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Cassandra Cole and Kathleen McCullough
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Evolution or Revolution? How
Solvency II Will Change the Balance
Between Reinsurance and ILS

Alexander Braun
Joel Weber



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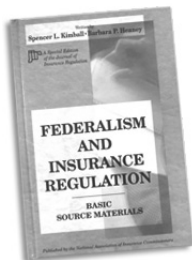
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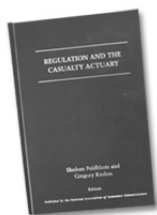
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Evolution or Revolution? How Solvency II Will Change the Balance Between Reinsurance and ILS

Alexander Braun*
Joel Weber**

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 beyond market prices. It is estimated by means of OLS, decomposed into a trend and a 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% of the global property-catastrophe reinsurance limit or approximately \$101 billion by the end of 2018.

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1. Introduction

In recent years, insurers have increasingly employed insurance-linked securities (ILS) to cede risks to the 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 \$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 (EU). 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 U.S. probably offered the most favorable regulatory environment. The National Association of Insurance Commissioners (NAIC) generally considers properly structured ILS as reinsurance. In the EU, in contrast, the regulatory framework was less obvious. Under Solvency I, risk transfer instruments without an indemnity trigger were generally not treated as reinsurance and therefore disregarded for solvency capital measurement (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, 2015c). The Committee of European Insurance and Occupational Pensions Supervisors (CEIOPS) 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 of insurance companies, thus decreasing the Solvency Capital Requirement in the same way as traditional reinsurance (see, e.g., Dittrich, 2010). Hence, according to both industry professionals and policymakers, the new regulatory framework

1. Apart from the prevailing regulatory regime, insurance companies also need to consider accounting standards, as well as the treatment of ILS by rating agencies. Under International Financial Reporting Standards (IFRS) and U.S. generally accepted accounting principles (GAAP), most ILS are treated as reinsurance (see, e.g., Swiss Re, 2009).

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) 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.”

The literature on ILS and regulation is generally scarce. An early advance was made by Cummins (2008), who suggested that an explicit inclusion of the financial strength of reinsurance providers into regulatory capital requirements would modernize solvency regulation in general and provide a substantial upswing to ILS markets. Similarly, Cummins and Weiss (2009) identified both the regulatory and the accounting treatment of ILS as major impediments for further growth of the alternative capital. In their view, a major issue for many ILS structures is that regulators are not prepared to grant sponsors the advantages of reinsurance accounting and solvency capital relief. Hence, a resolution to these obstacles would clearly benefit the market for ILS. Furthermore, Eling and Pankoke (2016) evaluate the contribution of the insurance sector to systemic risk. Based on their analysis, they conclude that ILS products are a valuable backstop for sponsors, since they tap into the financial markets to allow for the diversification of large insurance risks such as natural catastrophes or pandemics on a global scale. Finally, Smack (2016) focuses on the regulation of catastrophe bonds, which have been one of the fastest growing ILS market segments in recent years. She argues that regulators should address existing problems with regard to documentation, collateralization, accounting and tax treatment to promote a wider adoption of these instruments.

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 then conducted 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, we present our conclusion in section five.

2. Theoretical Analysis

2.1 The Model Economy

Profit Function

Our model economy is inspired by the work of Kojien and Yogo (2016).² It consists of a representative property/casualty (P/C) 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. The 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 :

$$\Pi_t = P_t \cdot Q_t - V_t \cdot Q_t - \gamma_t R_t \cdot ILS_t - PR_t \cdot RE_t + V_t \cdot ILS_t + V_t \cdot RE_t, \quad (1)$$

where V_t is the actuarially fair value of the insurance policy (expected value of the liabilities).³ 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 $\gamma_t R_t$ instead of the market price R_t . The coefficient $\gamma_t \geq 1$ represents the insurer's individual assessment of risk mitigation through ILS relative to traditional reinsurance.⁴ 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 underwriting assistance and advisory services to enter the model. For $\gamma_t = 1$, ILS and traditional reinsurance are perfect substitutes.⁵ For $\gamma_t > 1$, 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 $\gamma_t > 1$.⁶

