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# Diversification and Solvency II: the capital effect of portfolio swaps on non-life insurers

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## Abstract

Diversification plays a pivotal role under the risk-based capital regime of Solvency II. The new rules reward large and well-diversified insurance companies with relatively low capital requirements compared to those of small and specialised nature. To enhance diversification, insurance companies can adjust their strategy by engaging in mergers and acquisitions or new market entries. Alternatively, insurers can accept higher Solvency II capital requirements, displaying a competitive disadvantage and impeding future growth. This research proposes a Solvency II portfolio swap as a new diversification solution that allows small and specialised insurance companies to improve their diversification, and thus, mitigate their diversification disadvantage. The effect of such swaps is demonstrated through the use of two hypothetical insurance companies by swapping 20% of their portfolio over four different scenarios. The swap allowed for a 6% reduction in the Solvency Capital Requirement (SCR) and a maximum increase of the SCR coverage ratio of 17%. With Solvency II posited to stimulate further mergers and acquisitions within the European insurance market, this paper offers an alternative method for insurers to diversify their portfolio. Furthermore, it is suggested that the proposed alternative risk transfer method may improve insurance market competition within the EU by facilitating small and specialised insurers' competitiveness.

**Keywords** Solvency II · Insurance · Diversification · Alternative risk transfer · Regulation

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## Introduction

The implementation of Pan-European insurance regulations, Solvency II, has changed the regulatory capital requirements regime for insurers from a volume-based measure to a risk-based approach. The objective of this approach is to better reflect the underlying risk profile of an insurer. However, the new rules could also lead to higher capital requirements. Indeed, under the new rules of Solvency II, the Quantitative Impact Study 4 (QIS 4) found that non-life insurers face three to four times higher capital requirements in comparison to Solvency I (Timetric 2016). While diversification plays a pivotal role under the Solvency II regime, the new rules reward large and well-diversified insurance companies with lower capital requirements. On the other hand, small and specialised insurers may face relatively high capital requirements, possibly due to limited or non-existent geographical or product diversification. Such a diversification disadvantage could threaten the existence of these companies. Along with the limitation of diversification opportunities, they could become a vulnerable target amongst large insurers looking for investment opportunities to foster growth. This research proposes a Solvency II portfolio swap as an alternative diversification method allowing insurers with a high degree of risk concentration to overcome their diversification disadvantage under the current Solvency II regime. The swap benefits include a reduction of the Solvency Capital Requirement (SCR), an increase of the Solvency ratio, and a rise of the insurer's own funds, while simultaneously retaining the net premium income. Furthermore, through cost-effective diversification, this research will help small and medium insurers to persist in and contribute to sustaining a competitive insurance market for the European Union (EU). The effect of the Solvency II swap is illustrated using two hypothetical insurance companies swapping 20% of their insurance risks. For both insurers, the impact on the SCR, coverage ratio and Solvency II balance sheet is analysed.

The aim of Solvency II is to enhance the resilience of the insurance industry and improve customer protection (Swain and Swallow 2015). To do so, Solvency II pursues a holistic risk assessment approach based on three pillars: (1) quantitative requirements, (2) governance and supervision requirements, and (3) disclosure and transparency requirements (Lloyd's 2010). Within the first pillar, insurance companies are obliged to hold sufficient capital against their risks, which is referred to as the SCR. The SCR calculation can be conducted through the Standard Formula or a (partial) internal model (Heep-Altiner et al. 2018). This paper focuses on a portfolio swap for non-life insurers to enhance their diversification benefits under the Standard Formula. A functional Microsoft Excel model is provided in the Supplementary Material presenting how insurers may benefit from using a Solvency II portfolio swap. This model includes the relevant Solvency II Standard Formula calculations and can be adapted freely by readers to create and replicate swap scenarios.

The Standard Formula of Solvency II follows a modular approach in which the overall risk exposure is divided into different risk modules, each comprised of submodules (EIOPA 2014). Both the risk modules and submodules are



aggregated using a correlation matrix. The Standard Formula's risk modules contain market risk, counterparty default risk, life underwriting risk, health underwriting risk, non-life underwriting risk and intangible asset risk. For non-life insurers, the most significant risk module is the non-life underwriting risk, which amounts to 52.4% of the overall diversified solo Basic Solvency Requirement (BSCR) (EIOPA 2011). Additionally, diversification effects reduce the non-life underwriting SCR by 20% on average (EIOPA 2011). Insurers may also decide to develop an internal model to better reflect the company's unique risk profile, in accordance with the European Commission (2015) Delegated Regulation (Articles 114–127). Partial or full internal models are significantly individualised to the specific insurer for which it is created (Heep-Altiner et al. 2018). The realised capital benefits derived from the Solvency II portfolio swap would vary depending on the methodology taken during internal model development. However, the Solvency II Standard Formula (Articles 100–110) used in this research provides a standardised method to measure the risk reduction benefits of the portfolio swaps between two counterparties in an equivalent manner.

The non-life risk is further divided into premium and reserve risk, catastrophe risk and lapse risk. The premium and reserve risk covers the risk arising “[...] from fluctuations in the timing, frequency and severity of insured events” as well as risk occurring from fluctuations “[...] in the timing and amount of claim settlements” (European Commission 2009, Article 105a) and has the highest proportion of the risk charge for the non-life module (EIOPA 2011). The non-life catastrophe risk contains “the risk of loss, or of adverse change in the value of insurance liabilities, resulting from significant uncertainty of pricing and provisioning assumptions related to extreme or exceptional events” (European Commission 2009, Article 105b). Last, the lapse risk covers risks stemming from the policyholder's opportunity to exercise contractually agreed options *inter alia* premature contract termination and contract renewal to previously agreed conditions (European Commission 2010). However, the lapse risk can be seen as insignificant as its contribution to overall non-life risk capital charge is less than 1% (EIOPA 2011). Both the catastrophe and the premium and reserve risk are seen as the primary drivers of the non-life SCR.

Previous research has investigated the determinants of insurer insolvency risk, methods of efficient insurance portfolio risk allocation and the impact of risk transfer methods on capital requirements. Caporale et al. (2017) highlight that the lines of business underwritten by general insurance companies and their reinsurance levels are key determinants of insolvency in the U.K. Similarly, Gestel et al. (2007) investigated the relationship between financial ratios and credit ratings for different types of insurers. The authors found that different credit rating models were needed for different insurer business types (non-life, life, composite, reinsurance, financial guarantors). Nguyen and Vo (2020) also show that European insurers who concentrate on insurance as their core business and operate in more mature markets have a higher solvency level. With risk concentration identified as a key determinant of insurer insolvency risk, this research article proposes a novel swap innovation for insurance counterparties to diversify their portfolios, geographically and by business line.



Kim and Hardy (2009) propose a capital allocation methodology based on a solvency exchange option. Similar to the Solvency II Standard Formula outlined in European Commission (2015) Articles 100–110, the proposed method seeks to adjust capital allocation using a risk-based approach at a line-of-business level. Specifically, the property insurance line of business was shown to better diversify with Energy Efficiency Insurances than other financial market instruments such as weather derivatives (Baltuttis et al. 2020). For large insurance conglomerates, intra-group transfers of insurance underwriting risk have been shown to be an effective risk management tool for optimising capital requirements (Asimit et al. 2016). From a risk transfer perspective, Asimit et al. (2015) describe how to structure an optimal non-life reinsurance contract under the Solvency II regulatory framework. The authors find similar optimal reinsurance structures derived from two different calculation methods of the risk margin. While previous literature has investigated the potential to optimise insurance portfolio risk under the Solvency II framework, no previous research has considered insurance portfolio swaps as a mechanism to achieve this. This is the first paper to evaluate the diversification, risk reduction and solvency capital effect of two insurance counterparties mutually benefitting from portfolio swap under the Solvency II regime.

Many practitioners and researchers have predicted that Solvency II could foster merger and acquisition (M&A) activities across the insurance sector. Stoyanova and Gründl (2014) provide empirical evidence that Solvency II could evoke a wave of M&As within the European non-life insurance sector. The authors applied a theoretical model to assess an insurer's decision to consolidate based on input factors such as the costs associated with the M&A, the SCR calculation method post-merger, the riskiness of an insurer's business, and the size of the merging insurers. Their findings suggest that through cross-border consolidation, insurance companies could take advantage of geographic diversification, resulting in an enhanced cost efficiency due to reduced capital requirements. Furthermore, Conning and Company (1995) (as cited in Cummins and Xie 2008) noted that upon the implementation of the risk-based capital (RBC) standard in 1994 (a major regulatory change in U.S. property-liability insurance), the number of M&As spurred due to well-capitalised insurers acquiring financially vulnerable companies. Likewise, Cummins and Xie (2008) and Cummins et al. (1999) found that financially vulnerable companies are more likely to be acquired than insurers with a strong financial record for the U.S. property-liability insurance sector and U.S. life insurance industry, respectively.

