but not limited to the transfer of risk (see, e.g., Gibson et al., 2014).

[6] The strong growth in first-time issuance might have additionally been fueled by hurricane Katrina, which led to a sharp increase in U.S. property-catastrophe reinsurance rates (see, e.g., Hartwig, 2012).

[7] Braun et al. (2013) confirm this assumption by showing that experience and expertise is a key determinant of insurers' demand for cat bond investments.

The marginal costs are decreasing until quantity RE^* is reached. From this point on, they begin to increase. According to Froot and Stein (1998), a U-shaped marginal cost curve makes theoretically sense, as reinsurers face financing constraints that make larger coverage more expensive. Similarly, 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.*" In contrast to individual reinsurance companies, risk transfer solutions that tap into the financial markets are associated with a lower cost of capital and are nowadays virtually unconstrained in terms of volume (see, e.g., Gibson et al., 2014). We therefore assume that the marginal costs of ILS are constant. In such a setting, insurance companies will have an incentive to cover lower loss layers through traditional reinsurance and higher layers (low-frequency, high-severity events) through ILS.

Balance Sheet Dynamics

Since a major purpose of risk management instruments is capital relief, we are now going to model the effects of traditional reinsurance and ILS on the capital requirements of the insurance company under Solvency II. To this end, we first need to describe how the balance sheet of the insurance company evolves from one period to another. The change in the liabilities of the insurance company in period t, $\triangle L_t$, can be described as follows:

$$\triangle L_t = V_t(Q_t - RE_t - ILS_t). \tag{3}$$

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. Selling policies generates revenue, while ceding the risk to a reinsurance entity or to the financial markets generates costs. Both effects are reflected in the change of the insurer's assets in period t, $\triangle A_t$:

$$\triangle A_t = P_t \cdot Q_t - \delta_t R_t \cdot ILS_t - PR_t \cdot RE_t. \tag{4}$$

While conducting its activities, the insurance company has to comply with the Solvency II capital requirements K^*, imposed by the regulator. The latter are based on the two measures Solvency Capital Requirement (SCR) and Minimum Capital Requirement (MCR). For the purpose of simplicity, we focus on SCR, which is set above MCR (see, e.g., European Comission, 2015). Given the dynamics for the assets and liabilities, the firm's available regulatory capital in period t, K_t, is defined as:

$$K_t = A_t - (1 + \rho)L_t. \tag{5}$$

The risk charge ρ (> 1) is the decision variable of the regulator and governs the SCR, i.e., it describes how much capital an insurer needs to hold in excess of its liabilities. Due to the low frequency of changes in regulatory standards, we are going to treat ρ as a constant. By decreasing the liabilities L_t, both reinsurance and ILS can have a positive impact on the available capital K_t.

Cost of Regulatory Friction

If the insurance company's capital falls below the SCR, a costly intervention by the regulator is triggered. Costs are particularly high for very low levels of capital (e.g., close to MCR) as in this case the regulator may withdraw the insurer's authorization to operate (see European Comission, 2015). We model these regulatory costs in line with Koijen and Yogo (2016) through a cost function C_t, which depends on the capital level K_t held by the insurance company:

$$C_t = C(K_t). \tag{6}$$

C_t exhibits the following first and second-order derivatives:

$$\frac{dC_t}{dK_t} < 0, \tag{7}$$

$$\frac{d^2C_t}{dK_t^2} > 0. \tag{8}$$

Hence, an increasing level of capital K_t reduces regulatory costs, while low levels of capital are associated with costly regulatory intervention by the supervisory body.

2.2 Insurance Company's Maximization Problem

Firm Value Function

Taking these costs into account leads to the following firm value function:

$$J_t = \Pi_t - C_t + \mathrm{E}_t[d_{t+1} \cdot J_{t+1}], \tag{9}$$

where d_{t+1} is the stochastic discount factor. The insurance company maximizes J_t by deciding on the price P_t, the amount of traditional reinsurance RE_t, and the amount of risk transferred to the capital markets ILS_t. Since the level of capital held today has implications for the expected discounted future profit, the present value of the latter is included as an additional term.

Optimal Insurance Price

Since, in the following paragraphs, δ is also used to denote partial derivatives, we will print the subjective price factor in bold. The first-order condition for the insurance price can be obtained by taking the first partial derivative with regard to P_t and applying the envelop theorem:

$$\frac{\delta J_t}{\delta P_t} = \frac{\delta \Pi_t}{\delta P_t} - \frac{\delta C_t}{\delta K_t} \cdot \frac{\delta K_t}{\delta P_t} + E_t \left[d_{t+1} \cdot \frac{\delta J_{t+1}}{\delta K_t} \cdot \frac{\delta K_t}{\delta P_t} \right] \stackrel{!}{=} 0. \tag{10}$$

Subtracting $\frac{\delta \Pi_t}{\delta P_t}$ and dividing both sides by $\frac{\delta K_t}{\delta P_t}$ yields

$$-\frac{\delta \Pi_t}{\delta P_t} \cdot \left(\frac{\delta K_t}{\delta P_t}\right)^{-1} = \underbrace{-\frac{\delta C_t}{\delta K_t} + E_t\left[d_{t+1} \cdot \frac{\delta J_{t+1}}{\delta K_t}\right]}_{c_t}, \tag{11}$$

with c_t being the cost of regulatory friction. The latter measures the marginal reduction in profit that the insurance company is willing to accept in order to raise its capital level by one dollar (see Koijen and Yogo, 2016). Inserting in (10), we obtain

$$\frac{\delta J_t}{\delta P_t} = \frac{\delta \Pi_t}{\delta P_t} + c_t \cdot \frac{\delta K_t}{\delta P_t} \stackrel{!}{=} 0, \tag{12}$$

which describes how changes in the insurance price influence the firm value J_t.