2. An overview of the notations for our theoretical framework can be found in the Appendix.

3. For the sake of simplicity, we abstain from modelling operating costs of the insurance company.

4. In other words, traditional reinsurance acts as a numeraire good.

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

6. The provision of underwriting assistance and other technical services by reinsurance companies are often mentioned as additional benefits of a reinsurance contract. The price of the

The Subjective ILS Price Coefficient γ_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 \$800 million and the market was dominated by repeat issuers, this changed between 2005 and 2007. The strong growth in first-time issuance has additionally been fueled by Hurricane Katrina, which led to a sharp increase in U.S. property-catastrophe reinsurance rates (see, e.g., Hartwig, 2012). Due to this hard reinsurance market, the industry likely became more comfortable with the use of ILS as a substitute for traditional contracts. In 2007, the issuance volume of first-time issuers grew significantly and reached \$3.5 billion. 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 estimated γ_t . (See Figure 2.) Consequently, 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 ($PR_t < \gamma_t R_t$) or vice versa ($PR_t > \gamma_t R_t$). 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:

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

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 theoretical sense, as reinsurers face financing constraints that render larger coverages more expensive. Similarly, Froot and O'Connell (1999) argue that capital market imperfections "raise the marginal costs

latter can, thus, be seen as the cost for the whole package, including, but not limited to, the transfer of risk (see, e.g., Gibson et al., 2014).

7. This is consistent with the results of Braun et al. (2013), who show that experience and expertise are key determinants of insurers' demand for cat bond investments.

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 , ΔL_t , can be described as follows:

$$\Delta L_t = V_t(Q_t - RE_t - ILS_t). \quad (3)$$

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 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 , ΔA_t :

$$\Delta A_t = P_t \cdot Q_t - \gamma_t R_t \cdot ILS_t - PR_t \cdot RE_t. \quad (4)$$

While conducting its activities, the insurance company has to comply with the statutory capital requirements under Solvency II, K_t^* , imposed by the regulator. The latter are based on two measures: 1) the Solvency Capital Requirement (SCR); and 2) the Minimum Capital Requirement (MCR). For the purpose of simplicity, we focus on SCR, which is set above MCR (see, e.g., European Commission, 2015).⁸ Given the dynamics for the assets and liabilities, the firm’s available regulatory capital in period t , K_t , is defined as:

$$K_t = A_t - (1 + \rho)L_t. \quad (5)$$

8. The European Commission (2015) defines SCR and MCR as follows: “The Solvency Capital Requirement is a level of financial resources that enables insurers to absorb significant losses and that gives reasonable assurance to policyholders and beneficiaries that payments will be made as they fall due. The Minimum Capital Requirement is a lower, minimum level of security below which the amount of insurers’ financial resources should not fall, otherwise supervisory authorities may withdraw authorisation.”

The risk charge ρ (> 0) is the decision variable of the regulator and inflates the insurer's liabilities to create an additional capital buffer for the absorption of shocks. The higher it is, the tighter the regulation. 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 K_t falls below K_t^* , 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 Commission, 2015). We model these regulatory costs in line with Kojien and Yogo (2016) through a function C_t , which depends on the capital level K_t held by the insurance company:

$$C_t = C(K_t). \quad (6)$$

C_t exhibits the following first and second-order derivatives:

$$\frac{dC_t}{dK_t} < 0, \quad (7)$$

$$\frac{d^2C_t}{dK_t^2} > 0. \quad (8)$$

Hence, an increasing level of capital K_t reduces regulatory frictions, 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 :

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

where d_{t+1} is the stochastic discount factor. In other words, firm value consists of current profits minus regulatory costs plus the present value of expected future profits. The latter are summarized in the firm value at time $t + 1$, which is also influenced by the level of capital held today. 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 .