For example, the leading global insurer AXA received approval to acquire the Bermuda-based specialist insurer, XL Group. According to AXA (2018), the acquisition of XL is expected to reduce XL Group's SCR by approximately 30%, benefiting AXA Group's solvency ratio by about 5 to 10 points. Other effects resulting from the acquisition were cost synergies, revenue synergies and reinsurance synergies, altogether amounting to approximately USD 400 million pre-tax earnings per annum. In contrast, a wave of M&A activities in the wake of Solvency II could be disadvantageous for the European insurance market. Particularly, the disappearance of small and specialised insurers could encourage the formation of only a few large market participants who then dominate the market and determine prices. Furthermore, these large, well-diversified companies may have a financially stronger



position but also increase risk, which could promote a higher risk concentration and ultimately enable the emergence of systemic risk.

Currently, the two leading theories in the literature on the impact of M&As on a firm's functioning are the conglomeration hypothesis and the strategic focus hypothesis. Advocates of the conglomeration hypothesis claim diversified firms that operate in several business lines, or offer a broad product variety, can profit from cost and revenues scope economies, and therefore achieve better efficiency than specialised firms (Berger et al. 2000; Liebenberg and Sommer 2008; Cummins et al. 2010; Biener et al. 2016). Cost scope economies can arise from reduced production costs through the utilisation of shared resources, whereas revenue scope economies result from 'one-stop shopping' customer preferences (Cummins and Xie 2008). In contrast to the conglomeration hypothesis, advocates of the strategic focus hypothesis emphasise the benefits of specialisation (Berger et al. 2000; Cummins and Nini 2002; Liebenberg and Sommer 2008; Cummins et al. 2010). According to this theory, concentrating on the main business and core competencies is value-maximising for firms.

Utilising the concept of profit scope economies, Berger et al. (2000) sought to contrast the relative efficiency between diversified and specialised insurers in the U.S. during the period between 1988 and 1992. Their work defined insurers conducting business in both property-liability (P-L) and life-health (L-H) insurance as diversified, while those operating in only one segment were labelled as specialists. The results were mixed and dependent on the type of firm. For large insurers that specialised in offering personal lines, the conglomeration hypothesis dominated. In contrast, for small insurers specialised in offering commercial lines, the strategic focus hypothesis is deemed more appropriate. Similarly, Cummins et al. (2010), analysed the economies of scope for the U.S. insurance sector between 1993 and 2006. Their research compared insurers providing both P-L and L-H insurance with those specialising in either one of these segments (P-L or L-H). Opposite to Berger et al. (2000), their findings suggest no robust support for scope economies. Hence, Cummins et al. (2010) conclude that insurers specialising in only one insurance segment (P-L or L-H) are superior to companies pursuing a strategy of diversification, which is consistent with the strategic focus hypothesis.

While the aforementioned studies of Berger et al. (2000) and Cummins et al. (2010) investigated the difference between P-L and L-H insurers, several studies have focused specifically on diversification effects within the property-liability insurance market. Using a sample of 914 property-liability insurers between 1995 and 2004, Liebenberg and Sommer (2008) examined the impact of line-of-business diversification on insurers' performance. Their results demonstrated a diversification penalty of 1% of return on assets (ROA), or 2% of return on equity (ROE), indicating that non-diversified insurers outperform those of a diversified nature. Furthermore, using a sample of 718 U.S. property-liability insurers between 1994 and 2002, Elango et al. (2008) found that geographic diversification affected the relationship between product diversification and firm performance. Their results indicated that inefficiencies tend to outweigh any prospect synergies; thus, high levels of diversification across both geography and products is disadvantageous with respect to the



insurer's performance. Firms showed the best performance results with high product diversification and modest geographical diversification.

In agreement with Elango et al. (2008), Shim (2011) found that higher product diversification for insurers seems to be associated with lower financial performance, indicating that additional diversification costs outweigh any possible synergy effects. Using a sample of U.S. property-liability insurers over a 15-year period (1989–2004), Shim (2011) provided empirical evidence that the financial performance of the acquiring insurer decreased while its earnings volatility increased during the post-merger integration time. With respect to cost efficiency, Luhnén (2009) analysed the productivity of 295 companies in the German property-liability insurance industry between 1995 and 2006. They labelled specialised insurers as those gaining more than two thirds of their annual premium income in one line of business. Their results indicated that specialised insurers were superior to diversified insurers that spread their business across various lines of business. Furthermore, Luhnén's (2009) results revealed that, in Germany, 90% of the large and 75% of the medium-sized property-liability insurers operate under decreasing returns to scale (DRS). This indicated that further growth (e.g. through M&As) would not improve these insurers' efficiency.

Apart from the impact of M&As on the efficiency of insurers, another area of concern is their effect on the financial stability of the insurance market. A wave of M&As could lead to an increase in insurance market concentration and lead towards a market with only a few large insurers. Among the existing literature, two contradicting hypotheses regarding the effect of market concentration have evolved: the concentration-stability view and the concentration-fragility view (Beck et al. 2006; Uhde and Heimeshoff 2009; Shim 2017). The concentration-stability view emphasises the benefits of market concentration, arguing that higher market concentration is allied with enhanced financial stability (Shim 2017). On the other hand, the concentration-fragility view suggests that market concentration is negatively related to financial stability (Shim 2017). Most of the literature focuses on the banking sector, however, with studies explicitly targeting the insurance industry being limited.

Shim (2017) scrutinises the relationship between market concentration and financial stability of insurance companies and argues in agreement with the concentration-fragility view. Using a sample of U.S. property-liability insurers between 1992 and 2010, Shim (2017) applied a Z-score as a proxy measure for financial stability and the industry Herfindahl index to replicate market concentration. The results demonstrated a negative relationship between market concentration and financial stability or, in other words, higher market concentration was linked to lower financial stability. The results of Shim (2017) are in line with the findings of Altuntas and Rauch (2017), who investigated the impact of concentration on an insurer's financial stability using regression analysis. Their sample comprised 14,402 firm-years of property-liability insurers in 29 countries between 2004 and 2012. Altuntas and Rauch (2017) provided empirical evidence for the concentration-fragility view. In contrast to Shim (2017) and Altuntas and Rauch (2017), who focused on the relationship between risk concentration and financial stability on a broader scale, Mühlnickel and Weiß (2015) examine the contribution of consolidation in the insurance industry, specifically to systemic risk. Their study comprised 394 M&As



with transaction volumes of at least USD 50 million, or purchased stakes of 50% or higher. Their results indicated a strong positive relationship between consolidation and moderate systemic risk, and they conclude that insurance mergers can cause destabilisation in the insurance and banking industries.

Past research, as demonstrated above, explores the potential effects of M&As on the insurance industry, as well as emphasises the benefits of specialised insurers for the industry. Insurers seek to use their capital in the most efficient way; however, with the current Solvency II regime in place, small and specialised insurers are at a disadvantage. These companies are being penalised by capital charges due to missing or limited diversification. To manage their capital, insurers can use special forms of reinsurance, such as structured reinsurance, or engage in M&As. Swaps can also be an effective alternative to reinsurance or M&As. Swaps are an agreement between two counterparties to exchange cash flows of an underlying asset (Liebwein 2009). Since the first swap agreement between IBM and the World Bank in 1981 (Smith et al. 1988), financial swaps have grown in popularity as a tool for market participants to manage financial market turbulence and increasing volatility (Takeda 2002). In addition to financial swaps, there is also the opportunity to exchange insurance risks through so-called risk swaps – a financial instrument enabling the exchange of two (one-on-one risk swap) or more insurance risks (multi-risk-swap) (Takeda 2002). In a risk swap, two insurers agree to exchange the cash flows of an insurance portfolio serving as the underlying asset (Liebwein 2009). For example, two insurance companies, one located in Ireland and one located in Germany, can agree to exchange 20% of each other's motor insurance portfolio (including premiums and future claims). In principle, such an exchange is comparable to the concept of reciprocity (Swiss Re 1996; Kielholz and Durrer 1997), which dates back to 1881 when reciprocal reinsurance arrangements were first used (Norgaard 1964). In reciprocal reinsurance agreements, the cedent obtains insurance risk (usually a similar proportion) from its reinsurer in return for its cession (Carter et al. 2000).

With risk swaps, both entities can swap their overexposure (or at least a part of it) against another risk class not contained in their portfolio prior to the swap. This allows diversification effects of multi-dimensional scope, and thus enables a more efficient portfolio of insurance risks (Grandi and Müller 1999). According to Takeda (2002), risk swaps must be clearly defined and quantified to be on a parity condition, meaning both sides of the swap have the same expected loss. Although they do not necessarily have to be designed on a parity basis, it is advantageous as no exchange of money is required (Cummins 2008; Njegomir and Maksimović 2009). In the past, risk swaps were mainly associated with catastrophe exposures. For example, in 2010 Tokio Marine and State Farm exchanged Tokyo earthquake exposure against Madrid earthquake exposure, each worth USD 200 million (Takeda 2002). At an insurance group level, intra-group transfers have been shown to optimise the risk position while reducing the technical provisions and capital requirements for the entire conglomerate (Asimit et al. 2016). Similar to the proposed portfolio swaps, these intra-group transfers utilise proportional risk transfers. However, to achieve optimal insurance risk diversification, the risk management tool is shown to be most beneficial to large insurance groups. This research article extends this concept to small insurers



who may achieve risk diversification through Solvency II portfolio swaps with an insurance counterparty.