Optimal Traditional Reinsurance

Employing the definition of c_t, we can write the first-order condition for traditional reinsurance as follows:

$$\frac{\delta J_t}{\delta RE_t} = \frac{\delta \Pi_t}{\delta RE_t} + c_t \cdot \frac{\delta K_t}{\delta RE_t} \stackrel{!}{=} 0. \tag{13}$$

When deriving (9) explicitly, we obtain

$$V_t - PR_t(RE_t) - PR_t'(RE_t) \cdot RE_t + c_t\left(-PR_t(RE_t) - PR_t'(RE_t) \cdot RE_t + (1+\rho)V_t\right) \stackrel{!}{=} 0. \tag{14}$$

Rearranging yields the following expression for the reservation price of traditional reinsurance:

$$PR_t^r(RE_t) \leq \left(\frac{1 + c_t(1+\rho)}{1 + c_t}\right) V_t - PR_t'(RE_t) \cdot RE_t, \tag{15}$$

where $PR_t^r(RE_t)$ represents the insurer's reservation price for traditional coverage. The firm therefore purchases reinsurance as long as PR_t is smaller or equal than $PR_t^r(RE_t)$. Equation (15) also shows how the reservation price behaves, given changes in its various components. More specifically, it increases in the cost of regulatory friction (c_t) and the regulator's risk charge for the capital requirements (ρ_t). In addition, marginal costs have an impact. Whether the corresponding relationship is positive or negative depends on the quantity of traditional reinsurance purchased. Let R_t^r be the reservation price for ILS. Hence, due to the convex cost function, the reservation price for traditional reinsurance will drop below the reservation price for ILS at a quantity $RE_t^* + \epsilon$, with ϵ being some non-negative parameter:

$$PR_t^r(RE) = \begin{cases} \geq R_t^r, & RE_t \leq RE_t^* + \epsilon \\ < R_t^r, & RE_t > RE_t^* + \epsilon \end{cases} \tag{16}$$

Optimal Reinsurance through ILS

In the same spirit, we can write the first-order condition for ILS coverage as follows:

$$\frac{\delta J_t}{\delta ILS_t} = \frac{\delta \Pi_t}{\delta ILS_t} + c_t \cdot \frac{\delta K_t}{\delta ILS_t} \stackrel{!}{=} 0. \tag{17}$$

Explicitly calculating the partial derivatives from (9), we obtain

$$V_t - \boldsymbol{\delta} R_t + c_t \left(-\boldsymbol{\delta} R_t + (1+\rho) V_t\right) \stackrel{!}{=} 0. \tag{18}$$

Hence, the ILS reservation price (R_t^r), is given by:

$$R_t^r \leq \left(\frac{1 + c_t(1+\rho)}{\boldsymbol{\delta}_t(1+c_t)}\right) V_t. \tag{19}$$

It is now apparent that the willingness to pay for ILS depends four factors: the actuarial fair value V_t of the insurance policy, the strictness of the regulatory capital requirements (ρ), the costs of regulatory friction (c_t), and the subjective ILS price coefficient ($\boldsymbol{\delta}_t$).[8]

The Relationship Between Reinsurance and ILS

Finally, we compare the reservation prices for reinsurance and ILS:

$$\left(\frac{1 + c_t(1+\rho)}{1+c_t}\right) V_t - PR_t'(RE_t) \cdot RE_t \gtreqless \left(\frac{1 + c_t(1+\rho)}{\boldsymbol{\delta}_t(1+c_t)}\right) V_t. \tag{20}$$

Since, $\boldsymbol{\delta}_t$ plays a crucial role in Equation (20), it is a key driver of the relative demand for the two risk mitigation instruments. For $\boldsymbol{\delta}_t = 1$, reinsurance and ILS are perfect substitutes. Thus, the only decisive factor are the marginal costs $PR_t'(RE_t)$. In contrast, if $\boldsymbol{\delta}_t > 1$ (e.g., due to additional benefits provided by the reinsurer), ILS are perceived to be less attractive than reinsurance, implying that the marginal costs for the latter need to be high so the insurer also purchases ILS coverage.

As discussed above, regulatory acceptance has the potential to improve the insurance company's perception of ILS compared to traditional reinsurance. We therefore expect a decline in δ_t associated with the recent introduction of Solvency II. According to our model framework, we should, in turn, witness an acceleration in the growth of ILS relative to traditional reinsurance. Based on this theory, we will now conduct an empirical analysis with the goal of forecasting the future balance of volumes ceded in the two markets.

[8] Note that if the insurance company already has a sufficiently high amount of traditional reinsurance in place, c_t and hence the 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 and vice-versa.

3 Empirical Analysis

3.1 Regression Model

We begin by developing an econometric framework for the estimation of the key variables that have been identified based on our theoretical model. Since c_t and ρ are the same for both ILS and reinsurance, we ignore them in favor of parsimony. Hence, our empirical analysis is centered on the market prices per unit of risk, R_t and PR_t, as well as the subjective ILS price coefficient δ_t. More specifically, we conjecture that the ratio of ILS to total dedicated reinsurance capital, $ILS_t/(RE_t + ILS_t)$, can be well described by the following linear regression:

$$\frac{ILS_t}{RE_t + ILS_t} = \alpha + \beta \left(\frac{R_t}{PR_t} - 1 \right) + \epsilon_t, \tag{21}$$

with intercept α, regression coefficient β, and error term ϵ_t. Assuming a well-behaved empirical demand function, the volume of ILS relative to traditional reinsurance (ILS_t/RE_t) must decrease in the price ratio $R_t/PR_t - 1$. Therefore, we expect the estimate for β to turn out negative. As the time-varying parameter δ_t in our theoretical model by definition summarizes all determinants of the relative attractiveness of the two instruments other than market prices, its mean will be captured by α and its variation by ϵ_t.[9] However, the relationship between δ_t and ϵ_t is an inverse one: a reduction of the former, implying that the representative insurance company perceives ILS to be more appealing, must lead to an increase in the ILS volume relative traditional reinsurance. We therefore obtain our estimate $\hat{\delta}_t$ as the reciprocal of the sum of the estimates for the intercept $\hat{\alpha}$ and the fitted residuals $\hat{e}_t$:

$$\hat{\delta}_t = \frac{1}{2} \cdot \frac{1}{(\hat{\alpha} + \hat{e}_t)} = \frac{1}{2} \cdot \left(\frac{ILS_t}{RE_t + ILS_t} - \hat{\beta} \left(\frac{R_t}{PR_t} - 1 \right) \right)^{-1}. \tag{22}$$

Hence, the simple regression model in (21) is aligned with our theory from the previous section. In case both instruments exhibit exactly the same price ($R_t = PR_t$), the dependent variable is solely determined by ϵ_t.[10] If additionally $\delta_t = 1$, both instruments should have the same volume ($ILS_t = RE_t$).