Optimal Insurance Price

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 envelope theorem:

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

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

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

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

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

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:

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

When deriving (9) explicitly, we obtain

$$\begin{aligned} V_t - PR_t(RE_t) - PR_t'(RE_t) \cdot RE_t \\ + c_t(-PR_t(RE_t) - PR_t'(RE_t) \cdot RE_t + (1 + \rho)V_t) \stackrel{!}{=} 0. \end{aligned} \quad (14)$$

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

$$PR_t^r(RE_t) = \left(\frac{1 + c_t(1 + \rho)}{1 + c_t} \right) V_t - PR'_t(RE_t) \cdot RE_t, \quad (15)$$

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 than or equal to $PR_t^r(RE_t)$. Equation (15) also shows how the reservation price behaves, given changes in its various components. More specifically, it increases in the marginal costs of regulatory friction (c_t) and in the regulator's risk charge for the capital requirements (ρ). In addition, marginal reinsurance costs have an impact. Whether the corresponding relationship is positive or negative depends on the quantity of coverage purchased. Due to the convex cost function $PR_t(RE_t)$, the reservation price for traditional reinsurance will drop below the reservation price for ILS once some non-negative quantity RE_t^* is exceeded.

Optimal Reinsurance through ILS

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

$$\frac{\delta J_t}{\delta ILS_t} = \frac{\delta \Pi_t}{\delta ILS_t} + c_t \cdot \frac{\delta K_t}{\delta ILS_t} \stackrel{!}{=} 0. \quad (16)$$

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

$$V_t - \gamma_t R_t + c_t(-\gamma_t R_t + (1 + \rho)V_t) \stackrel{!}{=} 0. \quad (17)$$

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

$$R_t^r = \left(\frac{1 + c_t(1 + \rho)}{\gamma_t(1 + c_t)} \right) V_t. \quad (18)$$

It is now apparent that the willingness to pay for ILS depends on four factors: 1) the actuarially fair value of the insurance policy (V_t); 2) the strictness of the regulatory capital requirements (ρ); 3) the marginal costs of regulatory frictions (c_t); and 4) the subjective ILS price coefficient (γ_t).⁹

9. 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.

The Relationship Between Reinsurance and ILS

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

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

Since γ_t plays a crucial role in Equation (19), it is a key driver of the relative demand for the two risk mitigation instruments. For $\gamma_t = 1$, reinsurance and ILS are perfect substitutes. Thus, the only decisive factor are the marginal reinsurance costs $PR'_t(RE_t)$. In contrast, if $\gamma_t > 1$ (e.g., due to additional benefits provided by the reinsurer), ILS are perceived to be less attractive than reinsurance. Consequently, the marginal costs for the latter need to be high so that 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 γ_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.

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 γ_t . More specifically, the ratio of alternative reinsurance capital to total reinsurance capital, $ILS_t/(RE_t + ILS_t)$, will be described by the following linear regression:¹⁰

$$\frac{ILS_t}{RE_t + ILS_t} = \alpha + \beta \left(\frac{R_t}{PR_t} - 1\right) + \epsilon_t, \quad (20)$$

10. By considering the sum of traditional and alternative capital, we accommodate the fact that Solvency II will improve the sponsors' ability to account for ILS as reinsurance, thus being able to treat the two risk transfer channels as real substitutes.

with intercept α , regression coefficient β , and error term ϵ_t .¹¹ Assuming a well-behaved empirical demand function, the volume ratio ($ILS_t/(RE_t + ILS_t)$) 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 γ_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 .¹² The relationship, however, is an inverse one: A reduction of γ_t , 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 $\hat{\gamma}_t$ by halving the reciprocal of the sum of the estimate for the intercept $\hat{\alpha}$ and the fitted residuals $\hat{\epsilon}_t$:

$$\hat{\gamma}_t = \frac{1}{2} \cdot \frac{1}{(\hat{\alpha} + \hat{\epsilon}_t)} = \frac{1}{2} \cdot \left(\frac{ILS_t}{RE_t + ILS_t} - \hat{\beta} \left(\frac{R_t}{PR_t} - 1 \right) \right)^{-1}. \quad (2)$$