Currently, under the Solvency II regime, risk swaps have the potential to serve as an effective instrument for small and specialised insurers in managing their risk capital. As specialised insurance companies tend to outperform insurers of a more diversified nature, the Solvency II swap provides a useful diversification solution for such insurers. By exchanging a specific amount of insurance risks, specialised insurers could enhance their risk diversification while avoiding an acquisition or a new market entry. In theory, the swap enables them to synthesise the efficiency of specialised insurers with the lower capital requirements of a diversified insurance company.

This research proposes Solvency II portfolio swaps as an alternative diversification method for small and specialised insurance companies. These Solvency II portfolio swaps would enable these companies to benefit from geographical or product diversification under the Standard Formula of Solvency II and, as a consequence, reduce their SCR. Furthermore, such a swap will contribute to sustaining a competitive insurance market for the EU. A key differentiator between M&As and Solvency II portfolio swaps as a tool for non-life insurance portfolio diversification is the exchange of equity. Portfolio swaps do not involve real equity transfer between insurers. The swaps represent a strategic alliance between two insurance counterparties who may mutually benefit from exchanging insurance risks.

The remainder of the paper is organised as follows. First, we introduce the methodology, including the structure of the Solvency II portfolio swap, the different scenarios conducted, and the data used. The subsequent section presents the results of the Solvency II portfolio swap. The Discussion and Conclusion sections outline the swap's impact and implications for the European insurance industry, and provide a proposal for future research.

## Research methodology

This research proposes a Solvency II portfolio swap to optimise primary insurers' capital efficiency through enhanced diversification. The purpose of the swap is to provide primary insurers with a tool to diversify their portfolio and reduce their SCR, while also maintaining their net premium earned. The Solvency II swap was constructed as a reciprocal exchange of insurance risk between two insurance companies (see Fig. 1).



Fig. 1 Solvency II swap



To analyse the swap effect, we established two hypothetical insurance companies that swapped a predefined proportion of their insurance portfolio in four different scenarios. In order to broaden the generality of the resulting portfolio swap benefits, this research details four scenarios, which reflect all methods an insurer may use to diversify their non-life insurance risk and optimise their portfolio through geographical diversification and line-of-business diversification. The four scenarios illustrate the diversification benefits of portfolio swaps on single-line/multi-line insurers in the same/different geographical regions.

The first scenario comprises an Irish and German insurer in which the Irish insurer's exposure consisted of property insurance only (referring to line of business no.4 in Annex I, European Commission 2015), while the portfolio of the German insurer solely comprised motor insurance risks (referring to line of business no.7 in Annex I, European Commission 2015) (see Table 1). The proportion swapped between the two counterparties amounted to 20% of their portfolio. This threshold was chosen based on the '80/20' rule, limiting inwards reinsurance to 20% of gross net premiums for Irish insurers. Although the Central Bank of Ireland removed the 20% limitation on inwards reinsurance, insurers that seek to exceed the 20% threshold are obliged to submit a business plan that requires approval from the central bank (Central Bank of Ireland 2010). Furthermore, we assumed the swap to be set up on a funds-withheld basis to mitigate the counterparty default risk (Bank of England 2016). In a funds-withheld agreement, all or a specified share of the ceded premium remains at the cedent as collateral against future obligations against the reinsurer (Hayes et al. 2011). In this swap, the collateral is equal to the exposure for the counterparty default calculation; therefore, there is no increase in the capital requirement for the counterparty default risk. In order to assess the impact of the swap on the two insurers under the current Solvency II regime, the Standard Formula was modelled in Excel. To gain a clearer understanding of the effect of the Solvency II swap, we also illustrated its impact for the premium and reserve risk module as well as the catastrophe risk module hereinafter.

According to the European Commission (2015), the capital charge for the premium and reserve risk is calculated as follows:

$$SCR_{pre\&res} = 3 \cdot \sigma_{nl} \cdot V_{nl}$$

where  $\sigma_{nl}$  refers to the combined standard deviation for the non-life premium and reserve risk and  $V_{nl}$  refers to the volume measure for the non-life premium and reserve risk. The volume measure  $V_{nl}$  is calculated as the sum of the volume measures for each line of business  $V_s$  with

$$V_s = (V_{prem,s} + V_{res,s}) \times (0.75 + 0.25 \times DIV_s).$$

$DIV_s$  displays the factor for geographical diversification within each line of business and allows for a diversification effect up to 25%. In order to quantify the diversification effect, the Herfindahl index is used (European Commission 2015, Annex III). This is defined as the sum of the squared volume measures for the premium and reserve risk for each geographical region relative to the squared sum of the overall line of business volume measure (Hürlimann 2009). Within Europe, the Standard



Table 1 Input data scenario 1

Counterparty details	Counterparty 1		Counterparty 2	
	Name of Entity	Irish property insurer	German motor insurer	
Geographic exposure country	Ireland		Germany	
Geographic exposure region	Northern Europe		Western Europe	
Loss ratio	80%		80%	
Combined ratio	95%		95%	
SCR ratio as reported	165%		165%	
Non-life premium & reserve risk submodule	V prem	V res	V prem	V res
Motor liability insurance**	0	0	200,000	200,000
Other motor insurance and proportional reinsurance**	0	0	0	0
Marine, aviation and transport insurance**	0	0	0	0
Fire and other damage to property insurance**	200,000	200,000	0	0
Sum	200,000	200,000	200,000	200,000
<i>Non-Life catastrophe risk submodule</i>				
SCR Cat	55,000		55,000	
<i>Non-life lapse risk submodule</i>				
SCR lapse	1000		1000	
<i>Market risk submodule</i>				
SCR market	45,000		45,000	
<i>Life risk submodule</i>				
SCR life	0		0	
<i>Health risk submodule</i>				
SCR health	0		0	
<i>Intangible assets risk submodule</i>				
SCR intangible asset	1000		1000	
<i>Operational risk submodule</i>				
SCR operational risk	6000		6000	



**Table 1** (continued)

Counterparty details	Counterparty 1	Counterparty 2
<i>Adjustment submodule</i>		
SCR adjustments	38,000	38,000

\* All figures in EUR thousand

\*\* And proportional reinsurance



Formula allows insurers to diversify their business across four geographic regions: Northern, Western, Eastern and Southern Europe (European Commission 2015, Annex III). The combined standard deviation ( $\sigma_{nl}$ ) for the premium and reserve risk follows a two-step procedure. For each line of business, the Standard Formula defines one standard deviation for the premium risk ( $\sigma_{prem}$ ) and one for the reserve risk ( $\sigma_{res}$ ), which are then aggregated to a combined standard deviation per insurance segment. Using a given correlation matrix, all line of business standard deviations are aggregated to the overall standard deviation ( $\sigma_{nl}$ ) for the non-life premium and reserve risk (European Commission 2015, Annex IV), which allows for diversification across business lines.

In scenario one, the volume measure for the premium and reserve risk was equally weighted for both insurers and consisted of EUR 200 million for both the premium risk and reserve risk, respectively (see Table 1). The Solvency II swap enabled both insurers to exchange 20% of their premium exposure while their reserve volume was not affected. Prior to the swap, the Irish insurer had EUR 200 million Northern European property exposure, whereas the German insurer held EUR 200 million Western European motor exposure. As the swap was set as 20% of the premium exposure, the notional amount swapped consisted of EUR 40 million. After the swap, the Irish insurer's Northern European property exposure reduced to EUR 160 million and it simultaneously received EUR 40 million Western European motor exposure. The German insurer held EUR 160 million Western European motor exposure and EUR 40 million property exposure post-swap. Regarding the volume of the premium and reserve risk, both counterparties had the same exposure pre- and post-swap; however, the swap allowed the insurers to diversify their exposure through different lines of business. Geographical diversification only occurs at the line-of-business level (i.e. swapped portfolios must be the same line of business originating in different regions), making geographical diversification benefits unachievable in this scenario.

The catastrophe risk module for non-life insurers comprises natural catastrophes and man-made catastrophes (European Commission 2015). The Standard Formula provides a scenario-based and a factor-based approach to calculate the capital charge. This research uses the scenario-based calculation. Furthermore, man-made catastrophe risk is excluded from our calculation. This simplification allowed for a better illustration, as the non-life underwriting risk module and especially the catastrophe risk submodule was subject to criticism due to its high complexity (EIOPA 2011).