3.2 Dataset

Our dataset has been compiled based on several sources and covers the period from 2002 to 2016. Whenever possible, we performed cross checks to ensure reliability. We measure the variable $ILS_t/(RE_t+ILS_t)$ through the ratio of alternative capital in percent of the global catastrophe reinsurance limit, published by Guy Carpenter (2016*a*).[11] Their reported alternative capacity is an aggregate measure, comprising the volumes of cat bonds, ILWs, sidecars and collateralized reinsurance.[12]

[9] As a corollary, we do not need to include any further control variables.

[10] This is why, in the regression model, the actual price ratio ILS_t/RE_t has been corrected by minus 1.

[11] All figures have been cross checked with data from the annual reinsurance market report by AON Benfield (2017). Although the individual observations do not match perfectly, they are highly correlated.

[12] AON Benfield additionally provides a breakdown across different types of ILS, showing that collateralized reinsurance has outgrown cat bonds to become the largest ILS segment in 2013.

Furthermore, an operationalization of $(R_t/PR_t - 1)$ has to rely on a measure for the reinsurance price per unit of risk (R_t) and the ILS price per unit of risk (PR_t). First, we construct R_t based on the Rate on Line Index by Guy Carpenter (2016*b*), which captures the annual growth rates of the global property catastrophe reinsurance prices. As a starting point for the time series, we use the average U.S. catastrophe reinsurance price (in US-dollars) per unit of ceded exposure for the year 1990 as published by Froot and O'Connell (1999).[13] We deem this to be a reasonable approximation, since the U.S. are the largest property-catastrophe reinsurance market in the world (see, e.g., Standard & Poor's, 2014).[14] Second, PR_t is proxied by the *ILS multiple*, i.e., the ratio of ILS spread to expected loss. Time series of the averages for both variables across all transactions in a given year are reported by Artemis (2016).[15]

Table 1 contains descriptive statistics for our data set. The mean of $ILS_t/(RE_t + ILS_t)$ equals 0.11, indicating that alternative capital averaged 11 percent of overall reinsurance capital over the period under investigation. Traditional reinsurance capital, in turn, made up 89 percent of the total. Moreover, the mean of the ILS multiple (R_t) is 3.65. On average, investors therefore received a spread of 3.65 percentage points above the risk-free interest rate for each percentage point of expected loss that they assumed. This compares to a mean reinsurance price per unit of risk (PR_t) of 4.51. Since the average risk-adjusted ILS price was lower than the average risk-adjusted price for traditional reinsurance, the price ratio $(R_t/PR_t - 1)$ exhibits a negative mean. Figure 1 shows the time series of both the volume ratio $ILS_t/(RE_t + ILS_t)$ and the price ratio $(R_t/PR_t - 1)$. The former, increased quite steadily over the years, peaking at almost 18 percent in 2016. The only large drop can be observed between 2007 and 2008 and coincides with the bankruptcy of Lehman Brothers at the peak of the financial crisis.[16]

T = 15	Mean	Min.	Max.
$ILS_t/(RE_t + ILS_t)$	0.11	0.05	0.18
R_t	3.65	2.35	5.42
PR_t	4.51	3.37	5.58
$R_t/PR_t - 1$	-0.19	-0.34	0.17

Table 1: Descriptive Statistics (2002−2016)

This table contains the mean, minimum, and maximum values of the annual times series between 2002 and 2016 of the following four variables: ratio of alternative capital in percent of the global catastrophe reinsurance limit $ILS_t/(RE_t + ILS_t)$, ILS multiple (R_t), reinsurance price per unit of risk (PR_t), and ratio of ILS to reinsurance prices per unit of risk $(R_t/PR_t - 1)$.

[13]It should be noted that this prices is "[...]*based on the contract prices and exposures for four insurers that purchased reinsurance through Guy Carpenter in every year from 1975 to 1993.*" In addition, Froot and O'Connell (1999) state that "*the series are representative of the behavior of prices and quantities for the other insurers*" in their database.

[14]To ensure robustness, we performed a cross check with a time series of global reinsurance premium volumes divided by insured losses provided by Swiss RE (2015*a*). The figures of both approximations are largely consistent.

[15]Artemis.bm is a well-known industry website specializing on ILS.

[16]Lehman Brothers acted as a total return swap counterparty in four cat bond structures, which suffered losses after its default in September 2008. Due to this event, issuance volumes in the cat bond market slumped, causing the observed reduction of the alternative capital as a percentage of the overall reinsurance capital.