Hence, the simple regression model in (1) is aligned with our theory from the previous section. In case both instruments exhibit exactly the same objective price ($R_t = PR_t$), the dependent variable is solely determined by $\alpha + \epsilon_t$.¹³ If additionally $\gamma_t = 1$, both instruments 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, as published by Guy Carpenter (2016a).¹⁴ Their reported alternative capacity is an aggregate measure, comprising the volumes of cat bonds, Industry Loss Warranties (ILWs), sidecars and collateralized reinsurance.¹⁵

11. The linear relationship between the two variables has been chosen based on a scatterplot. Although the R^2 of the trendline can be further improved by resorting to higher-order polynomial functions, this is not advisable due to the limited degrees of freedom offered by our short data series.

12. As a corollary, we do not need to include any further control variables.

13. This is why, in the regression model, the actual price ratio R_t/PR_t has been corrected by minus 1.

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

15. 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.

Table 1: Descriptive Statistics (2002–2016)

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 contains the mean, minimum and maximum values of the annual time 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 spread multiple (R_t), reinsurance price per unit of risk (PR_t) and ratio of ILS to reinsurance prices per unit of risk ($R_t/PR_t - 1$).

Furthermore, an operationalization of $R_t/PR_t - 1$ has to rely on a measure for the reinsurance price per unit of risk (PR_t) and the ILS price per unit of risk (R_t). First, we construct PR_t based on the Rate on Line Index by Guy Carpenter (2016b), 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 premium per unit of ceded exposure for the year 1990 as published by Froot and O’Connell (1999).¹⁶ We deem this to be a reasonable approximation because the U.S. is the largest property-catastrophe reinsurance market in the world (see, e.g., Standard & Poor’s, 2014).¹⁷ Second, R_t is proxied by the ILS multiple, i.e., the ratio of ILS spread to expected loss. Time series of averages for both variables across all transactions in a given year are reported by Artemis (2016).¹⁸

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% of the total. Moreover, the mean of the ILS multiple (R_t) is 3.65. Therefore, the coupon spread that ILS investors received on average equaled 3.65 times the expected loss that they assumed over the given time period. This compares to a mean reinsurance price per unit of risk (PR_t) of 4.51. The latter implies that between 2002 and 2016, ceding one unit of catastrophe risk through traditional contracts was associated with an average annual premium of 4.51 times the actuarial expected loss. 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

16. It should be noted that this premium 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.

17. To ensure robustness, we performed a cross-check with a time series of global reinsurance premium volumes divided by insured losses that has been provided by Swiss Re (2015a). The figures of both approximations are largely consistent.

18. Artemis.bm is a well-known industry website specializing in ILS.

$(R_t/PR_t - 1)$. The former increased quite steadily over the years, peaking at almost 18% 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.¹⁹