Natural catastrophe risk contains five perils: windstorm risk, earthquake risk, flood risk, hail risk and subsidence risk (only for France) (European Commission 2015). For each of these perils, a capital charge is calculated at the country level (Ehrlich and Kuschel 2011). Thereby, the sums insured serve as a volume measure, which are multiplied with a given risk factor. Additionally, the Standard Formula defines specific scenarios in which the capital requirement equals the larger of the sequence of two events. Using a correlation matrix, the countries' capital requirements are aggregated to the overall capital charge for each peril. Finally, the natural catastrophe risk submodule is determined as the root of the sum of each peril's squared capital requirements (European Commission 2015).



Due to the nature of the catastrophe risk module, the Irish insurer was exposed to windstorm risk in Ireland, while the German insurer was subject to exposure for flood and hail risk in Germany. Following a 20% swap, the Irish and German insurer reduced their windstorm risk and flood and hail risk, respectively, to 80% of their initial exposure and simultaneously assumed 20% of their counterparty's risk. Consequently, both insurers were exposed to windstorm, flood and hail risk, with the Irish insurer's major exposure being windstorm and the German insurer's flood and hail risk. The swap allowed for diversification via different perils because, under the Standard Formula, both property (windstorm for Ireland) and motor (flood and hail for Germany) business cover different perils. In order to additionally diversify across geographic areas within the catastrophe risk module, both counterparties needed to hold exposure of the same peril (e.g. a German and Irish insurer with windstorm exposure).

Apart from scenario one, we conducted three additional scenarios, all of which followed the aforementioned methodology. For the second scenario, we conducted a swap between an Irish property and a German property insurer (Table 4, Appendix A), controlling for geographical diversification. Scenario three examined Irish and German diversified insurers, with both holding an equally weighted portfolio of insurance risks (Table 7, Appendix B). Within this scenario, business line and geographical diversification benefits can be achieved. Last, scenario four investigated the impact of the swap between two German insurance companies, one only with property and one only with motor exposure (Table 10, Appendix C). The underwriting risks investigated in the study are derived from the non-life line of business segments as defined in Annex I to Delegated Regulation (E.U.) 2015/35. The inclusion of other segments, for example marine, aviation and transport insurance, would change the standard deviations included for non-life premium and reserve risk used to calculate the SCR, resulting in alternative risk-based SCR reductions (European Commission 2015).

The data used to calculate the SCR ratio was based on the QIS 5 (EIOPA 2011). According to this study, the average insurer has an SCR ratio of 165%, which served as the pre-swap SCR in this research. Furthermore, to assess the swap's impact on each counterparty's Solvency II balance sheets, we compiled a balance sheet based on the average QIS 5 solo insurer. Overall, the QIS 5 study comprised data of 2,520 insurance companies, of which 1,284 were non-life insurers. Of the non-life insurers, only 72 were classified as large companies (> EUR 1 billion gross written premiums), 378 were considered medium (EUR 0.1 billion – 1 billion gross written premiums), and 834 were labelled as small (< EUR 0.1 billion gross written premiums) (EIOPA 2011). As small and medium-sized insurers were our target group, the QIS 5 served as a comprehensive data set for our research.

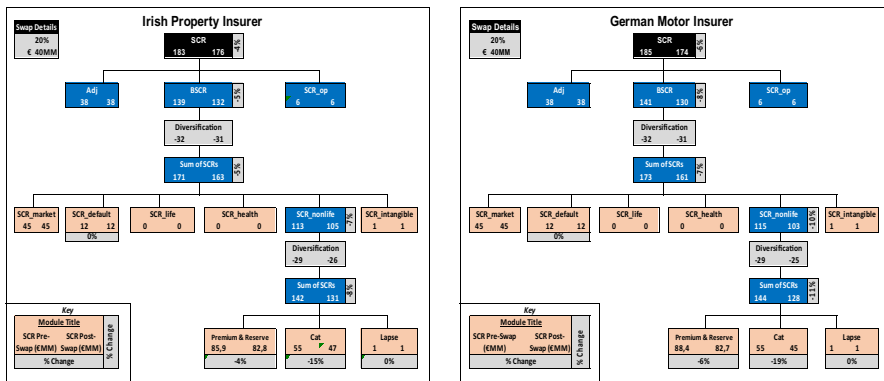
## Results

Table 2 summarises the Solvency II portfolio swap results for scenario one in which Irish property risk was exchanged against German motor risk. Prior to the swap, the combined ratio for both counterparties was set at 95%. Consequently,



**Table 2** Swap summary scenario 1

Company name	Counterparty 1 Irish property insurer	Counterparty 2 German motor insurer
Geographic region	Northern Europe	Western Europe
Life / non-life	Non-life	Non-life
Line of business	Property	Motor
Premium volume	200 m	200 m
Reserve volume	200 m	200 m
Combined ratio %	95%	95%
SCR (pre-swap)	183 m	185 m
Combined ratio % (post-swap)	95%	95%
SCR (post-swap)	176 m	174M
Capital relief from swap	8 m	11 m
Portfolio swap %	20%	20%
Portfolio swap notional EUR	40 m	40 m



**Fig. 2** Capital relief decomposed by risk modules for scenario 1

there was no change in the combined ratio post-swap. A capital reduction of 4.2% is observed for the Irish property insurer and 6.0% for the German motor insurer, resulting in a total amount of EUR 8 million and EUR 11 million, respectively. Figure 2 illustrates the capital relief decomposed into the various risk modules of the Standard Formula. For each module, the capital requirement pre- and post-swap and the percentage share of the capital relief are highlighted. A functional Microsoft Excel model is provided in the Supplementary Material illustrating the portfolio swap scenario one. This model includes the relevant Solvency II Standard Formula calculations and can be adapted freely by readers to replicate each swap scenario. Furthermore, the detailed calculation of the impact of the Solvency II portfolio swap on the premium and reserve underwriting risk for both insurance counterparties in scenario 1 is provided in Appendix D. For a detailed



description of SCR calculation using the Standard Formula, readers are referred to European Commission (2015) Delegated Regulation (Articles 100–110).

The swap reduced the Irish insurer's capital requirement by 3.6% for premium and reserve risk (85.9 million to 82.8 million) and by 14.8% for catastrophe risk (55.0 million to 47.0 million). In contrast, for the German insurer, the premium and reserve risk decreased by 6.5% (88.4 million to 82.7 million) and catastrophe risk decreased by 18.8% (55.0 million to 45.0 million) through the swap. Both counterparties experienced no change in lapse risk. The non-life SCR results from the aggregation of premium and reserve risk, catastrophe risk and lapse under consideration of predefined correlations (European Commission 2015). Regarding the swap's impact on the non-life SCR, a 7.2% decrease is observed for the Irish insurer and a 10.3% reduction for the German insurer. With respect to the Solvency II balance sheet, own funds increased by 4.4% and 3.5% for the Irish property insurer and German motor insurer, respectively, while the Solvency ratio rose by 15% and 17%, respectively (Fig. 3, Table 3).

The results for scenario two (Irish property and German property insurer) showed a capital reduction of 4.6% for the Irish property insurer and 4.8% for the Germany property insurer and an increase in the Solvency ratio of 14% and 15%, respectively (Appendix A). Scenario three (Irish diversified vs. German diversified insurer) illustrates a reduced capital requirement of 3.7% for the Irish diversified insurer and 5.3% for the German diversified insurer, while the coverage ratio increased, respectively, by 12% and 17% (Appendix B). In scenario four (German property vs. German motor insurer) the Germany property insurer's capital reduced by 1.8% and its solvency ratio increased by 7%, while the German motor insurer experienced a 3.9% lower capital requirement and 10% higher coverage ratio (Appendix C). Detailed information for scenarios two to four, such as the decomposed capital relief per risk module and the balance sheet impact, are illustrated in their respective appendices.

**Table 3** Solvency II balance sheet impact (pre- and post-swap) for scenario 1

Company name	Counterparty 1		Counterparty 2	
	Irish property insurer	Swap estimated impact	German motor insurer	Swap estimated impact
Total assets	2,387 m	2,387 m	2,415 m	2,415 m
Best estimate (non-life)	1,606 m	-4M	1,624M	4M
Risk margin (non-life)	136 m	-9.8 m	138 m	-14.2 m
Other liabilities*	343 m		347 m	
Total liabilities	2,085 m	2,072 m	2,109 m	2,098 m
Assets less liabilities	302 m	316 m	306 m	316 m
Subordinated liabilities	0 m	0 m	0 m	0 m
Total basic own funds	302 m	316 m	306 m	316 m
Solvency Capital Requirement	183 m	176 m	185 m	174M
Solvency ratio	165%	180%	165%	182%

\*Excluding liabilities subordinates



## Discussion

This research provides an alternative diversification method that allows insurers to improve their capital efficiency under the current Solvency II regulation, particularly those of small and specialised nature. The operation and effect of the swap using two hypothetical insurance companies is demonstrated by swapping 20% of their insurance portfolio. The swap's impact on various Solvency II risk modules, the SCR, coverage ratio and balance sheet is illustrated for four different scenarios. In this section, the key findings of this research are summarised, implications for the insurance market are explored, and limitations are discussed. Furthermore, directions for future research are suggested.

