

Effects of Solvency II on Portfolio Efficiency, The Case of Real Estate and Infrastructure Investments

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ABSTRACT (ENGLISH)

We examine the potential effects of Solvency II on general portfolio efficiency, and specifically on the allocation of alternative assets by European insurers. The paper starts with a brief introduction to the Solvency II Directive, focusing on the rules for calculating the Solvency capital requirements (SCR), according to the standard formula. The following empirical analysis entails several portfolio optimizations considering six relevant asset classes for the time period from 1993-2013. We derive optimal portfolios with respect to portfolio risk and capital requirements, and finally combine both optimization problems. Our results suggest that, although the capital charges for real estate and infrastructure assets are not adequately calibrated, a significant shift of portfolio weights is not expected for the majority of European insurers. However, after Solvency II comes into effect, undercapitalized insurers may often not be capable of holding risk-optimal allocations of alternative assets.

Keywords: Risk Based Regulation, Real Estate, Infrastructure, Life Insurance, Financial Crisis

Efectos de Solvencia II en el Riesgo de Inversión, El Caso de Inversiones Inmobiliarias e Infraestructuras

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ABSTRACT (SPANISH)

Examinamos los efectos potenciales de Solvencia II sobre la eficiencia general de la cartera, y específicamente sobre la asignación de activos alternativos por las aseguradoras europeas. El documento comienza con una breve introducción a la Directiva Solvencia II, centrada en las normas para calcular los requisitos de capital de solvencia (SCR), de acuerdo con la fórmula estándar. El siguiente análisis empírico implica varias optimizaciones de cartera considerando seis clases de activos relevantes para el período de tiempo comprendido entre 1993 y 2013. Obtenemos carteras óptimas con respecto al riesgo de cartera y requisitos de capital, y finalmente combinamos ambos problemas de optimización. Nuestros resultados sugieren que, aunque las cargas de capital para bienes raíces e infraestructura no están adecuadamente calibradas, no se espera un cambio significativo en el peso de la cartera para la mayoría de las aseguradoras europeas. Sin embargo, después de que Solvencia II entre en vigor, las aseguradoras subcapitalizadas a menudo no son capaces de mantener asignaciones óptimas de riesgo de activos alternativos.

Keywords: Risk Based Regulation, Real Estate, Infrastructure, Life Insurance, Financial Crisis

1 Introduction

The current structural low interest rate environment is forcing institutional investors to rethink their asset allocation strategies and increase their exposure alternative assets, such as real estate and infrastructure. This is particularly the case for life insurance companies, which come under pressure to reduce their investment in currently low-yielding government bonds, given the high interest rate guarantees associated with obligations from existing life insurance policies. In addition, insurers also aim for a broadly diversified portfolio structure, in order to minimize portfolio risk, thereby protecting shareholders as well as policyholders. Recent studies conclude that real estate and infrastructure assets are more complements than substitutes for each other and can therefore help to reduce overall portfolio risk (e.g. Oyedele *et al.*, 2014). Accordingly, insurer's appetite for real estate and infrastructure assets is growing steadily over the past years and higher target allocations are observed (Blackrock, 2013; Allianz, 2013).

However, the forthcoming Solvency II Directive could counteract this trend, since it introduces a risk-based regulatory standard for European insurance companies, in order to determine their Solvency capital requirements (SCR). After Solvency II comes into effect, insurance companies will be subject to higher capital requirements aimed at ensuring policyholder protection, even in the case of severe macroeconomic shocks. The SCR varies by asset class and can be determined using the Solvency II standard formula provided by the regulatory authority, the European Insurance and Occupational Pensions Authority (EIOPA). Concerning the calibration of the standard formula, there is a general belief that the regulator overstates certain risks, especially for illiquid assets such as infrastructure and real estate, which in turn results in unreasonably high capital requirements (IPD, 2013; GDV, 2013; Braun *et al.*, 2014). Depending on their individual capitalization, profitability and the general competitive dynamics, it may become necessary for insurers to minimize their SCR. One possible field of action would thus be to restructure the asset portfolio accordingly, most likely by decreasing exposure to illiquid (and capital intensive) assets. If the results of such an "SCR-optimal" portfolio optimization are not in accordance with those of the conventional (mean variance) optimal asset allocation, Solvency II may lead to inefficient capital allocation in practice. As a result, the portfolio risk would increase, which contradicts the original purpose of the regulation. Furthermore, since insurance companies represent the largest European institutional investors, with approximately €8.5 tn of

assets under management (Insurance Europe and Oliver Wyman, 2013), changes in their investment patterns might also have severe effects on the pricing and product range offered on the capital markets.

We therefore analyze whether the Solvency II standard formula could indeed cause the above-mentioned incentive incompatibility with respect to the asset allocation process. Our focus lies primarily on the potential shift of real estate and infrastructure weights within a multi-asset portfolio. We firstly use the traditional Markowitz (1952) portfolio optimization technique, in order to derive efficient portfolios with respect to risk. In a second step, we replace the empirical covariance matrix with a synthetic covariance matrix imposed by the regulator and determine SCR-optimal portfolios, i.e. we minimize the capital requirements for a certain target rate of return. Afterwards, we compare the derived portfolio weights with the results from the first optimization and can hence observe whether the Solvency II standard formula could indeed theoretically affect portfolio selection. Thirdly, we combine both optimizations and derive optimal portfolios with respect to capital constraints, i.e. we introduce an exogenously given Solvency Capital Budget (SCB) representing the actual capitalization of an insurer. These results show the potential effect that is most likely to be observable in practice. The contribution of our paper is therefore manifold. This is the first study to analyze the role of direct European infrastructure investments in a mixed asset portfolio. In addition, to the best of our knowledge, no other study has yet examined the potential effect of Solvency II on portfolio efficiency and asset allocation, accounting for different levels of capital budget. Most studies focus solely on the calibration of the standard formula and disregard the portfolio effects. Lastly, this paper adds to the research stream in the real estate literature on the disparity between theoretically optimal real estate (infrastructure) allocations and the actual allocations observed in practice.