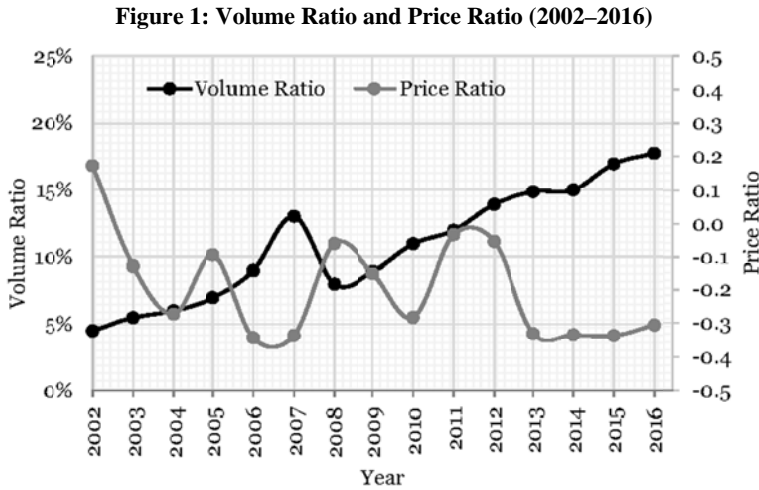


Figure 1 shows the time series of the ratio of alternative capital in percent of the global catastrophe reinsurance limit ($ILS_t/(RE_t + ILS_t)$) and the ratio of ILS prices per unit of risk to reinsurance prices per unit of risk ($R_t/PR_t - 1$). These two variables form the basis for our time series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

3.3 Estimation of β and γ_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, $\hat{\gamma}_t$ 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 $\hat{\gamma}_t$ 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 γ_t , we will be able to predict the impact of Solvency II on the balance between reinsurance and ILS.

19. 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 (see, e.g., Braun, 2016).

Table 2 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 $\hat{\gamma}_t$ has been plotted in Figure 2. Consistent with our theory, $\hat{\gamma}_t$ 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.

Table 2: OLS Regression Results

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 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: * ($p < 0.1$), ** ($p < 0.05$), *** ($p < 0.01$).

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 $\hat{\gamma}_t$ 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), which reports that between 2005 and 2007, first-time sponsors were responsible for a substantial part of the increased ILS issuance activity.

The first wipeout of a cat bond after Hurricane Katrina marked another important milestone in the evolution of $\hat{\gamma}_t$. According to Cummins and Weiss (2009), the wipeout 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.” Therefore, it is not surprising that $\hat{\gamma}_t$ decreased substantially from 2004 to 2005, as the insurance industry received a positive signal regarding the reliability of ILS.

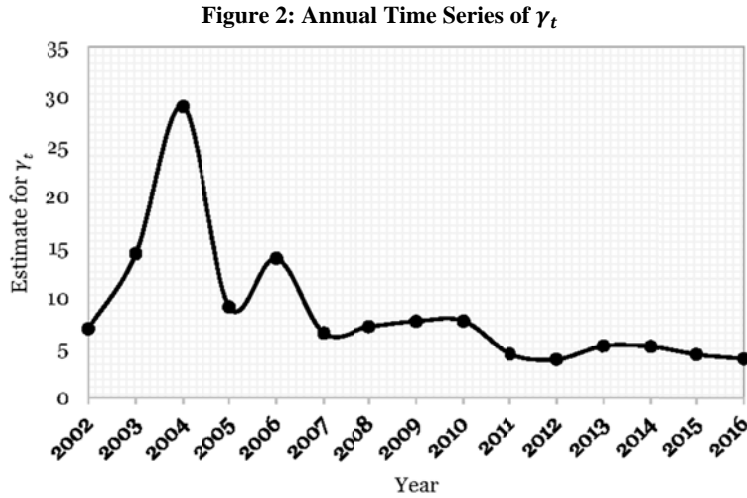


Figure 2 shows the estimated time series of the subjective price factor $\hat{\gamma}_t$ between 2002 and 2016. It has been calculated as the reciprocal of (two times) the sum of the intercept $\hat{\alpha}$ and the fitted residuals $\hat{\epsilon}_t$. The decreasing trend is in line with our expectation that the insurance industry has gone through a constant learning process with regard to the usage of ILS as a risk mitigation tool.

Finally, it is worth pointing out that the default of Lehman Brothers in 2008 only led to a slight upward movement in $\hat{\gamma}_t$, although it caused 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 that 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 $\hat{\gamma}_t$ in the following years.