The ex-ante diversification benefits derived from the portfolio swap are demonstrated through the relative reduction in SCR using the Solvency II predefined Standard Formula. This risk-based computation provides a standardised, equivalent and industry-endorsed method for comparing the relative risk reductions of two insurance counterparties resulting from a portfolio swap. Indeed, insurance companies may use full or partial internal models to determine their specific SCR. These alternative models may enhance or weaken the capital effect of the diversification benefits from portfolio swaps, depending on the approach (Heep-Altiner et al. 2018). However, QIS 5 showed that SCR results derived from an internal model were very close to the SCR calculated using the Standard Formula at the individual insurer level (EIOPA 2011).

Overall, the results show that for all scenarios conducted, both insurers improved their capital efficiency through the utilisation of geographic or business line diversification, or through a combination of both. The reduction of the capital requirement ranged from 3.7% and 6.0% over all scenarios, with the exception of scenario four (German property vs German motor insurer), in which one counterparty only achieved a 1.8% decrease. The study finds that the swap achieves the best economic results for single line insurers operating in different Solvency II regions (e.g. Northern and Western Europe (scenarios two and three)). Furthermore, the swap results indicate that for insurers diversified through various business lines, the economic benefit is slightly less than for non-diversified insurers. The increase in basic own funds varied between 1.7% and 4.5%, whereas the SCR coverage ratios increased by between 7% and 17% post-swap across all scenarios.

Additionally, for both scenarios one (Irish property and German motor insurer) and four (German property and German motor insurer), the swap was more beneficial for the motor insurer due to the lower volatility of the property business. Within the Standard Formula, the adjusted standard deviation for the premium risk is 6.4% for property business and 8% for motor business (European Commission 2015, Annex II). Similar differences can be seen when looking at the different perils within the natural catastrophe risk module. For flood and hail risk, the initial motor exposure is adjusted by a factor of 1.5 and 5, respectively, whereas there is no adjustment for the initial property exposure (European Commission 2015). Therefore, by swapping motor exposure for property exposure, the motor insurer cedes a certain proportion of risk requiring a higher capital charge while



simultaneously assuming the same proportion of risk requiring a lower capital charge. However, the capital efficiency also improved for the property insurer post-swap as enhanced diversification outweighed the slightly higher capital charge for the assumed motor exposure. Additionally, it should be noted that both portfolios were equally profitable with a combined ratio of 95%.

The results of the Solvency II swap indicate a performance-enhancing effect on insurers' solvency, especially the SCR, coverage ratio and own funds. Insurance companies with a high degree of risk concentration could use our swap to enhance their diversification under the Standard Formula and thus reduce their solvency capital requirements. Although diversification is not the only factor driving an insurer's capital requirements, the British insurer Esure is an exemplar of the critical role of diversification. In 2015, under Solvency I, the coverage ratio for Esure was 390%, but it declined to 123% under Solvency II (Esure 2016). According to Fitch (2016), this was mainly driven by Esure's low diversified business profile (83% of its premiums came from its U.K. motor insurance portfolio) and only in part from their credit risk (approximately 10% investments in non-investment grade bonds).

The proposed portfolio swaps reflect, in principle, the diversification benefits derived from long-established reciprocal insurance (Carter et al. 2000) and risk swaps (Takeda 2002). Previously, insurers who engage in these exchanges seek to benefit, ex-post, from gaining a more efficient portfolio of insurance risks. However, this diversified risk allocation is now also reflected in lower risk-based Solvency II capital requirements. Therefore, the benefits of insurance portfolio diversification may be determined ex-ante, showcasing the potential for portfolio swaps and other risk exchange mechanisms to spread risk concentration and, thereby improve market competition and stability.

Alternatively, insurers could diversify their portfolios by entering new markets or even by acquiring another insurer. While both alternatives are deemed appropriate for large insurance companies, they may not be feasible for small and specialised insurers. Reasons for this may include a lack of knowledge that hinders entry into new and unknown markets, the high costs of an acquisition, and the uncertainty around as well as the long-term impact of such a decision. Furthermore, a wave of M&As within the European insurance sector could be negative as such a development, in which smaller insurers are acquired by large insurers, would ultimately strengthen large insurers' market power and reduce competition. As noted by Takeda (2002), the great advantage of risk swaps is that they reduce risk while keeping its cost at a minimum. Thus, the Solvency II swap provides an alternative diversification method that allows small and specialised insurance companies to overcome their diversification disadvantage at relatively low costs and enable them to prosper. By doing so, the swap also promotes a competitive EU insurance market.

Theoretically, the swap works; however, a disadvantage of such reciprocal reinsurance agreements is the possibility that the insurance risks ceded between the counterparties are different in their profitability. This research took the assumption that the risks ceded were equally profitable with a combined ratio of 95%, meaning both counterparties had the same expected loss. In practice, it is most likely that two insurers that are willing to conduct such a swap hold portfolios of different profitability, e.g. one portfolio has a combined ratio of 96% and the other portfolio's



combined ratio is 98%. In such a scenario, one company would benefit more than the other. Carter et al. (2000) argue that in such a case the agreement is highly likely to be terminated within a short time. Further, if the economic results of one portfolio are negative and the other positive, one counterparty would worsen their economic result. In the worst case, this could even turn a profit into a loss, which might hinder insurers from engaging in such swap activities. Other difficulties can be seen in finding an appropriate counterparty that also holds a low diversified portfolio and the uncertainty of the counterparty's underwriting quality. While the Solvency II swap provides an attractive diversification method, it also contains a certain degree of risk and uncertainty, which needs to be addressed.

Given the nature of the proposed Solvency II portfolio swap, the insurance risk reduction on each counterparty's portfolio is reflected in a lower SCR. This innovation is derived from the European regulatory capital requirements regime for insurers changing from a volume-based measure to a risk-based framework. Indeed, the portfolio swap benefits from the risk-based SCR computation, but it does not benefit from capital arbitrage in the structure presented. Capital arbitrage opportunities have been demonstrated with tail risk transfers between lighter (value-at-risk-based) and stricter (expected-shortfall-based) regulatory regimes (Asimit et al., 2013). However, the proposed portfolio swap does not exploit mispricing since the common Standard Formula is used to determine the SCR before and after the swap to determine the risk reduction. Furthermore, the portfolio swap does not benefit from regulatory arbitrage as the explicit capital and risk reductions are only clear for insurers within the Solvency II regulatory framework.

The implementation of a profit-based commission could help to overcome the hindrance of unequally profitable portfolios. In such a case, the counterparty with the lower profitability would compensate the other through the payment of an appropriate amount of money. The appropriate compensation would be the amount of money at which both insurers have the same profitability in their portfolios. In order to calculate the commission, the combined ratios of both counterparties, the notional amount swapped, and the current interest rate should be considered. By doing this, insurance portfolios with different profitability would be aligned, so that both insurers are at parity. This paper did not demonstrate this in the swap, as we had attempted to keep the swap at its most basic level to truly understand its impact. Future studies should consider the complexities that might be included in the model.

## Conclusion

This research proposes a diversification method that can be used by primary insurers to improve their portfolio diversification and enhance their capital efficiency. While risk swaps have been used within the insurance industry, mainly for catastrophe risk, we showed how the concept of swaps could be used by insurers as a capital management tool under the Solvency II regime. Using two hypothetical insurance companies swapping 20% of their insurance risk, the impact of the Solvency II swap is



illustrated across four different scenarios. The scenarios included separate diversification through geographical area or business line, as well as a combination of both. The results showed a positive impact on insurers' financial performance for all four scenarios conducted, including an SCR reduction of up to 6%. Furthermore, all scenarios showed an increase in insurers' solvency coverage and own funds.

With the presented research, insurers can use the swap to enhance their diversification under the Standard Formula. By exchanging a specific amount of insurance risks, insurers could enhance their risk diversification while avoiding an acquisition or a new market entry. More predominantly, small organisations could use it as a new method to offset diversification disadvantages that exist for them under Solvency II at relatively low cost. Specialised insurance companies tend to outperform insurers of a more diversified nature. In theory, the swap enables the synthesis of the benefits of a specialised insurer with those of a diversified company. However, companies should consider their organisational strategy and choose a diversification method that aligns with their business model. To fully understand the benefits, companies could use internal data and examine the impact specific to their company, and then compare the results to their current reinsurance solution.

The research findings indicate that the swap is an effective method for smaller insurance companies to avoid the diversification disadvantages of Solvency II. Although some limitations exist and additional features are needed for the swap to be more efficient, it provides a new diversification solution. It is clear that the Solvency II portfolio swap and other methods of diversification need to be further explored within the Solvency II literature. The initiation of Solvency II regulations allows space for financial innovation by allowing insurers to alleviate their geographical or product offering concentrations through the use of a Solvency II portfolio swap (Fig. 4).