The paper is structured as follows. Section 2 introduces the most relevant information concerning the Solvency II Framework and the rules for calculating and aggregating the SCR, using the standard formula. We further present the relevant literature on Solvency II and the role of real estate and infrastructure within the mixed asset portfolio in Section 3. Section 4 presents the empirical data, as well as the standard formula calibration for the relevant asset classes. The methodology and results are outlined in Sections 5 and 6. Section 7 discusses the results and the practical implications. Finally, Section 8 concludes on the main findings.

2 Solvency II Framework and Market Risk Standard Formula

The Solvency II Directive represents the most striking project for insurance supervision within the European Union and is hence of great importance for the industry. The primary aim of Solvency II is to increase the protection of policyholders by reducing the probability of insurance companies becoming insolvent. Additionally, uniform supervisory and regulatory standards are introduced, in order to create a level playing field in the European single market. These goals will be achieved by defining capital and risk management requirements, as well as consistent reporting and disclosure standards to be applied by all insurance undertakings across all 28 EU Member States and in three Member States of the European Economic Area.

In the remainder of this paper, we focus on the most relevant information on the Solvency II Directive with respect to our research question. Without a loss of generality, we do not consider the extensive (legal) sources and rather present a comprehensive overview alongside with few simplifications. Therefore, we concentrate on the passages specifying the methodology for calculating the SCR. Generally, the SCR can be calculated either using the standard formula imposed by the regulator or by implementing an internal model, which is able to more adequately reflect the individual risk structure of the particular insurance company. The focus of this paper is accordingly on the implementation of the Solvency II standard formula, which serves as a reference point for all insurance companies. Particularly small and medium-sized insurers will most likely not be capable of developing an internal model.

The standard formula aims to quantify the risk profile of a typical European insurance company as a whole. Technically, the formula refers to basic actuarial principles and is calibrated according to historical data. Generally, the Solvency II standard model consists of separate risk modules, including market risk, counterparty default risk, life underwriting risk, non-life underwriting risk, health underwriting risk and intangible asset risk, with each module consisting of further sub-modules (EIOPA, 2012). All risk modules are aggregated using (preset) correlations, as it is not likely that all potential risks occur at the same time. With respect to our research focus, we limit our analysis to the market risk module which is of particular importance, as it depends directly on the insurer's asset allocation. In addition, according to the results of the fifth Quantitative Impact Study (QIS5) (EIOPA, 2011) and a study from Fitch Ratings (2011), the market risk module accounts for 70-80% of the total SCR, emphasizing its predominant role in determining the overall SCR.

The market risk module itself consists of seven sub-modules that have to be aggregated in order to calculate the overall SCR for market risk (SCR_{mkt}): interest rate risk, equity risk, property risk, spread risk, concentration risk, illiquidity risk and exchange rate risk. In line with previous empirical studies (e.g. Gatzert and Martin, 2012; Braun *et al.*, 2014), we limit our analysis to the most important sub-modules, i.e. interest rate risk, equity risk, property risk and spread risk, which account for approximately 80% of the overall market risk (CEIOPS, 2009). Generally, the SCR for each sub-module refers to the change in the basic own funds (ΔBOF), that occurs due to a shock or stress in the financial markets (e.g. real estate crisis, shifts in the term structure of interest rates etc.), where BOF is defined as the difference between the market values of assets and liabilities. Without loss of generality, BOF is assumed to equal the equity position on the balance sheet. All specifications presented in the section below are from the “Revised Technical Specifications for the valuation and Solvency Capital Requirements calculations” released by EIOPA (2012).

The interest rate risk (Mkt_{int}) accounts for the fact that both assets and liabilities react to changes in the term structure of interest rates or interest rate volatility. As assets and liabilities are typically not perfectly matched (duration matched), both upward and downward shocks to the yield curve might have a negative effect on the BOF . Hence, the capital requirement for interest rate risk depends on two possible states,

$$Mkt_{int}^{up} = \Delta BOF|_{up} \quad (1)$$

$$Mkt_{int}^{down} = \Delta BOF|_{down} \quad (2)$$

where $\Delta BOF|_{up}$ and $\Delta BOF|_{down}$ are the changes in the net asset value of assets minus liabilities, caused by an upward or downward change in the term structure. The altered term structures are calculated by multiplying the current interest rate for a given maturity (r_t) with predefined upward and downward stress factors (s_t^{up} and s_t^{down}), which are specified by EIOPA (2012) and shown in Appendix 1:

$$r_t = (1 + s_t^{up}) \quad (3)$$

$$r_t = (1 + s_t^{down}) \quad (4)$$

In any case, the absolute change in interest rates should be at least 1%-point. In practice, the downward stress scenario is of greater importance, especially for life insurance companies. This is due to the typically higher duration of insurer’s liabilities compared to assets, causing the

market values of liabilities to rise more than those of assets. Moreover, the value of liabilities usually exceeds that of interest-rate-sensitive assets. Hence, only a downward shift of the yield curve would have a negative impact on the *BOF*. In general, nonetheless, depending on which (negative) effect on the *BOF* overweighs, either the upward or downward stress scenario must be used for further calculations.

The equity risk sub-module refers to sudden changes in the market value of equities and its influence on the *BOF*. Generally, EIOPA (2012) distinguishes between two types of equities: “type 1” and “type 2” equities. While “type 1” equities include all those listed in regulated markets in countries of the EEA or OECD, “type 2” equities comprise all equities listed in countries that are not members of the EEA or OECD. Moreover, all non-listed equity investments such as private equity, hedge funds, commodities and alternative investments (e.g. infrastructure investments) are also labeled as “type 2” equities. As a result, the capital requirement calculations for equity risk have to be carried out in two steps. First, the individual capital requirements ($Mkt_{eq,i}$) for each type of equity (i) are determined by the predefined stress factors:

$$Mkt_{eq,i} = \max(\Delta BOF | equity\ shock_i; 0) \quad (5)$$

where the stress factors for type 1 and type 2 equities add up to -39% and -49% respectively. These figures are based on historical total return data and refer to the value at risk (VaR) with a confidence level of 99.5% on a yearly basis. [1] Second, the resulting overall equity risk capital requirement is aggregated using a preset correlation matrix:

$$Mkt_{eq} = \sqrt{\sum_i \sum_j CorrIndex_{ij} * Mkt_{eq,i} * Mkt_{eq,j}} \quad (6)$$

where $CorrIndex_{ij}$ is the predefined correlation coefficient of 0.75 between “type 1” and “type 2” equities.