3.4 Forecasting the Model

Having developed an understanding of the historical evolution of $\hat{\gamma}_t$ 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 $\hat{\gamma}_t$, 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).²⁰

20. The HP filter is often applied in the context of Business Cycle Analysis (see Hodrick and Prescott, 1997). In contrast to the method of differencing, it is well suited for shorter time

We apply the HP-Filter to the log-transformed \hat{y}_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) suggest 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 ascertain that autocorrelation is not an issue. Moreover, unreported QQ-plots of the residuals indicate that they are almost normally distributed. Hence, there is no need for further model refinements.

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

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 contains the results for the ARMA(3,3) model fitted to the cyclical component of the time series of \hat{y}_t , as generated by the HP filter. All coefficients, including the constant, turn out statistically significant. The R^2 -figure indicates 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.

In a next step, we forecast values for \hat{y}_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. This describes the learning process of the insurance industry and the steady advancement of ILS instruments. The resulting \hat{y}_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.²¹

series because it avoids the loss of observations.

21. Although Solvency II came into force in January 2016, some insurers may have adapted

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

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 $\hat{\gamma}_t$ 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 $\hat{\gamma}_t$. 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. (See Figure 3.)

In Table 4, we develop a range of scenarios for the change in the trend of $\hat{\gamma}_t$. 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% of the second largest segment of cat bonds, which are based on indemnity triggers (see Artemis, 2015b; AON Benfield, 2017). However, even for the remaining 40% 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 $\hat{\gamma}_t$ and adopt a slight slowdown 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 $\hat{\gamma}_t$ -trend of merely 0.5 times the one that occurs in the baseline scenario (i.e., -0.045 instead of -0.09).

their operations beforehand. This, however, refers to the models for economic capital and internal processes. The improved regulatory recognition of ILS, in contrast, could not be exploited before the actual launch of the new framework. In addition, even after the new rules have been put in place, some uncertainty about the actual interpretation of the ILS rules ILS in practice remains to date. Hence, the long time period from 2002 to 2016 allows for the derivation of a clean baseline scenario.

The corresponding $\hat{\gamma}_t$ -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 $\hat{\gamma}_t$ -trend (i.e., -0.14 instead of -0.09). This leads to $\hat{\gamma}_t$ -values of 2.76 for 2017 and 2.38 for 2018. In the most optimistic scenario, we let the trend component of $\hat{\gamma}_t$ decline 2.25 times as quickly as in the baseline scenario. Therefore, we obtain $\hat{\gamma}_t$ -values of 2.58 for 2017 and 2.07 for 2018.

Figure 3: Forecast of Trend and Cyclical Component Under Solvency II

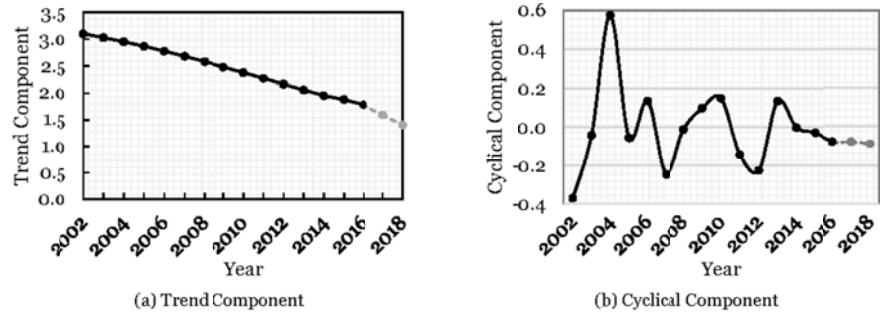


Figure 3 shows the trend component and the cyclical component of the subjective price factor $\hat{\gamma}_t$. The forecast values for 2017 and 2018 have been derived as follows. The trend component has been adjusted in line with the expected impact of Solvency II under the optimistic scenario (2x faster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

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 $\hat{\gamma}_t$ 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 $\hat{\gamma}_t$ -scenarios based on a negatively-skewed Gumbel distribution with parameters $\mu = 2.25$ and $\sigma = 0.40$.²² In doing so, we ensure that outcomes for the subjective price factor $\hat{\gamma}_t$ below the optimistic scenario and above the pessimistic scenario occur only in 10% of the cases. To put it differently, 80% 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.