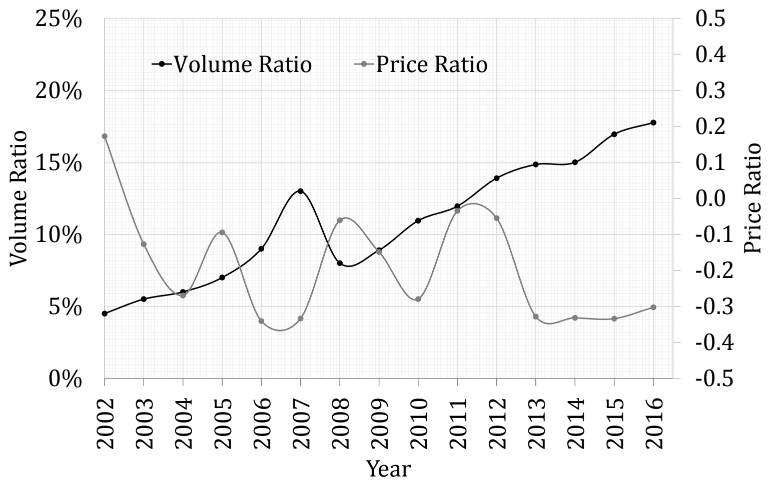


Figure 1: Volumen Ratio and Price Ratio (2002−2016)

This figures shows the time series of the ratio of alternative capital in percent of the global catastrophe reinsurance limit $ILS_t/(RE_t + ILS_t)$ and the ratio of ILS prices per unit of risk to reinsurance prices per unit of risk $(R_t/PR_t - 1)$. These two variables form the basis for our following time series regression and the associated estimation of δ_t.

3.3 Estimation of β and δ_t

We estimate the regression model (21) by means of OLS. Accordingly, $\hat{\beta}$ represents the average effect of the price ratio on the volume ratio over time. Due to competitive pressures in the insurance market, it is fair to assume that the industry-level impact of relative prices on the decision between the two risk mitigation instruments is constant over time. In contrast, $\hat{\delta}_t$ needs to be time-varying, since the ILS experience of the representative insurance firm, the regulatory recognition of ILS coverage, and the perceived advantages of traditional reinsurance may change over the years. Therefore, we calculate the time series for $\hat{\delta}_t$ as (two times) the reciprocal of the sum of the intercept $\hat{\alpha}$ and the fitted residuals $\hat{\epsilon}_t$. Based on the resulting historical evolution of δ_t, we will be able to predict the impact of Solvency II on the balance between reinsurance and ILS.

Table 3.3 contains the OLS results. A White-Test confirms that the variance of error terms is homoskedastic. As expected, $\hat{\beta}$ turns out negative and statistically significant, implying that an increase in the price ratio $(R_t/PR_t - 1)$ leads to a decrease in the volume ratio $ILS_t/(RE_t + ILS_t)$. In other words, the ILS market tends to expand relative to the traditional reinsurance market, whenever ILS coverage becomes cheaper. Furthermore, the corresponding time series for $\hat{\delta}_t$ has been plotted in Figure 2. Consistent with our theory in chapter 2, $\hat{\delta}_t$ exhibits a decreasing trend over time, which can be attributed to a learning process of the representative insurance company. The latter lowers its subjective costs of hedging via ILS instruments.

Regressors	$ILS_t/(RE_t + ILS_t)$
Intercept (α)	0.0785***
	(-2.5294)
Price Ratio ($R_t/PR_t - 1$)	–0.1586**
	(5.1529)
T	15
R^2	0.3298

Table 2: OLS Regression Results

This table contains the OLS regression results. The dependent variable is the ratio of alternative capital in percent of the global catastrophe reinsurance limit $ILS_t/(RE_t + ILS_t)$ and the independent variable is the ratio of ILS prices per unit of risk to reinsurance prices per unit of risk ($R_t/PR_t - 1$). Heteroskedasticity is ruled out by means of a non-significant White-Test: Chi-sq(2): 0.019, p-value: 0.99. The t-statistics are shown in parentheses. Significance levels are denoted as follows: * ($p < 0.1$), ** ($p < 0.05$),*** ($p < 0.01$)

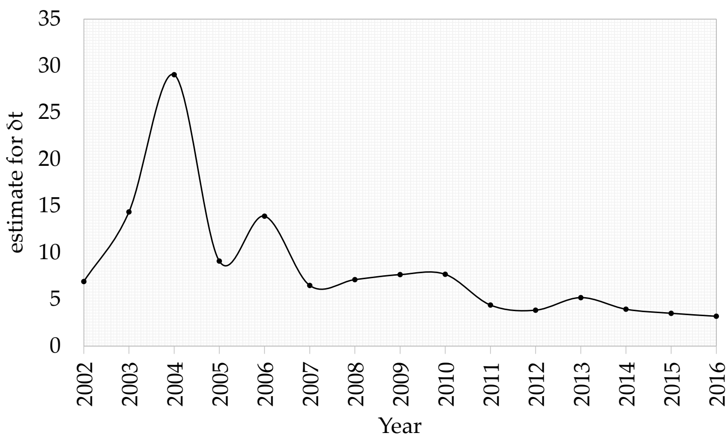


Figure 2: Yearly Delta

This figures shows the estimated time series of the subjective price factor $\hat{\delta}_t$ between 2002 and 2016. It has been calculated as the reciprocal of (two times) the sum of the intercept $\hat{\alpha}$ and the fitted residuals $\hat{\epsilon}_t$. The decreasing trend is in line with our expectation that the insurance industry has gone through a constant learning process with regard to the usage of ILS as a risk mitigation tool.

Due to the occurrence of high-impact, low-probability events such as the tsunami in the Indian Ocean, the catastrophe year 2004 was exceptionally severe (see, e.g., Swiss RE, 2005). Consequently, the sharp drop of $\hat{\delta}_t$ following in 2005 might have been the result of an increased desire for coverage in the insurance industry. It is quite likely that, in this challenging market environment, more resources were spent on acquiring the necessary knowledge to unlock the potential of ILS. A further indication for this assumption is given by Guy Carpenter (2008), who report that between 2005 and 2007, first-time sponsors were responsible for a substantial part of the increased ILS issuance activity.

The first wipe out of a cat bond after Hurricane Katrina marked another important milestone in the evolution of $\hat{\delta}_t$. According to Cummins and Weiss (2009) 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 $\hat{\delta}_t$ decreased substantially from 2004 to 2005, as the insurance industry received a positive signal regarding the reliability of ILS.