Likewise, the property risk sub-module accounts for risks arising from volatility in the real estate markets. This risk sub-module explicitly applies to direct investments (land, buildings and immovable property rights) and real estate fund investments, if it is possible to assess and evaluate the risks of the underlying assets (look-through approach). The capital requirement for property risk (Mkt_{prop}) is again determined by the 99.5% VaR on historical total return data and adds to -25%:

$$Mkt_{prop} = \max(\Delta BOF | \text{property shock}; 0) \quad (7)$$

Ultimately, the spread risk sub-module captures all risks that may occur due to changes in the level or in the volatility of credit spreads over the risk-free interest rate term structure. In particular, it comprises traditional fixed-income products (e.g. corporate bonds), asset-backed securities and other structured credit products, as well as credit derivatives. Depending on the type of product, the individual spread shock on bonds is determined as follows:

$$\text{spread shock on bonds} = \sum_i MV_i * F^{up}(\text{rating}_i) \quad (8)$$

where MV_i is the market value of the credit risk exposure of bond i and $F^{up}(\text{rating}_i)$ is a function of the individual credit quality and duration of each bond or loan. The actual factors can be derived using the table presented in Appendix 2. In this paper, we limit our analysis to the credit risk of corporate bonds, so that the capital requirement for credit spread (Mkt_{spread}) refers to the spread shock on corporate bonds as calculated with Equation (8) above.

$$Mkt_{spread} = \max(\Delta BOF | \text{spread shock on bonds}; 0) \quad (9)$$

Finally, the total capital requirement (SCR_{mkt}) is an aggregation of all sub-risks using the pre-defined correlation matrix (the specific correlation figures are presented in Appendix 3) as follows:

$$SCR_{mkt} = \max \left\{ \sqrt{\sum_i \sum_j CorrMkt_{ij}^{up} * Mkt_i^{up} * Mkt_j^{up}}; \sqrt{\sum_i \sum_j CorrMkt_{ij}^{down} * Mkt_i^{down} * Mkt_j^{down}} \right\} \quad (10)$$

with $i, j \in \{\text{interest risk}, \text{equity risk}, \text{property risk}, \text{spread risk}\}$ and “up” and “down”, indicating whether the upward or downward stress scenario for interest rate risk is relevant. The correlation coefficients differ slightly depending on the “up” or “down”-scenario. The actual calibration of the standard model for our empirical analysis will be presented in Section 4 together with the descriptive statistics of the dataset.

3 Literature Review

3.1 Solvency II

A considerable body of literature has been published on Solvency II related issues. Many of these studies focus mainly on the inappropriateness of risk measures and the underlying covariance matrix in the Solvency II standard formula (e.g. Mittnik, 2011; Christiansen *et al.*, 2012; Gatzert and Martin, 2012) or conduct a qualitative analysis of the potential effects (e.g. Fitch, 2011; CFGS, 2011; Ernst & Young, 2011, 2012; Severinson and Yermo, 2012). Another research stream investigates the conjoint effects of the implementation of the new Basel III regulation for the bank sector and Solvency II (e.g. Kaserer, 2011; Al-Darwish *et al.*, 2011). In this section, we therefore focus only on the publications most relevant to our research question. We shed light on important industry and academic publications that concentrate on the implications for asset allocation and the investment policies of insurers.

Based on the results of the QIS4, Rudschuck *et al.* (2010) conclude that the new risk-based capital requirements will force insurers to reduce their equity investments (e.g. stocks). As a result, insurers will struggle to meet required returns in the current low-interest-rate environment. Van Bragt *et al.* (2010) analyze the impact of different investment policies on the capital requirements (according to QIS4) for a representative life insurer. They find that the investment policy, in terms of portfolio structure and asset duration, may impact decisively on the regulatory capital requirements. For instance, a decrease in real estate allocation yields smaller capital requirements for the insurer when the duration of total assets remains constant. However, when allowing the total asset duration to change, a similar capital requirement can also be obtained with an allocation of real estate in the portfolio. Therefore, no definite conclusions can be made, based on these results. In addition, the risk factor for property in QIS4 corresponds to the equity risk factor, since a separate property risk factor was not introduced until QIS5.

Using the results of QIS5, a study by Morgan Stanley and Oliver Wyman (2010) investigates the effects of Solvency II on four different virtual insurance companies and finds similar results concerning the potential investment policy. They expect a shift away from illiquid assets, such as real estate and private equity, especially for insurers with a low market-risk appetite. Nonetheless, companies may still hold such assets tactically, in order to maximize portfolio returns. They further hint at the fact that the capital requirements of rating agencies, such as Standard & Poors (S&P), will potentially still play an important role and may be the binding capital constraint for insurers. This view is supported by Hoering (2012), who compares the capital

requirements of a representative European insurer, both under Solvency II standard formula and the S&P rating model. Accordingly, the S&P model requires 68% more capital than the standard model for a comparable level of confidence.

Fischer and Schlütter (2012) analyze the influence of the equity risk parameter calibration of the standard formula on the insurer's optimal investment strategy and capital structure. If the insurer's individual capitalization is considered as an endogenous variable, the authors interestingly find constellations in which a higher equity risk charge does not yield a significant reduction in insolvency risk. The insurer may not only react with a reduction of stock investments, but also reduce the overall capitalization accordingly. Recently, Braun *et al.* (2013) conduct portfolio optimizations including a broad range of assets accounting for capital charges according to the Solvency II standard formula and a partial internal model. As the standard formula is focuses purely on the risk of individual assets, the influence of expected returns is neglected. Thus, efficient portfolios are not systematically preferred under the Solvency II standard formula. That is the insurer is regulatorily forced to hold more risky portfolios in order to achieve the desired target portfolio return, which contradicts the primarily aim of Solvency II. In contrast, a partial internal model may overcome these limitations and permit insurers to hold efficient portfolios in terms of desirable risk-and-return profiles. Ultimately, Braun *et al.* (2014) investigate the impact of private equity investments on the capital requirements of a representative life insurer under Solvency II and Swiss Solvency Test (SST). They conclude that Solvency II and SST heavily penalize private equity investments, whereas the implementation of an economically sound internal model can lower the capital requirements, hence enabling potential investments in alternative asset classes.