22. To adequately represent our scenarios, we need a negatively skewed probability distribution with a mean well below the status quo value and 10% of the outcomes above the optimistic and below the pessimistic case, respectively. We found that the Gumbel distribution, which is commonly used in Extreme Value Theory, fulfills these requirements. However, any other distribution with similar characteristics could be employed as well.

Table 4: Scenario Analysis for $\hat{\gamma}_t$ in 2018

Trend	1.69	1.59	1.50	1.36
Cycle				
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 shows the range of outcomes for the subjective price factor $\hat{\gamma}_t$ in 2018 based on the different scenarios for the trend and the cyclical component. For the trend component, the following four scenarios are considered: pessimistic (1.69), baseline (1.59), mean (1.50) and optimistic (1.41). For the cyclical component, 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 20 outcomes are derived from a Gumbel distribution.

3.6 Probability Distribution for the Volume Ratio

We can now translate the values for $\hat{\gamma}_t$ into volume ratios in 2017 and 2018. For this purpose, we employ the relationship shown in Equation (20) and assume that the price ratio stays on its historical average level.²³ Overall, the outcomes for 2018 lie between a minimum of 19% and a maximum of 28%. Figure 4 illustrates our four main scenarios. In the pessimistic scenario, we obtain volume ratios of approximately 19% in 2017 and 20% in 2018. Furthermore, the respective values in the baseline scenario are 20% in 2017 and 22% in 2018, and the mean scenario is associated with volume ratios of 21% in 2017 and 24% in 2018. Finally, the optimistic scenario leads to volume ratios of 22% in 2017 and 27% in 2018. Thus, we expect the volume ratio in 2018 to be approximately 10% higher than without Solvency II (compare mean and baseline scenario).²⁴

Due to the shape of the Gumbel distribution for $\hat{\gamma}_t$, 80% of the potential outcomes for the volume ratio in 2018 are located between 20% and 27%. 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 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 \$85.93 billion to \$114.58 billion. The expected volume ratio of 24% in 2018 (mean scenario) corresponds to an ILS volume of around \$101.14 billion, which is \$8 billion higher than in the baseline scenario (without Solvency II) and corresponds to an increase of approximately \$27 billion compared to 2016.

23. 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, 2015a). Therefore, a constant price ratio does not seem to be a strong assumption.

24. The following calculation applies: $24/22 = 1.10$.

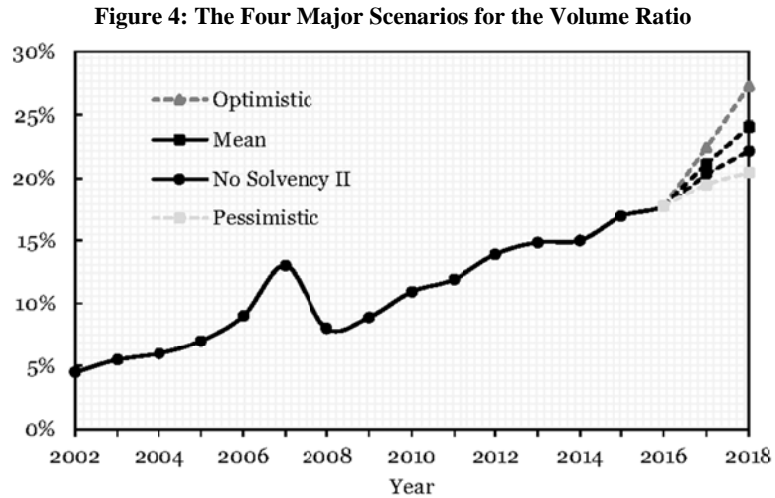


Figure 4 depicts the future evolution of the volume ratio (ILS as percentage of global reinsurance limit) in the four main scenarios. The baseline scenario is an extrapolation of the historical development without the impact of Solvency II. The optimistic scenario with only 10% of the probability mass above it describes a strong impact of Solvency II. The pessimistic scenario with 90% 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.