Finally, it is worth pointing out that the default of Lehman Brothers in 2008 only led to a slight upward movement in $\hat{\delta}_t$, although it lead to the technical default of four outstanding cat bonds (see, e.g., Cummins and Weiss, 2009). In fact, ILS emerged stronger from this setback, as the industry was able to quickly address the credit risk issues which surfaced during the financial crisis (see, e.g., AON Capital Markets, 2008). The resulting structural improvements of cat bonds are a likely reason for the further decrease of $\hat{\delta}_t$ in the following years.

3.4 Forecasting the Model

Having developed an understanding of the historical evolution of $\hat{\delta}_t$ between 2002 and 2016, we now aim to forecast its future development and, in turn, the market share of ILS relative to traditional reinsurance. To this end, we rely on the well-known Box-Jenkins method for time series analysis (see, e.g., Shumway and Stoffer, 2010). The negative trend of $\hat{\delta}_t$, which can be observed in Figure 2, suggests non-stationarity. We confirm this conjecture by means of a Dickey-Fuller test. In addition, the up and down movements in the time series hint at the presence of a cyclical component. Based on these findings, we decide to employ the Hodrick-Prescott (HP) filter, which decomposes the time series into a trend and a cyclical component (see, e.g., Mathworks, 2015).[17]

We apply the HP-Filter to the log-transformed $\hat{\delta}_t$-series, given a smoothing parameter λ of 100 as commonly applied in time-series econometrics (see, e.g., Mathworks, 2015). The resulting series for the cyclical component is stationary so that we can proceed by estimating different ARMA(p,q) models. The Bayesian Information Criterion (BIC) and the Akaike Information Criterion (AIC) suggests that an ARMA(3,3) representation (with constant) exhibits the best fit. The results for this model are presented in Table 3. We continue with an analysis of the corresponding residuals. Based on a Ljung-Box test, we cannot reject the null hypothesis of no autocorrelation. Moreover, unreported QQ-plots of the residuals indicate that they are almost normally distributed. Hence, there is no need for further model refinements.

In a next step, we forecast values for $\hat{\delta}_t$ two years into the future, distinguishing between the cyclical and the trend component. The forecast for the cyclical component relies on the ARMA(3,3) representation, while the trend component is assumed to pursue the same linear trajectory as in the previous periods. More specifically, the latter exhibited an average annual decrease of 0.09 between 2002 and 2016.

[17]The HP filter is often applied in the context of Business Cycle Analysis (see Hodrick and Prescott, 1997). In contrast to differencing, it is well suited for shorter time series, since it avoids the loss of observations.

This describes the learning process of the insurance industry and the steady advancement of ILS instruments. The resulting $\hat{\delta}_t$-values amount to 2.90 for 2017 and 2.61 for 2018 and represent our expectation without the impact of Solvency II. These results will serve as the baseline scenario for the analysis in the next section.

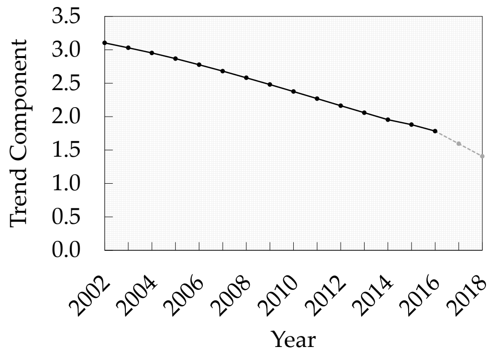
Parameters	Estimate	SE	t-stat.	p-value
Constant	–0.0072	0.0004	–16.4760	0
AR(1)	–0.2012	0.0001	–1860.3500	0
AR(2)	0.2785	0.0028	98.4396	0
AR(3)	–0.1552	0.0003	–614.6897	0
MA(1)	–1.2917	0.0768	–16.8105	0
MA(2)	–3.9073	0.0706	–55.3481	0
MA(3)	–6.4398	0.5105	–12.6148	0
R^2	0.9663	|	AIC	–6.4704
Adjusted R^2	0.8988	|	BIC	–6.1662
Standard Error	0.0476	|	HQC	–6.5329
F-Statistic	14.3284	|	Pr(F-stat.)	0.0260

Table 3: Results for ARMA(3,3) Model with HP-Filter

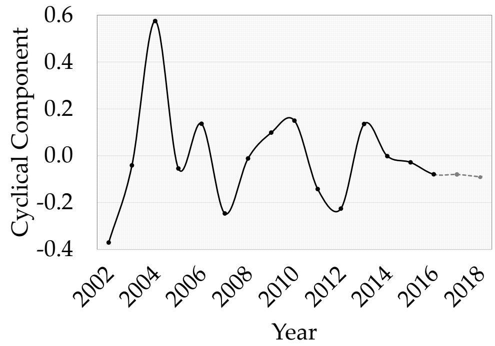
This table contains the results for the ARMA(3,3) model fitted to the cyclical component of the time series of $\hat{\delta}_t$, as generated by HP filter. All coefficients, including the constant, turn out statistically significant. The R^2-figures indicate a high degree of explained variance. Both the Bayesian Information Criterion (BIC) and the Akaike Information Criterion (AIC) suggest a superior fit compared to alternative ARMA(p,q) specifications.

3.5 Scenario Analysis for $\hat{\delta}_t$

Building on the baseline scenario without Solvency II as introduced above, we will now consider potential positive and negative consequences of the new regulation for $\hat{\delta}_t$ and, in turn, the volume ratio. On the one hand, a positive impact could arise due to an improved regulatory treatment. On the other hand, a negative effect could be caused by relatively high practical hurdles for a full recognition of ILS. In both cases, we would expect to see a change in the trend of $\hat{\delta}_t$. There are two ways to incorporate such a change into our model forecast. First, it could be treated as a shock, which instantly disrupts the historical path in the form of a jump. Second, one could assume that the transformational potential of Solvency II will unfold over some period of time, thus changing the slope of the trend. We opt for the second alternative, as we did not detect any signs of a jump since the introduction of the new framework in January 2016. In addition, we will assume that any structural breaks in the trend pattern will be a temporary phenomenon. By the end of 2018, the impact of the new regulation should have fully kicked in. Hence, in the absence of further groundbreaking events in this market, we deem it reasonable that within three years of Solvency II being in place, the trend component will return to its original trajectory, at least in the short term.