In summary, no empirical studies focus on the impact of Solvency II on real estate and infrastructure and the potential shift of weights within the insurer's portfolio. Investment Property Database (IPD) (2011, 2013) research reports offer a detailed review of the Solvency II regulatory framework with respect to the property shock factor calibration, which is based on the U.K. real estate market. They criticize the lack of comparability between the general European real estate market performance and the performance of the U.K. real estate market, particularly during the recent financial crisis. Based on newly available national and pan-European quarterly property indices, IPD finds no 0.5% tail value at risk exceeding -15% in markets besides the U.K.. Hence, the property shock factor of -25% does not seem appropriate for direct real estate

investments. Therefore, IPD expects decisive impacts upon the real estate allocation of European insurers. However, it is not likely that the regulator will change the property risk factor, so that -25% SCR based on QIS5 will have to be applied.

Likewise, the literature contains no study on the potential impact of Solvency II on infrastructure allocations. This can be attributed mainly to the fact that infrastructure, as an emerging asset class, is not classified separately and no general accepted performance benchmark exists so far. As a consequence, the risk factors for private equity investments have to be applied in the standard formula, which may overestimate the potential risk associated with direct infrastructure investments, rendering it unattractive for insurance companies, despite its desirable risk-and-return characteristics. Hence, the German Insurance Association (GDV) recently released a proposal “for an appropriate solvency capital requirement for long-term investments in infrastructure or renewable energies” (GDV, 2013). They advocate a new sub-module “infrastructure risk”, with a risk factor of -20% and zero correlation to equity risk, interest rate risk or any other market risk sub-module for selected direct infrastructure investments that meet a list of qualitative criteria (e.g. located in the OECD, regulated business, unlisted investments, low default risk etc.). All other infrastructure assets that do not meet these criteria should instead be subject to the property risk sub-module. However, the European Insurance and Occupational Pensions Authority (EIOPA) recently announced that the standard formula calibration will not be changed in the near future, since improved data is needed for a reliable reassessment of risk. A general overview of the treatment of different infrastructure investment vehicles under Solvency II and related issues can be found in Gatzert and Kosub (2014) and EIOPA (2013).

3.2 Real Estate and Infrastructure Allocation in Insurers’ Portfolios

Concerning the role of alternative assets in the mixed-asset portfolio, the real estate literature already contains numerous studies on the optimal direct real estate allocation, using different optimization techniques. Recent studies conclude that the optimal weight of direct real estate investments in a mixed-asset portfolio should be about 15-30% (Ziobrowski and Ziobrowski, 1997; Chun *et al.*, 2000; Brounen and Eichholtz, 2003; Hoesli *et al.*, 2003, 2004; Bond *et al.*, 2006, Lee and Stevenson, 2006; Hoesli and Lizieri, 2007; Brounen *et al.*, 2010; Rehring, 2012). However, the theoretically optimal direct real estate allocation does not correspond with the allocation in practice of institutional investors, more precisely of insurance companies. According to a representative survey among German insurers, the allocation of direct real estate is only about 5.4% of total assets (Ernst & Young, 2014). Similarly, the average real estate allocation

of European insurers amounts to about 4% (Insurance Europe and Oliver Wyman, 2013), showing a remarkable disparity between theoretical and practical real estate asset allocations of insurers. This figure is supported further by the information provided in the QIS5 study in which 90% of all insurers affected by Solvency II took part. After adjusting the balance sheet for assets that are not capital investments, the percentage of direct real estate investments amounts to 4.8% of the total balance sheet (EIOPA, 2011).

The disparity between theoretical and actual real estate allocations formed the basis for further extensive research streams. Chun *et al.* (2000) were the first to show that institutional investors not only aim to construct efficient portfolios and minimize investment risk, they also aim to match their assets with their liabilities. This study was followed by several others (e.g. Craft, 2001; Booth 2002; Chun *et al.*, 2004; Brounen *et al.*, 2010) using an asset-liability framework in order to investigate the optimal portfolio composition of institutional investors. The majority of these studies conclude that the optimal share of direct real estate with respect to an Asset Liability Management (ALM) is merely 6-16%. Another possible explanation refers to the investment characteristics of direct real estate that can only partly be reflected by performance indices such as high transaction costs and illiquidity (Hoesli and Lizieri (2007)). In this context, Bond *et al.* (2006) show that the real estate allocation estimated via mean-variance optimizations may decrease decisively, as soon as lengthy transaction periods are accounted for. More recently, Rehring (2012) examines the role of real estate in a mixed-asset portfolio and finds that transaction costs and the investment horizon predominantly affect the allocation of short- and medium- term real estate investors, thus revealing lower theoretical allocations.

By contrast, there are few empirical studies on the role of direct infrastructure investment in mixed asset portfolios, as most studies only consider the listed infrastructure universe, due to limited data availability. Finkenzeller *et al.* (2010) were among the first to investigate the role of unlisted infrastructure in a downside-risk framework, and find considerably high theoretical allocations in low to medium expected-return portfolios. However, when the expected return increases, theoretical allocations decrease to 3-20%. Using a professionally constructed US-transaction-based infrastructure index, Dechant and Finkenzeller (2013) examine the role of direct infrastructure in a dynamic asset allocation framework. Similar to the previous findings, they discover high optimal allocations of direct infrastructure up to approximately 30% in low-to medium risk portfolios. In addition, direct infrastructure may be particularly beneficial for investors with a long-term investment horizon.