4. Economic Implications

The expected increase in the volume of ILS relative to traditional reinsurance associated with Solvency II will have consequences for investors, insurers, reinsurers and regulators. In the following, we are going to provide some thoughts on how these groups 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, 2015a). 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, as those who are adept at transferring risk via 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 the ability of ILS to gain further market share through a reduction of the objective price will be limited in the next years.

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 Investor 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 our subjective price factor γ_t . According to Moody's Investor 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., suggests that companies that 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 became more specialized and ILS more standardized, the two instruments could continue to be complements instead of substitutes.

Regulators need to be aware of the aforementioned consequences for both ILS and reinsurance markets. One explicit objective of Solvency II is to reward companies with appropriate risk-management techniques in place (see European Commission, 2007). Hence, the capital relief that will now be achievable for a wider range of instruments and the associated increase in the adoption of ILS coverage is certainly a desired outcome. In addition, the further dissemination of modern risk transfer techniques meets the regulatory goal of promoting financial stability. It is also in the interest of regulators to establish a level playing field between different providers of coverage. We expect this to be achieved, although certain ILS with non-negligible basis risk will only be admissible, if the sponsor runs a complex internal solvency model rather than the Solvency II standard formula. Finally, regulatory authorities need to consider potential negative consequences for both the insurance and reinsurance sector as well. Since Solvency II is likely going to strengthen ILS as a substitute and, therefore, as a competitor for traditional reinsurance contracts, the reinsurance industry might face a prolongation of the

currently prevailing soft market, as well as a further deterioration of their financials.

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 an OLS regression based on data for the period from 2002 to 2016. We decomposed the resulting time series into a trend and a 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 \$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.

A major limitation of our work is the lack of suitable data for a purely objective assessment of the relationship between Solvency II and the subjective ILS price coefficient. Hence, our results need to be treated with all due caution, and follow-up research throughout the upcoming months should focus on the accumulation of additional evidence to support our forecast.

Appendix

Table 5: Overview of Notations for the Theoretical Framework

Variable	Description
γ_t	Subjective ILS price coefficient
Π_t	Profit function of the insurer
P_t	Premium of the insurance policy
Q_t	Quantity of the insurance policy
V_t	Actuarially fair value of the insurance policy
R_t	ILS spread per unit of risk ceded (spread multiple)
PR_t	Reinsurance premium per unit of risk ceded
ILS_t	Volume of alternative reinsurance capital (ILS)
RE_t	Volume of traditional reinsurance capital
RE_t^*	Inflection point of marginal reinsurance costs
ΔL_t	Change in the liabilities of the insurance company
ΔA_t	Change in the assets of the insurance company
K_t^*	Capital requirement imposed by the regulator
K_t	Available regulatory capital of the insurer
ρ	Regulatory capital (risk) charge
C_t	Regulatory cost function
J_t	Firm value function
d_{t+1}	Stochastic discount factor
c_t	Marginal cost of regulatory friction
R_t^r	Reservation price for ILS coverage
PR_t^r	Reservation price for reinsurance coverage

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Cummins, J. David and Richard A. Derrig, eds., 1989. *Financial Models of Insurance Solvency*, Norwell, Mass.: Kluwer Academic Publishers.

Manders, John M., Therese M. Vaughan and Robert H. Myers, Jr., 1994. “Insurance Regulation in the Public Interest: Where Do We Go from Here?” *Journal of Insurance Regulation*, 12: 285.

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