(a) Trend Component



(b) Cyclical Component

Figure 3: Forecast of Trend and Cylical Component Under Solvency II
This figure shows then trend component and the cyclical component of the subjective price factor $\hat{\delta}_t$. The forecast values for 2017 and 2018 have been derived as follows. The trend component has been adjusted in line with the expected impact of Solvency II under the optimistic scenario (2x faster annual reduction than in the baseline scenario) and the cyclical component has been forecasted with the ARMA(3,3) model from Table 3.

Below we develop a range of scenarios for the change in the trend of $\hat{\delta}_t$. As there are no precedents to Solvency II in the history of ILS, we need to rely on expert judgment. Instruments with an indemnity trigger will be fully recognized under the Solvency II standard formula (see Swiss Re, 2009). In addition, the 5th Quantitative Impact Study (QIS5) indicates that mitigation instruments without basis risk or those for which it can be shown to be immaterial, may be used under the standard formula (see CEIOPS, 2010). This currently holds for the largest ILS market segment of collateralized reinsurance and for around 60 percent of the second largest segment of cat bonds, which are based on indemnity triggers (see Artemis, 2015*b*; AON Benfield, 2017). However, even for the remaining 40 percent of cat bonds as well as other types of ILS with nonindemnity triggers, a deterioration of the regulatory treatment under the new rules is hardly conceivable.

We therefore deem it to be extremely unlikely that Solvency II will reverse the normal trend of $\hat{\delta}_t$ and adopt a slight slow down as the worst case scenario. More specifically, we assume that relatively high practical hurdles for a full regulatory recognition of ILS instruments, such as the necessity to run a complex internal model, could lead to an absolute annual change in the $\hat{\delta}_t$-trend of merely 0.5 times the one that occurs in the baseline scenario (i.e., -0.05 instead of -0.09). The corresponding $\hat{\delta}_t$-values amount to 2.97 for 2017 and 2.74 for 2018. Furthermore, our mean scenario is centered on a 1.5 times faster annual reduction in the $\hat{\delta}_t$-trend (i.e., -0.14 instead of -0.09). This leads to $\hat{\delta}_t$-values of 2.76 for 2017 and 2.38 for 2018. In the most optimistic scenario, we let the trend component of $\hat{\delta}_t$ decline 2.25 as quickly as in the baseline scenario. Therefore, we obtain $\hat{\delta}_t$-values of 2.58 for 2017 and 2.06 for 2018.

In addition to these considerations, we vary the cyclical component by two equally-sized steps above and below its mean to generate five subscenarios for each value of the trend component. The resulting full range of outcomes for $\hat{\delta}_t$ in 2018 is displayed in Table 4 and lies between a minimum of 1.89 and a maximum of 3.14. Finally, we derive probabilities for the different $\hat{\delta}_t$-scenarios based on a negatively-skewed Gumbel distribution with parameters $\mu = 2.25$ and $\sigma = 0.40$. In doing so, we ensure that outcomes for the subjective price factor $\hat{\delta}_t$ below the optimistic scenario and above the pessimistic scenario occur only in 10 percent of the cases. To put it differently, 80 percent of the probability mass is concentrated between these two scenarios. Based on this distribution we are also able to make probabilistic statements about the future volume of ILS relative to traditional reinsurance.

Trend / Cycle	1.69	**1.59**	1.50	1.36
0.00	3.14	2.86	2.60	2.26
-0.05	3.01	2.73	2.49	2.16
-0.09	2.87	**2.61**	2.38	2.07
-0.14	2.75	2.50	2.27	1.97
-0.18	2.63	2.39	2.17	1.89

Table 4: Scenario Analysis for Delta in 2018

This figure shows the range of outcomes for the subjective price factor $\hat{\delta}_t$ in 2018 based on the different scenarios for the trend and the cyclical component. For the former, the following four scenarios are considered: pessimistic (1.69), baseline (1.59), mean (1.50), optimistic (1.41). For the latter, we add two equally-sized steps above and below its mean (-0.09) to generate five subscenarios for each value of the trend component. The probabilities for all twenty outcomes are derived from a Gumbel distribution.

3.6 Probability Distribution for the Volume Ratio

We can now translate the values for $\hat{\delta}_t$ into volume ratios in 2017 and 2018. For this purpose, we employ the relationship shown in Equation (21) and assume that the price ratio stays on its historical average level.[18] Overall, the outcomes for 2018 lie between a minimum of 19 and a maximum of 28 percent. Figure 4 illustrates our four main scenarios. In the pessimistic scenario, we obtain volume ratios of approximately 19 percent in 2017 and 20 percent in 2018. Furthermore, the respective values in the baseline scenario are 20 percent in 2017 and 22 percent in 2018 and the mean scenario is associated with volume ratios of 21 percent in 2017 and 24 percent in 2018. Finally, the optimistic scenario leads to volume ratios of to 22 in 2017 and 27 percent in 2018. Thus, we expect the volume ratio in 2018 to be approximately 10 percent higher than without Solvency II.[19]

Due to the shape of the Gumbel distribution for $\hat{\delta}_t$, 80 percent of the potential outcomes for the volume ratio in 2018 are located between 20 percent and 27 percent. To translate the volume ratios into absolute figures, we will rely on approximations based on the overall market size (ILS plus reinsurance capital) of 420 billion USD at year-end 2016 (see Guy Carpenter). Assuming that this figure will stay roughly constant, our most likely estimates for the ILS market range from USD 85.93 to USD 114.58 billion. The expected volume ratio of 24 percent in 2018 (mean scenario) corresponds to an ILS volume

[18] Given the comments of industry experts, pricing for both reinsurance and ILS has reached a floor and could stay there for some time (see, e.g., Artemis, 2014, 2015*a*). Therefore, the assumption of a constant price ratio is not far fetched.