Yet, the actual infrastructure allocations in the mixed-asset portfolios of institutional investors differ decisively from the theoretical allocations suggested by recent asset allocation studies. As shown in a recent survey of Mercer including 1,200 institutional investors in 13 European countries, the average infrastructure allocation adds to approximately 3% of the overall assets (Mercer, 2013). A joint study by the Steinbeis Research Center for Financial Services and Commerz Real reveals the average infrastructure allocation among German institutional investors to be around 1%. However, according to the study, insurance companies are the leading infrastructure investors with an average allocation of 2% (Steinbeis, 2012). According to Preqin, 173 insurance companies reporting to its database exhibit a mean current allocation to infrastructure of 1.9% which is in line with the abovementioned figures (Preqin, 2013). Hence, the actual infrastructure allocation of insurance companies is roughly 2% in practice. Nevertheless, the appetite of institutional investors for infrastructure investments is notable; several surveys provide evidence that investors aim to increase their infrastructure allocations (Blackrock, 2013; Preqin, 2013; Insurance Europe and Oliver Wyman, 2013; Tower Watson, 2013). This emphasizes the potential for the asset class to grow decisively in the future. Since real estate and infrastructure assets exhibit common features, such as illiquidity and high transaction costs, the discrepancy might also be well explained by the arguments stated for real estate investments. Nevertheless, no study has yet examined this issue empirically.

4 Data and Descriptive Statistics

4.1 Data Selection

In this section, we present the data set used in the empirical analysis, as well as the corresponding standard formula parameters. We aim at constructing a representative portfolio of a European insurer, by using common benchmark indices as a proxy for the respective asset class performance. That is, we assume each intra-asset class portfolio has already been optimized prior to the overall portfolio optimization. Our dataset consists of the following six asset classes: real estate, infrastructure, government bonds, corporate bonds, stocks and money market instruments. We use quarterly total return data over 21 years spanning the period from Q1 1993 to Q4 2013, i.e. our data sample contains 84 observations in total. [2] The 21-year horizon ensures a sufficiently long time frame, in order to cover several business cycles and the two severe economic downswings in the past two decades. All data, except for infrastructure, were obtained from Thomson Reuters Datastream.

Direct real estate performance is represented by the IPD U.K. Property Total Return Index which consists of approximately 3,500 directly held properties in the U.K. with a total capital value of 40,5 billion GBP (as of September 2014). Since the index is based on monthly valuations of the properties, the capital return component is subject to lagging and appraisal smoothing. Hence, we follow Rehring (2012) and correct the capital returns for these effects, using the approach of Barkham and Geltner (1994) with an unsmoothing parameter of 0.625. In addition, direct real estate investments entail high transaction costs for an investor, thus reducing the actual returns. Therefore, we further correct the total returns for roundtrip transaction costs of 7%, as proposed by Collet *et al.* (2003), Marcato and Key (2005) and Rehring (2012). [3]

Direct infrastructure performance is reflected by the CepreX Europe Infrastructure Index provided by the Center of Private Equity Research (CEPRES). A different regional sub-index was already used in an asset allocation context by Dechant and Finkenzeller (2013), as well as by Wurstbauer and Schaefer (2015). The infrastructure indices are sub-indices of the general private equity data base of CEPRES, which was the source for several empirical studies, including Franzoni *et al.* (2012) and Fuess and Schweizer (2012). The performance index is transaction-based and consists of 638 direct private equity investments in portfolio companies in infrastructure segments [4] across Europe with a total capitalization of €25.8 bn of invested capital. The index is corrected for gearing, transaction costs, carried interest and management fees so as to represent unbiased direct infrastructure performance. Thanks to a sufficient number of transactions, together with a high market capitalization, this index represents an appropriate benchmark of direct infrastructure performance in Europe.

To proxy the European government bond universe, we use the Citigroup European World Government Bond index with mixed maturities. The index covers 16 European countries and is frequently used by investment managers as a benchmark for the government bond markets. As there is no European-wide benchmark with a sufficiently long time series for corporate bonds, we employ the Barclays U.S. Corporate Bonds Market to represent corporate bonds in this study. [5] The index consists of different investment-grade bonds with different maturities, which is in line with the actual bond portfolios held by European insurance companies. The stock portfolio of insurers is represented by the total return index of the MSCI Europe Index, which covers 437 large and mid-cap stocks across 15 developed markets in Europe, thus representing approximately 85% of the total market capitalization in Europe. Lastly, short-term money market investments are represented by the JP Morgan Euro 1M Cash Total Return Index.

The respective standard formula calibration resulting from the chosen data set is presented in the section below.

4.2 Input Data for SCR Calculations and Descriptive Statistics

We use the information provided in Section 2 to calculate the individual SCR, as well as the aggregate SCR, for the overall portfolio (i.e. SCR_{mkt}). As for direct real estate investments, a single SCR of -25% has to be applied. The equity risk sub-module must be calculated and aggregated separately for type 1 and type 2 equities, before deriving the overall market risk capital charges. While the MSCI Europe Index represents type 1 equities with a -39% SCR, the infrastructure time series is clustered as type 2 equity thus requiring a -49% SCR. The gross capital charges for both types of equities are aggregated, using the regulatory prescribed correlation of 0.75. Government bonds, as well as money market instruments, are not subject to capital charges and therefore do not enter the capital charge calculations directly. Nevertheless, the overall SCR also depends on the allocation of government bonds, as it influences the total duration of the portfolio and therefore the interest rate risk charges. The interest rate sensitivity of government bonds is given by the modified duration of the Citigroup European World Government Bond index (6.66 as of 31 December 2013). [6]

To calculate the capital requirements for the spread risk module, we use Formula 8 from Section 2. That is the respective duration and rating of the corporate bonds portfolio determines the actual SCR. We use the modified duration of the Barclays U.S. Corporate Bonds Market index as of 31st December 2013, which amounts to 6.79. Since the bond index represents a bucket of investment-grade fixed-income securities, we average the spread shocks across the credit quality steps 0 to 3 for the duration of 6.79, using the prescribed formulas from the Appendix 2. As a result, we obtain a single shock factor of -8.9% for the spread risk module.