## **Appendix A: Irish property insurer vs. German property insurer**

See Tables 4, 5, 6, and Fig. 4 and 5.



Table 4 Input data scenario 2

Counterparty details		Counterparty 1	Counterparty 2
Name of entity		Irish property insurer	German property insurer
Geographic exposure – country		Ireland	Germany
Geographic Exposure – region		Northern Europe	Western Europe
Loss ratio		80%	80%
Combined ratio		95%	95%
SCR ratio as reported		165%	165%
<i>Non-life premium &amp; reserve risk submodule</i>		V prem	V prem
Motor liability insurance**		0	0
Other motor insurance and proportional reinsurance**		0	0
Marine, aviation and transport insurance**		0	0
Fire and other damage to property insurance**		200,000	200,000
Sum		200,000	200,000
<i>Non-life catastrophe risk submodule</i>			
SCR Cat		55,000	55,000
<i>Non-life lapse risk submodule</i>			
SCR lapse		1000	1000
<i>Market risk submodule</i>			
SCR market		45,000	45,000
<i>Life risk submodule</i>			
SCR life		0	0
<i>Health risk submodule</i>			
SCR health		0	0
<i>Intangible assets risk submodule</i>			
SCR intangible asset		1000	1000
<i>Operational risk submodule</i>			
SCR operational risk		6000	6000
		V res	V res
		0	0
		0	0
		0	0
		200,000	200,000
		200,000	200,000



**Table 4** (continued)

Counterparty details	Counterparty 1	Counterparty 2
<i>Adjustment submodule</i>		
SCR adjustments	38,000	38,000

\* All figures in EUR thousand  
 \*\* And proportional reinsurance



**Table 5 Swap summary scenario 2**

Company name	Counterparty 1 Irish property insurer	Counterparty 2 German property insurer
Geographic region	Northern Europe	Western Europe
Life / non-life	Non-life	Non-life
Line of business	Property	Property
Premium volume	200 m	200 m
Reserve volume	200 m	200 m
Combined ratio %	95%	95%
SCR (pre-swap)	183 m	183 m
Combined ratio % (post-swap)	95%	95%
SCR (post-swap)	175 m	174M
Capital relief from swap	8 m	9 m
Portfolio swap %	20%	20%
Portfolio swap notional EUR	40 m	40 m

**Table 6 Solvency II balance sheet impact (pre- and post-swap) for scenario 2**

Company name	Counterparty 1		Counterparty 2	
	Irish property insurer	Swap estimated impact	German property insurer	Swap estimated impact
Total assets	2,387 m	2,387 m	2,387 m	2,387 m
Best estimate (non-life)	1,606 m	0 m	1,606 m	0 m
Risk margin (non-life)	136 m	-10.9 m	136 m	-11.3 m
Other liabilities*	343 m		343 m	
Total liabilities	2,085 m	2,074M	2,085 m	2,074M
Assets less liabilities	302 m	313 m	302 m	314M
Subordinated liabilities	0 m	0 m	0 m	0 m
Total basic own funds	302 m	313 m	302 m	314M
Solvency Capital Requirement	183 m	175 m	183 m	174M
Solvency ratio	165%	179%	165%	180%

\*Excluding liabilities subordinates



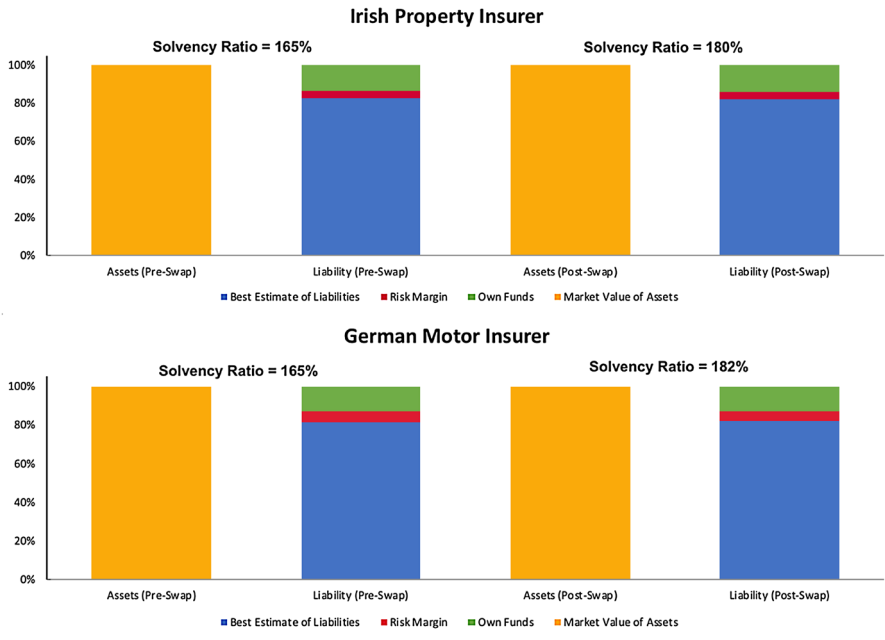


Fig. 3 Swap impact on the Solvency II balance sheet for scenario 1

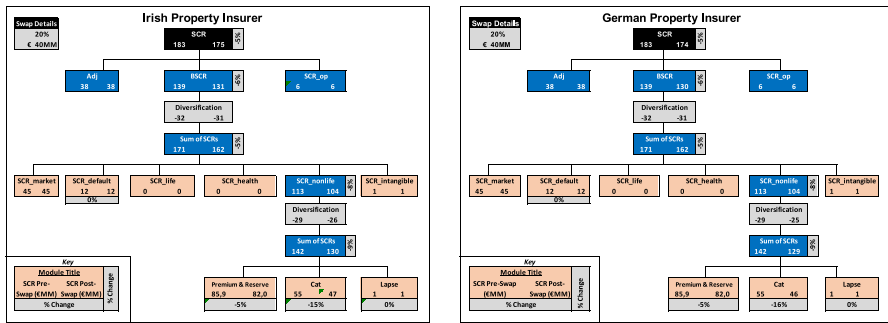


Fig. 4 Capital relief decomposed by risk modules for scenario 2



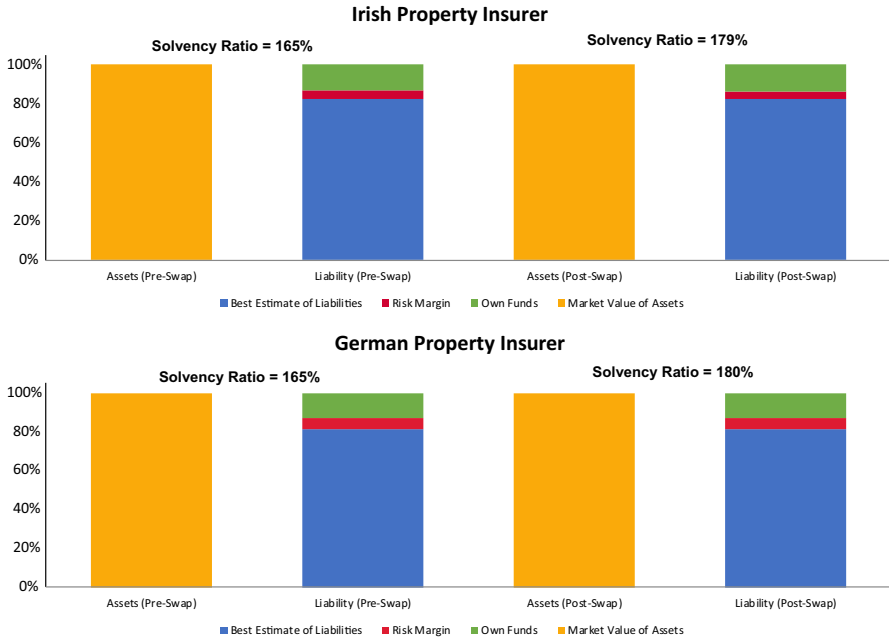


Fig. 5 Swap impact on the Solvency II balance sheet for scenario 2

**Appendix B: Irish diversified insurer vs. German diversified insurer**

See Tables 7, 8, 9 and Figs. 6 and 7.