[19] The following calculation applies: $24/22 = 1.10$

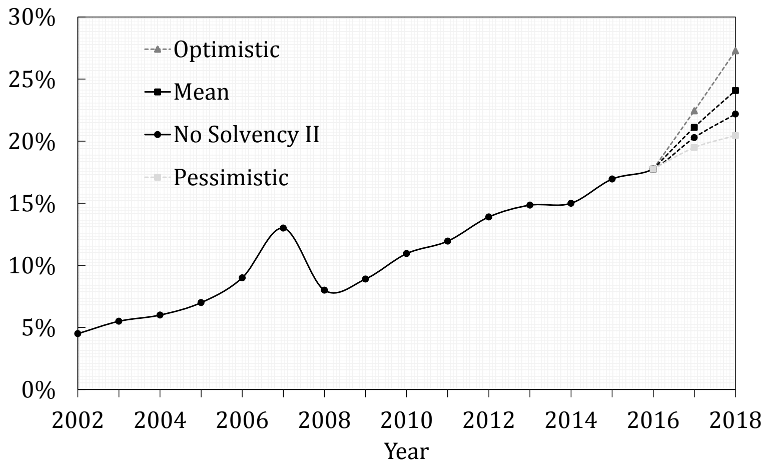


Figure 4: The Four Major Scenarios for the Volume Ratio

This figure depicts the future evolution of the volume ratio (ILS as percentage of global reinsurance limit) in the four main scenarios. The baseline scenario is an extrapolation of the historical development without the impact of Solvency II. The optimistic scenario with only 10 percent of the probability mass above it describes a strong impact of Solvency II. The pessimistic scenario with 90 percent of the probability mass above it assumes a slightly negative impact of the new regulatory framework. Finally, the mean scenario depicts the expected development of the ILS market volume relative to traditional reinsurance under Solvency II.

of around USD 101.14 billion, which is approximately USD 8 billion higher than in the baseline scenario (without Solvency II) and corresponds to an increase of approximately USD 27 billion compared to 2016.

4 Economic Implications

The expected increase in the volume of ILS relative to traditional reinsurance associated with Solvency II will have consequences for investors, insurance companies, and reinsurance companies. In the following, we are going to provide some thoughts on how these actors might be affected. For investors, the range of available assets is likely to increase, leading to a gravitation of further capital towards the ILS market. Apart from that, we may expect a greater diversity of perils and geographies, allowing for an improved diversification of ILS portfolios. Consequently, dedicated ILS funds might become even more appealing to their clients (see, e.g., AON Benfield, 2015*a*). Finally, a broader investor base will probably also lead to a more liquid secondary market, thus increasing the attractiveness of tradable ILS such as cat bonds.

For insurance companies, it will be worth building up knowledge to act as ILS sponsors, as those who are adept at using ILS might be able to outperform rivals without the same level of expertise. Furthermore, standardization, which might be triggered by the new regulatory requirements, could lead to lower costs and thus bring more first-time issuers into the market. Similarly, the expected growth of ILS may also enhance the bargaining power of insurers over reinsurers, implying that they can demand additional services or put pressure on the premiums. In general, ILS exhibit a price advantage over traditional contracts, because reinsurance companies exhibit a higher cost of capital (see, e.g., Cummins and Trainar, 2009). However, it is worth pointing out that prices for both instruments recently seem to have reached a lower bound (see, e.g., Artemis, 2014). This suggests that ability of ILS to gain further market share through a reduction of the objective price will be limited in the next years.

Finally, reinsurance companies will experience additional pressure on their market share. This is supported by a recent report of the rating agency Moody's, indicating that the number of traditional reinsurance contracts is in decline (see Moody's Inverstor Services, 2014). Also, AON Benfield (2015*b*) emphasizes that ILS have begun to progress into higher-margin lines, which represent the main profit pool for reinsurance companies. Given our forecast for the ILS market size, this tendency will probably increase. To cope with these developments, reinsurance companies will need to rethink their business models. AON Benfield (2015*b*) suggests that one solution is to offer better services and conditions to clients, implying an upward pressure on the subjective price factor δ_t. According to Moody's Inverstor Services (2014), it might be easier for large reinsurance companies to offer generous line sizes and a full product suite. Hence, some firms will pursue a growth strategy, while others will scale back their business or become acquisition targets. The consolidation of the reinsurance industry that we witnessed in the years 2014 and 2015 is therefore likely to continue (see, e.g., A. M. Best, 2015). The best solution for reinsurers to cope with the growing influence of alternative capital is not to fight it but to embrace it. AON Benfield (2015*b*), e.g., suggest that companies, which are successful in incorporating ILS into their value proposition, could be able to flourish in the new environment despite the increased competition. New activities could range from bridge covers between the issuance dates of cat bonds to ILS structuring advice (see Swiss RE, 2015*b*). All in all, if traditional reinsurance becomes more specialized and ILS more standardized, the two instruments will shift from being substitutes to being complements.

5 Conclusion

We took a two-step approach to assess the potential impact of Solvency II on the volume of ILS as a percentage of the global property-catastrophe reinsurance limit. First, we introduced a normative model framework to determine how insurance companies should decide between traditional and alternative reinsurance coverage. Second, we complemented our theory by an empirical analysis to generate a concrete set of potential future outcomes. Our key model parameter, the subjective price factor, was estimated by means of OLS for the period from 2002 to 2016. We decomposed the resulting time series into a trend and cyclical component using the Hodrick-Prescott Filter and forecasted it with an ARMA(3,3) model. Finally, we added a scenario analysis based on expert judgments and probabilities from a Gumbel distribution.