Concerning the interest rate risk module, we use the simplified approach suggested by Hoering (2013), who determines the capital requirements based on the duration gap between assets and liabilities. The duration gap is calculated as the difference between the duration of the asset side and the duration of the liability side and hence indicates the interest rate sensitivity of the basic own funds (*BOF*) of the insurer. While the duration of the asset side is determined by the actual portfolio allocation, more precisely, the relative weights of the duration of government bonds and corporate bonds, the duration of the liability side is given exogenously. We use the information provided by the Fourth Quantitative Impact Study QIS4 (CEIOPS, 2008), according to

which the median duration of liabilities of life insurers in Europe is approximately 8.9. Moreover, Braun *et al.* (2014) set the duration of a representative life insurance to 10.0, based on several practitioner studies for the German life insurance market. Hence, we use the average of both studies and define the duration of the liability side as 9.5 in this study.

Following Braun *et al.* (2014) and Hoering (2013), the interest rate shock is then approximated by a parallel upward and downward shift of the term structure of interest rates, i.e. we assume a flat interest rate curve. The unstressed interest rate is therefore given by the average of the AAA-rated euro area central government spot yield curve as of 31st December 2013, which amounts to 0.48%. Likewise, we average the prescribed shock factors from the Solvency II Directive for different maturities (cf. Appendix 1), which results in a single upward shock of +43% and a single downward shock of -37%. Given that the absolute change in the term structure should be at least 1 percentage point (cf. Chapter 2) and that the unstressed interest rate only amounts to 0.48%, these two shocks are not relevant, since the absolute change in the term structure would be less than 1 percentage point. Therefore, we assume interest rate changes of 1 percentage point for our calculations as prescribed by the regulator. In addition, the duration of liabilities exceeds the duration of assets for every possible portfolio composition, thus limiting the analysis to the downward scenario only, i.e. a change in the unstressed interest rate of -1 percentage point. Ultimately, the SCR for interest rate risk is calculated by multiplying the downward interest rate shock of -1 percentage point by the duration gap, which in turn is determined by the respective portfolio allocation. For example, a duration gap of 5.0 would require capital charges for the interest rate risk of -5%.

Table 1 summarizes the empirical risk and return characteristics, as well as the empirical and regulatory correlation matrices for the six asset classes. The upper figures in the first section of the table thus represent the empirical correlations, and the figures in parentheses below refer to the respective regulatory correlations as imposed by the regulator. Since government bonds and money market instruments are not subject to capital charges, some cells are left blank and we only present the empirical correlations. Likewise, the interest rate correlations are only relevant for the SCR calculations, so that no empirical correlations are presented. The second section of the table provides information on the mean quarterly returns, the respective standard deviations as well as the corresponding SCR, as already outlined in above sections. Ultimately, the durations of the bond investments are shown in the bottom row.

Table 1: Descriptive Statistics and Solvency II Standard Formula Calibration

	Real Es- tate	Infra- structure	Govern- ment	Corpo- rate	Stocks	Money Market	Interest
Real Es- tate	1.00 (1.00)						
Infra- structure	0.14 (0.75)	1.00 (1.00)					
Govern- ment	0.03 -	0.05 -	1.0 -				
Corporate Bonds	0.19 (0.50)	-0.04 (0.75)	0.52 -	1.0 (1.0)			
Stocks	0.47 (0.75)	0.18 (0.75/1.0)	0.06 -	0.14 (0.75)	1.00 (1.00)		
Money Market	-0.13 -	0.37 -	0.29 -	0.07 -	-0.02 -	1.00 -	
Interest	- (0.50)	- (0.50)	- -	- (0.50)	- (0.50)	- -	- (1.00)
Mean	2.06%	1.47%	1.57%	1.83%	2.55%	0.87%	
STD	5.28%	0.90%	1.99%	3.34%	9.49%	0.58%	
SCR	-25%	-49%	-	-8.9%	-39%	-	1% ×
Duration	-	-	6.66	6.79	-	-	

Notes: The upper division of the table shows the empirical correlation and the regulatory correlation coefficients (in parentheses below). All correlations refer to the downward interest shock scenario. Stocks and infrastructure are aggregated first at a 0.75 correlation. The lower division of the table shows the mean quarterly returns of the assets and the corresponding standard deviations (STD). Moreover, the Solvency capital requirements (SCR) are presented. The interest rate risk SCR needs to be calculated, depending on the actual duration gap (DG). The respective durations for the assets are outlined in the bottom row.

The descriptive statistics clearly reflect the expected risk and return relationship for the assets in this study. Short-term money market instruments yield the lowest returns and also exhibit the lowest risk in terms of the standard deviation. At the other extreme are stock investments with mean quarterly returns of 2.55% and 9.49% standard deviation, thus representing the riskiest and best-performing asset. The mean return of infrastructure is smaller than those of real estate and government bonds, emphasizing its defensive investment characteristics. However, the SCR for the six asset classes do not adequately reflect the corresponding empirical risk measures. While infrastructure exhibits a very conservative risk and return relationship, it is subject to the highest SCR of all asset classes. One would expect stock returns to be subject to the highest capital requirements, due to the risk profile. Likewise, the SCR for real estate investments is overstated compared to corporate bonds. All in all, real estate and infrastructure assets seem to be penalized and seem therefore not attractive for insurers on a SCR-adjusted basis.

In order to evaluate the potential role of real estate and infrastructure within the mixed asset portfolio, it is necessary also to take into account the correlation matrices. It is evident that the regulatory correlations, for both infrastructure and real estate, are severely overestimated in comparison to the empirical correlations. For example, the empirical correlation coefficient between real estate and stocks amounts to 0.47, whereas the regulatory correlation coefficient is 0.75. As a result, the desirable diversification benefits offered by the relatively low empirical correlations might be eroded from a SCR perspective. The figures suggest rather that the properties of infrastructure and real estate as portfolio diversifiers could be lost. As no reliable conclusions can be based only on these figures, we perform several optimization setups in order to evaluate the potential impact of Solvency II on the actual allocation. In the next section, we present the methodology used in our empirical analysis.