**Table 7** Input data scenario 3

Counterparty details	Counterparty 1		Counterparty 2	
Name of entity	Irish div. insurer		German div. insurer	
Geographic exposure – country	Ireland		Germany	
Geographic exposure – region	Northern Europe		Western Europe	
Loss ratio	80%		80%	
Combined ratio	95%		95%	
SCR ratio as reported	165%		165%	
Non-life premium & reserve risk submodule	V prem	V res	V prem	V res
Motor liability insurance**	50,000	50,000	50,000	50,000
Other motor insurance and proportional reinsurance**	20,000	20,000	20,000	20,000
Marine, aviation and transport insurance**	50,000	50,000	50,000	50,000
Fire and other damage to property insurance**	80,000	80,000	80,000	80,000
Sum	200,000	200,000	200,000	200,000
<i>Non-life catastrophe risk submodule</i>				
SCR Cat	55,000		55,000	
<i>Non-life lapse risk submodule</i>				
SCR éapse	1000		1000	
<i>Market risk submodule</i>				
SCR market	45,000		45,000	
<i>Life risk submodule</i>				
SCR life	0		0	
<i>Health risk submodule</i>				
SCR health	0		0	
<i>Intangible assets risk submodule</i>				
SCR intangible asset	1000		1000	
<i>Operational risk submodule</i>				
SCR operational risk	6000		6000	
<i>Adjustment submodule</i>				
SCR adjustments	38,000		38,000	

\*All figures in EUR thousand

\*\*And proportional reinsurance



**Table 8 Swap summary scenario 3**

Company name	Counterparty 1		Counterparty 2	
	Irish diversified insurer		German diversified insurer	
Geographic region	Northern Europe		Western Europe	
Life / non-life	Non-life		Non-life	
Line of business	Multi-line		Multi-line	
Premium volume	200 m		200 m	
Reserve volume	200 m		200 m	
Combined ratio %	95%		95%	
SCR (pre-swap)	171 m		171 m	
Combined ratio % (post-swap)	95%		95%	
SCR (post-swap)	165 m		162 m	
Capital relief from swap	6 m		9 m	
Portfolio swap %	20%		20%	
Portfolio swap optional EUR	40 m		40 m	

**Table 9 Solvency II balance sheet impact (pre- and post-swap) for scenario 3**

Company Name	Counterparty 1		Counterparty 2	
	Irish Diversified Insurer	Swap Estimated Impact	German Diversified Insurer	Swap Estimated Impact
Total Assets	2,232 m	2,232 m	2,232 m	2,232 m
Best Estimate (Non-Life)	1,501 m	0 m	1,501 m	0 m
Risk Margin (Non-Life)	128 m	-8.8 m	128 m	-12.7 m
Other liabilities*	321 m		321 m	
Total Liabilities	1,949 m	1,941 m	1,949 m	1,937 m
Assets less Liabilities	283 m	291 m	283 m	295 m
Subordinated Liabilities	0 m	0 m	0 m	0 m
Total Basic Own Funds	283 m	291 m	283 m	295 m
Solvency Capital Requirement	171 m	165 m	171 m	162 m
Solvency Ratio	165%	177%	165%	182%

\*Excluding liabilities subordinates



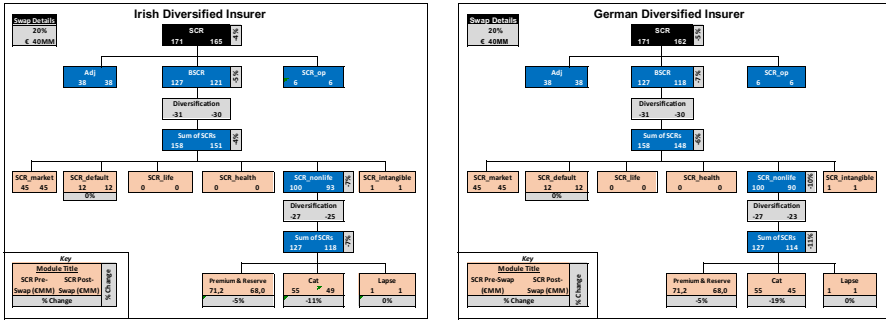


Fig. 6 Capital relief decomposed by risk modules for scenario 3

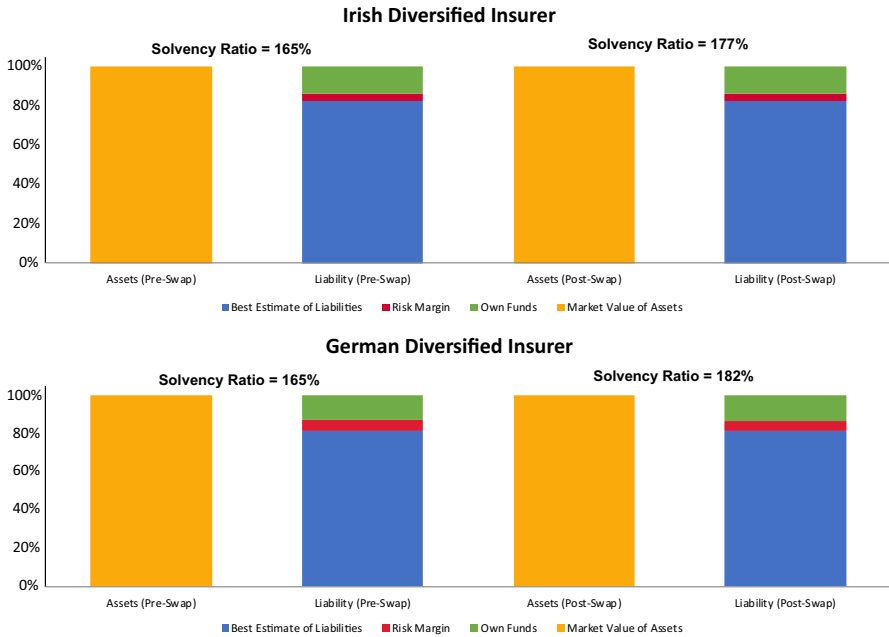


Fig. 7 Swap impact on the Solvency II balance sheet for scenario 3

## Appendix C: German property insurer vs. German motor insurer

See Tables 10, 11, 12 and Figs. 8 and 9.



**Table 10** Input data scenario 4

Counterparty details	Counterparty 1		Counterparty 2	
Name of entity	German property insurer		German motor insurer	
Geographic exposure – country	Germany		Germany	
Geographic exposure – region	Western Europe		Western Europe	
Loss ratio	80%		80%	
Combined ratio	95%		95%	
SCR ratio as reported	165%		165%	
<i>Non-life premium &amp; reserve risk submodule</i>	V prem	V res	V prem	V res
Motor liability insurance**	0	0	200,000	200,000
Other motor insurance and proportional reinsurance**	0	0	0	0
Marine, aviation and transport insurance**	0	0	0	0
Fire and other damage to property insurance**	200,000	200,000	0	0
<i>Sum</i>	200,000	200,000	200,000	200,000
<i>Non-life catastrophe risk submodule</i>				
SCR Cat	55,000		55,000	
<i>Non-life lapse risk submodule</i>				
SCR lapse	1000		1000	
<i>Market risk submodule</i>				
SCR market	45,000		45,000	
<i>Life risk submodule</i>				
SCR life	0		0	
<i>Health risk submodule</i>				
SCR health	0		0	
<i>Intangible assets risk submodule</i>				
SCR intangible asset	1000		1000	
<i>Operational risk submodule</i>				
SCR operational risk	6000		6000	
<i>Adjustment submodule</i>				
SCR adjustments	38,000		38,000	

\*All figures in EUR thousand

\*\*And proportional reinsurance



**Table 11 Swap summary scenario 4**

Company Name	Counterparty 1		Counterparty 2	
	German property insurer		German motor insurer	
Geographic region	Western Europe		Western Europe	
Life / non-life	Non-life		Non-life	
Line of business	Property		Motor	
Premium volume	200 m		200 m	
Reserve volume	200 m		200 m	
Combined ratio %	95%		95%	
SCR (pre-swap)	183 m		185 m	
Combined ratio % (post-swap)	95%		95%	
SCR (post-swap)	180 m		178 m	
Capital relief from swap	3 m		7 m	
Portfolio swap %	20%		20%	
Portfolio swap notional EUR	40 m		40 m	

**Table 12 Solvency II balance sheet impact (pre- and post-swap) for scenario 4**

Company name	Counterparty 1		Counterparty 2	
	German property insurer	Swap estimated impact	German motor insurer	Swap estimated impact
Total assets	2,387 m	2,387 m	2,415 m	2,415 m
Best estimate (non-life)	1,606 m	-4M	1,624M	0 m
Risk margin (non-life)	136 m	-4.1 m	138 m	-9.3 m
Other liabilities*	343 m		347 m	
Total liabilities	2,085 m	2,077 m	2,109 m	2,103 m
Assets less liabilities	302 m	310 m	306 m	311 m
Subordinated liabilities	0 m	0 m	0 m	0 m
Total basic own funds	302 m	310 m	306 m	311 m
Solvency Capital Requirement	183 m	180 m	185 m	178 m
Solvency ratio	165%	172%	165%	175%