Our results suggest that Solvency II will have a positive effect on the ILS markets, thus further increasing their importance within the risk transfer industry. In particular, we expect that their size will grow to more than 24% of the global property-catastrophe reinsurance limit by late 2018. Based on the overall amount of available reinsurance capital at the end of 2016, this is equivalent to an ILS market volume of approximately USD 101.14 billion. These findings bear important economic implications for investors, insurers, and reinsurance companies. Particularly the latter will need to rethink their business model to fully embrace ILS. Only then will it be possible to offer clients a comprehensive range of products and services tailored to their needs. Those who master this transition well, are likely to gain a competitive edge and see their profitability rise.

References

A. M. Best (2015), 'Global Reinsurers: M&A - A Strategy or Ultimatum?'.
URL: *http://www.bestweek.com/global/promo/GlobalReMandA.pdf*

AON Benfield (2015*a*), 'Reinsurance Market Outlook April 2015'.

AON Benfield (2015*b*), 'The Aon Benfield Aggregate Results for the Year Ended December 31, 2014'.

AON Benfield (2017), 'Reinsurance Market Outlook January 2017'.

AON Capital Markets (2008), 'Catastrophe Bonds Evolve in Brave New World'.
URL: *http://www.aon.com/reinsurance/capital-markets.jsp*

Artemis (2014), 'Reinsurer Returns Near Cost-of-Capital, ILS to Win More Market Share: Moodys'.
URL: *http://www.artemis.bm/blog/2014/12/08*

Artemis (2015*a*), '2015 Catastrophe Bond and ILS Issuance Passes 4 Billion'.
URL: *http://www.artemis.bm/blog/2015/05/14*

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

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

Artemis (2016), 'Catastrophe Bonds and ILS Outstanding by Coupon Pricing'.
URL: *http://www.artemis.bm/deal_directory/cat_bonds_ils_by_coupon_pricing.html*

Bantwal, V. J. and Kunreuther, H. C. (2000), 'A CAT Bond Premium Puzzle?', *Journal of Psychology and Financial Markets* **1**(1), 76–91.

Braun, A., Müller, K. and Schmeiser, H. (2013), 'What Drives Insurers Demand for Cat Bond Investments? Evidence from a Pan-European Survey', *The Geneva Papers on Risk and Insurance - Issues and Practice* **38**(3), 580–611.

CEIOPS (2009), 'Current Regulation and Potential Impact of Solvency II', *CEIOPS ILS Report* .
URL: *https://eiopa.europa.eu/fileadmin/files/publications/reports*

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

Cummins, J. D. and Trainar, P. (2009), 'Securitization, Insurance, and Reinsurance', *Journal of Risk and Insurance* **76**(3), 463–492.

Cummins, J. D. and Weiss, M. A. (2009), 'Convergence of Insurance and Financial Markets: Hybrid and Securitized Risk-Transfer Solutions', *Journal of Risk and Insurance* **76**(3), 493–545.
URL: *http://doi.wiley.com/10.1111/j.1539-6975.2009.01311.x*

Dittrich, J. (2010), 'The Impact of Reinsurance on Capital Requirements Under Solvency II'.

European Comission (2015), 'Solvency ll Overview - Frequently Asked Questions'.
URL: *http://europa.eu/rapid/press-release_MEMO-15-3120_en.html*

Froot, K. A. and O'Connell, P. G. J. (1999), The Pricing of US Catastrophe Reinsurance, *in* , ed., 'The Financing of Catastrophe Risk', University of Chicago Press, pp. 195–232.

Froot, K. A. and Stein, J. C. (1998), 'Risk Management, Capital Budgeting, and Capital Structure Policy for Financial Institutions: An Integrated Approach', *Journal of Financial Economics* **47**(1), 55–82.

Gibson, R., Habib, M. A. and Ziegler, A. (2014), 'Reinsurance or Securitization: The Case of Natural Catastrophe Risk', *Journal of Mathematical Economics* **53**(0), 79–100.

Guy Carpenter (2008), 'The Catastrophe Bond Market at Year-End 2007'.
URL: *http://gcportal.guycarp.com/portal/extranet/popup/insights/reportsPDF/2008/*

Guy Carpenter (2016*a*), 'Alternative Capital as Percentage of Global P&C Reinsurance Limit'.
URL: *http://www.gccapitalideas.com/2016/01/08*

Guy Carpenter (2016*b*), 'Global Property Catastrophe ROL Index 1990 to 2016'.
URL: *http://www.gccapitalideas.com/2015/01/08*

Hartwig, R. (2012), 'P/C Industry Should Not Expect Traditional Hard Market Soon: Hartwig'.
URL: *http://www.insurancejournal.com/news/national/2012/06/26/252936.htm*

Hodrick, R. J. and Prescott, E. C. (1997), 'Postwar US Business Cycles: An Empirical Investigation', *Journal of Money, credit, and Banking* pp. 1–16.

Koijen, R. S. J. and Yogo, M. (2016), 'Shadow Insurance', *Econometrica* **84**(3), 1265–1287.

Lloyd's (2015), 'Equivalency Under Solvency II'.
URL: *http://www.lloyds.com/The-Market/Operating-at-Lloyds/Solvency-II*

Mathworks (2015), 'Hodrick-Prescott Filter', *Matlab Documentation R2015a* .
URL: *http://ch.mathworks.com/help/econ/hodrick-prescott-filter.html*

Moody's Inverstor Services (2014), 'Global Reinsurance Negative Outlook: Buyers Wield Strong Bargaining Power and Continue to Explore Cheaper Alternatives to Traditional Reinsurance'.

Shumway, R. H. and Stoffer, D. S. (2010), *Time Series Analysis and Its Applications: With R Examples*, Springer Science & Business Media.

Standard & Poor's (2014), 'Global Reinsurance Highlights 1993 - 2014'.

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 4/2009* (Zurich, Switzerland).

Swiss RE (2015*a*), 'Natural Catastrophes and Man-Made Disasters in 2014: Convective and Winter Storms Generate Most Losses', *Sigma* **2**.

Swiss RE (2015*b*), 'Swiss Re Capital Markets Insurance-Linked Securities'.