5 Methodology

The first optimization problem serves as a reference point for the further analysis and is based on the standard Markowitz mean-variance framework with the empirical covariance matrix (Σ). The objective and restrictions are as follows:

$$\min_w: STD = \sqrt{w * ((\sigma_{STD})^T \times \Sigma_{emp} \times \sigma_{STD}) * w^T} \quad (11)$$

$$\text{subject to:} \quad E(r) = \bar{r} * w^T \quad (12)$$

$$w_i \geq 0 \quad (13)$$

$$\Sigma_i w_i = 1 \quad (14)$$

$$\text{and} \quad w_i \leq u_i \quad i \in \{1,2, \dots, 6\}. \quad (15)$$

The aim of the optimization is simply to minimize the portfolio risk with respect to all possible target returns (Equation 12). Equation (13) excludes short positions and Equation (14) serves as the budget constraint. To ensure that only realistic portfolio compositions are obtained, which do not conflict with existing investment regulations, we introduce different investment limits as upper boundaries (u_i) for the individual asset classes (w_i) in Equation 15. Given that these regulations vary across Europe and according to the relative importance of the German insur-

ance market, the investment limits in the empirical study are inspired by the German “Regulation on the Investment of Restricted Assets of Insurance Undertakings” (Investment Regulation; German: Anlageverordnung). Specifically, we restrict our analysis in the following manner: real estate weights are capped at 25%, infrastructure weights are capped at 5%, stocks are capped at 35% and infrastructure and stocks are not allowed to jointly exceed 35% of total assets. All other asset classes (government bonds, corporate bonds and money market) are not subject to any investment limits. Originally, corporate bonds would also be included in the joint 35% cap regulation with stocks and infrastructure. However, we abstain from introducing an investment limit to corporate bonds, due to their relative importance within the average European insurer’s asset allocation. According to the European insurance and reinsurance federation, the average corporate bond allocation amounts to 35% of the overall portfolio (Insurance Europe and Oliver Wyman, 2013), which also reveals that such a regulation does not prevail across all jurisdictions. [7]

In a second step, the information provided by the regulator (cf. Chapter 2) is used and the empirical correlation matrix is replaced with the imposed correlation matrix of the regulator. Likewise, the empirical risk measures for all asset classes are replaced with the SCR. In addition, the interest rate risk factor is now taken into account. This optimization problem can now be stated as follows:

$$\min_w: SCR = \sqrt{w * ((\sigma_{SCR})^T \times \Sigma_{reg} \times \sigma_{SCR}) * w^T} \quad (16)$$

$$\text{subject to:} \quad E(r) = \bar{r} * w^T \quad (17)$$

$$w_i \geq 0 \quad (18)$$

$$\Sigma_i w_i = 1 \quad (19)$$

$$\text{and} \quad w_i \leq u_i \quad i \in \{1, 2, \dots, 6\}. \quad (20)$$

Although this problem looks like the familiar quadratic optimization problem again, a variety of numerical issues are associated with changing the covariance matrix. First, the matrix imposed by the standard formula is not positive semi-definite. While this is not a problem for the simple aggregation of the overall SCR, it causes a discontinuity in the quadratic objective func-

tion, and hence leads to an overrun of the optimization algorithm. Therefore, we apply the algorithm of Higham (2002), in order to obtain the nearest positive semi-definite matrix. Second, both the equity risk SCR and the interest rate risk SCR are functions of the portfolio allocation itself. While the equity risk SCR accounts for diversification within the equity risk sub-module, the interest rate risk SCR is caused by the duration gap, which depends on the actual weights of corporate and government bonds. Consequently, the optimization problem itself alters, whenever the solution vector (i.e. portfolio weights) changes. This causes a circularity problem and again, discontinuity, within the optimization. Depending on the starting point of the optimization, the algorithm may therefore only find local minima. To overcome this issue, all N permissible combinations of infrastructure investments, stocks, corporate bonds and government bonds are enumerated up to the fourth decimal place. For any given target return, the original problem is now solved N times. Each of these N optimizations uses the corresponding preset asset weights as additional constraints (i.e. the weights of these four asset classes are fixed). Hence, the covariance matrix no longer exhibits circular references. Subsequently, only the remaining asset weights for money market and real estate are derived by the optimization. Finally, the portfolio allocation with the lowest SCR of all the N optimization results is chosen as the global optimum for the given target return.

Both optimization problems can be considered extreme points. No insurer will strictly adhere to only one of the optimization objectives (SCR *or* STD). Since any insurance company will not only face certain capital constraints, but also the need to manage the overall portfolio risk, it is rather the combination of both optimizations, which is of particular relevance. Therefore, we introduce a solvency capital budget (SCB) as an additional constraint into the original Markowitz optimization problem. The problem is now formulated as follows:

$$\min_w: STD = \sqrt{w * ((\sigma_{STD})^T \times \Sigma_{emp} \times \sigma_{STD}) * w^T} \quad (21)$$

$$\text{subject to: } SCB \geq \sqrt{w * ((\sigma_{SCR})^T \times \Sigma_{reg} \times \sigma_{SCR}) * w^T} \quad (22)$$

$$E(r) = \bar{r} * w^T \quad (23)$$

$$w_i \geq 0 \quad (24)$$

$$\Sigma_i w_i = 1 \quad (25)$$

$$\text{and} \quad w_i \leq u_i \quad i \in \{1, 2, \dots, 6\}. \quad (26)$$

Equation (22) ensures that the resulting SCR (right hand side) stays below a certain threshold (left hand side), while the portfolios are optimized with regard to standard deviation. The SCB thereby serves as an upper boundary and is given exogenously in practice by the capitalization of an individual insurance company. By varying the SCB, it is now possible to derive the optimal portfolio allocation, given a certain capital budget. Technically, the introduction of Equation (22) represents a quadratic constraint in the quadratic optimization problem.