\*Excluding liabilities subordinates



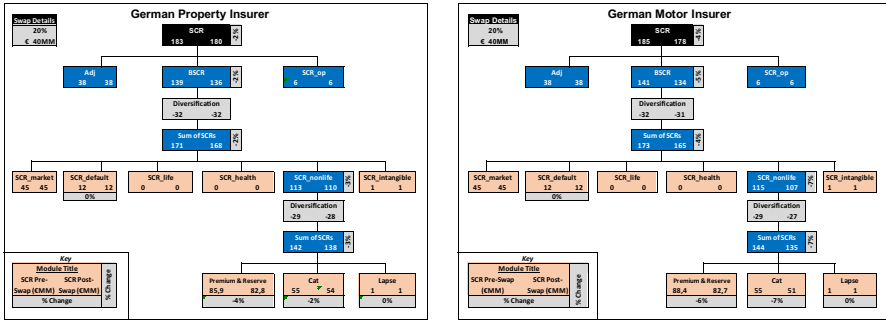


Fig. 8 Capital relief decomposed by risk modules for scenario 4

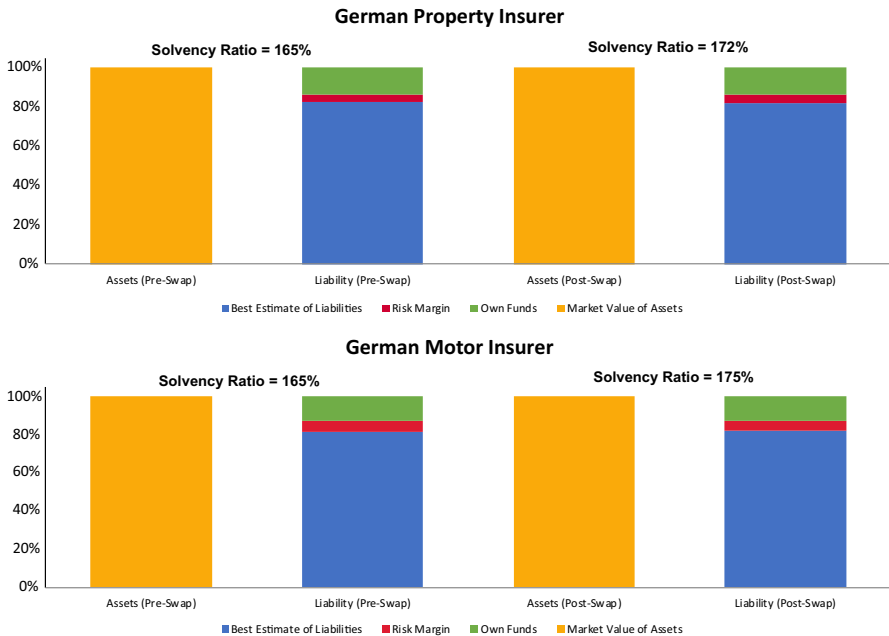


Fig. 9 Swap impact on the Solvency II balance sheet for scenario 4.

## Appendix D: Non-life premium and reserve SCR calculation pre- and post-swap

See Fig. 10.



Counterparty 1 Before Swap								Counterparty 2 Before Swap							
Non-Life $SCR_{\text{Premium & Reserve}} = 88$ $SCR_{\text{at given res}} = J * \alpha_{\text{MVE}} * V_{\text{MVE}}$ $\alpha_{\text{MVE}} = \sqrt{2 \cdot \sigma_{\text{MVE}}^2 * \text{Var}(\text{sum}_i \text{Corr}_i \text{Corr}_i) + \sigma_{\text{MVE}}^2 * \sum_i \sigma_{\text{MVE}}^2 * \alpha_{\text{MVE}}^2 * V_{\text{MVE}}^2}$ Standard Deviation <sub>SCR</sub> 7.28% $V_{\text{MVE}} = V / (\text{sum}_i \text{Corr}_i + V \text{Corr}_i) * (0.75 + 0.25 * \text{DIV}_i)$ Volume <sub>SCR</sub> 400								Non-Life $SCR_{\text{Premium & Reserve}} = 88$ $SCR_{\text{at given res}} = J * \alpha_{\text{MVE}} * V_{\text{MVE}}$ $\alpha_{\text{MVE}} = \sqrt{2 \cdot \sigma_{\text{MVE}}^2 * \text{Var}(\text{sum}_i \text{Corr}_i \text{Corr}_i) + \sigma_{\text{MVE}}^2 * \sum_i \sigma_{\text{MVE}}^2 * \alpha_{\text{MVE}}^2 * V_{\text{MVE}}^2}$ Standard Deviation <sub>SCR</sub> 7.33% $V_{\text{MVE}} = V / (\text{sum}_i \text{Corr}_i + V \text{Corr}_i) * (0.75 + 0.25 * \text{DIV}_i)$ Volume <sub>SCR</sub> 400							
Premium Volume	Reserve Volume	Premium Standard Deviation	Reserve Standard Deviation	Overall Standard Deviation	Geographic Diversification (DIV)	Non-Life Risk Capital Charge (V)		Premium Volume	Reserve Volume	Premium Standard Deviation	Reserve Standard Deviation	Overall Standard Deviation	Geographic Diversification (DIV)	Non-Life Risk Capital Charge (V)	
Motor Vehicle Liability	-	-	8.00%	8.00%	0.00%	0.00%	-	200	200	8.00%	9.00%	7.33%	100%	400	
Other Motor	-	-	8.00%	8.00%	0.00%	0.00%	-	-	-	8.00%	8.00%	0.00%	0%	-	
Marine, Aviation and Transportation	-	-	15.00%	11.00%	0.00%	0.00%	-	-	-	15.00%	11.00%	0.00%	0%	-	
Fire & Other Damage to Property	200	200	6.40%	10.00%	7.50%	100.00%	400	200	200	6.40%	10.00%	0.00%	0%	-	
<b>Total Non-Life</b>	<b>200</b>	<b>200</b>					<b>400</b>	<b>200</b>	<b>200</b>					<b>400</b>	
Counterparty 1 After Swap								Counterparty 2 After Swap							
Non-Life $SCR_{\text{Premium & Reserve}} = 85$ $SCR_{\text{at given res}} = J * \alpha_{\text{MVE}} * V_{\text{MVE}}$ $\alpha_{\text{MVE}} = \sqrt{2 \cdot \sigma_{\text{MVE}}^2 * \text{Var}(\text{sum}_i \text{Corr}_i \text{Corr}_i) + \sigma_{\text{MVE}}^2 * \sum_i \sigma_{\text{MVE}}^2 * \alpha_{\text{MVE}}^2 * V_{\text{MVE}}^2}$ Standard Deviation <sub>SCR</sub> 6.90% $V_{\text{MVE}} = V / (\text{sum}_i \text{Corr}_i + V \text{Corr}_i) * (0.75 + 0.25 * \text{DIV}_i)$ Volume <sub>SCR</sub> 400								Non-Life $SCR_{\text{Premium & Reserve}} = 85$ $SCR_{\text{at given res}} = J * \alpha_{\text{MVE}} * V_{\text{MVE}}$ $\alpha_{\text{MVE}} = \sqrt{2 \cdot \sigma_{\text{MVE}}^2 * \text{Var}(\text{sum}_i \text{Corr}_i \text{Corr}_i) + \sigma_{\text{MVE}}^2 * \sum_i \sigma_{\text{MVE}}^2 * \alpha_{\text{MVE}}^2 * V_{\text{MVE}}^2}$ Standard Deviation <sub>SCR</sub> 6.89% $V_{\text{MVE}} = V / (\text{sum}_i \text{Corr}_i + V \text{Corr}_i) * (0.75 + 0.25 * \text{DIV}_i)$ Volume <sub>SCR</sub> 400							
Premium Volume	Reserve Volume	Premium Standard Deviation	Reserve Standard Deviation	Overall Standard Deviation	Geographic Diversification (DIV)	Non-Life Risk Capital Charge (V)		Premium Volume	Reserve Volume	Premium Standard Deviation	Reserve Standard Deviation	Overall Standard Deviation	Geographic Diversification (DIV)	Non-Life Risk Capital Charge (V)	
Motor Vehicle Liability	40	-	8.00%	9.00%	8.00%	100%	40	160	200	8.00%	9.00%	7.44%	100%	360	
Other Motor	-	-	8.00%	8.00%	0.00%	0%	-	-	-	8.00%	8.00%	0.00%	0%	-	
Marine, Aviation and Transportation	-	-	15.00%	11.00%	0.00%	0%	-	-	-	15.00%	11.00%	0.00%	0%	-	
Fire & Other Damage to Property	160	200	6.40%	10.00%	7.40%	100%	360	40	-	6.40%	10.00%	6.40%	100%	40	
<b>Total Non-Life</b>	<b>200</b>	<b>200</b>					<b>400</b>	<b>200</b>	<b>200</b>					<b>400</b>	

Fig. 10 Detailed calculation of the impact of the Solvency II portfolio swap on the premium and reserve underwriting risk for both insurance counterparties in scenario 1. For a detailed description of SCR calculation using the Standard Formula, readers are referred to the Supplementary Materials and European Commission (2015) Delegated Regulation (Articles 100–110)

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**Declarations**

**Conflict of interest** On behalf of all authors, the corresponding author states that there is no conflict of interest.

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