We compute a set of 10.000 portfolios (i.e. target returns) for all three optimization problems, whose compositions are shown in Figure 1 in the next section. In order to reduce the runtime of the optimizations, especially for the more complex problem with a quadratic objective and quadratic restriction, we employ the fast trust-region-reflective algorithm introduced by Coleman and Li (1996).

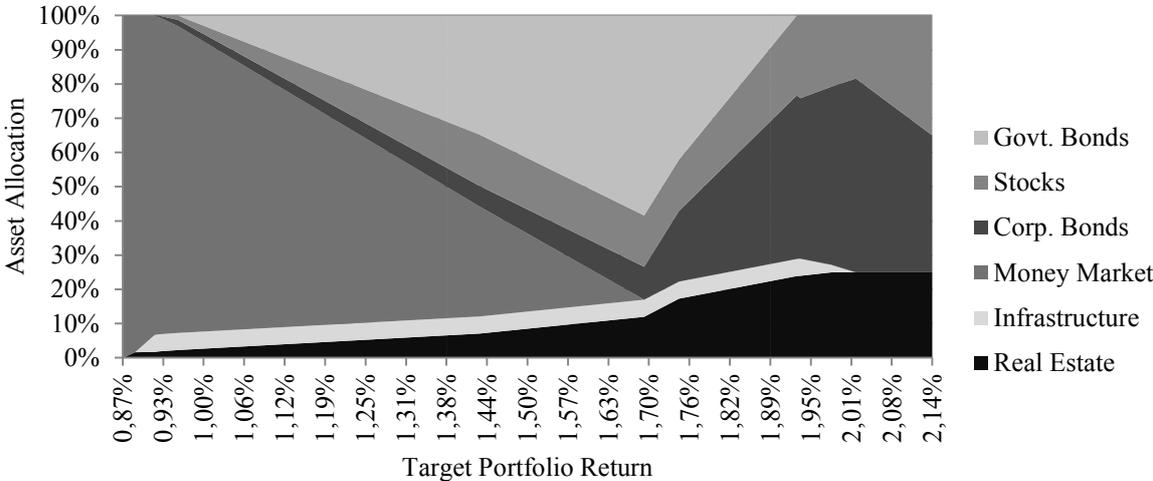
6 Results

The upper section in Figure 1 illustrates the portfolio allocations using the standard Markowitz optimization technique, as described in the previous section. Since the subset of efficient returns may differ for the STD- and the SCR-optimization, returns are represented along the whole attainable spectrum. The lowest portfolio target return (corner solution) is determined by the asset class with the lowest expected return, i.e. money market. At the other extreme, the highest portfolio target return is achieved by sequentially increasing the weights of the assets with the highest expected returns, until the individual investment limits are reached.

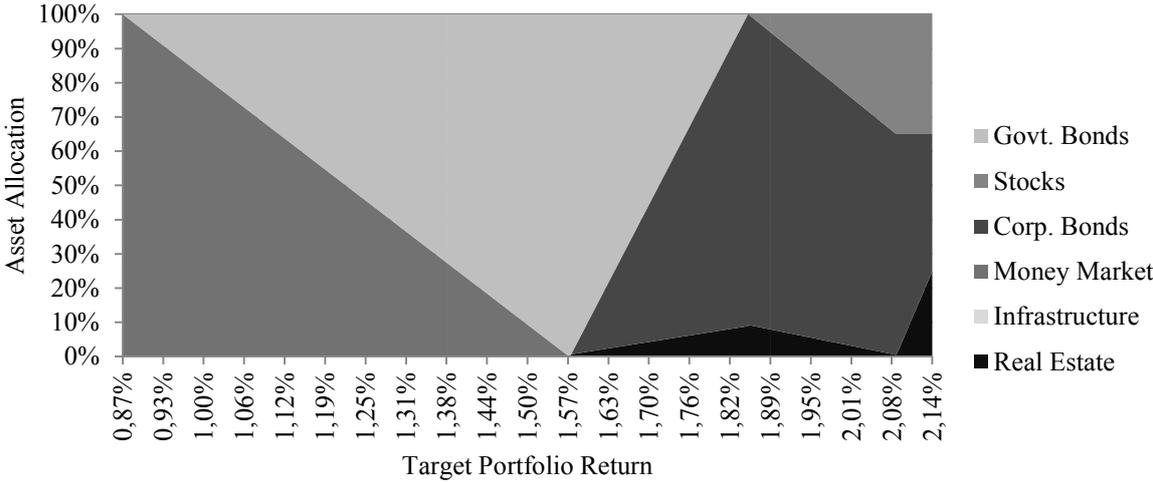
It is evident that almost the entire spectrum of target returns comprises real estate and infrastructure assets. More specifically, for almost all target returns, the allocation of infrastructure assets is only determined by its investment limit, suggesting that even higher (and more efficient) allocations could theoretically occur when investment limits were relaxed. This also holds true for real estate in the case of high target-portfolio returns. Therefore, both assets prove to provide desirable diversification benefits and to deliver high risk-adjusted returns within the mixed-asset portfolio, which is in line with other empirical findings so far. As a conclusion, investors aiming at efficient portfolios with respect to investment risk (in this case the portfolio standard deviation) should consider real estate and infrastructure assets within their investment strategy. However, considering efficient portfolios in terms of capital requirements, might yield a different optimal set of assets.

Figure 1: Efficient Portfolio Allocations

(a) STD-optimized Portfolio Allocations



(b) SCR-optimized Portfolio Allocations



Notes: Whereas Panel (a) shows the efficient portfolio allocations with respect to minimizing the standard deviation (STD) and increasing target portfolio returns from left to right, Panel (b) accounts for capital requirements (SCR).

Subfigure (b) in Figure 1 shows the portfolio allocations when the aim of the optimization is to minimize the overall capital requirements. That is, the empirical standard deviations and correlation matrix are replaced by the SCR and the regulatory correlation matrix imposed by EIOPA (including the dynamic SCR for interest-rate-sensitive assets, depending on the current duration gap and the dynamic SCR for the equity risk module). As expected, the optimal set of assets yields a decisively different picture in comparison to the standard Markowitz optimization. While infrastructure assets are completely removed from the optimal portfolio allocation, real

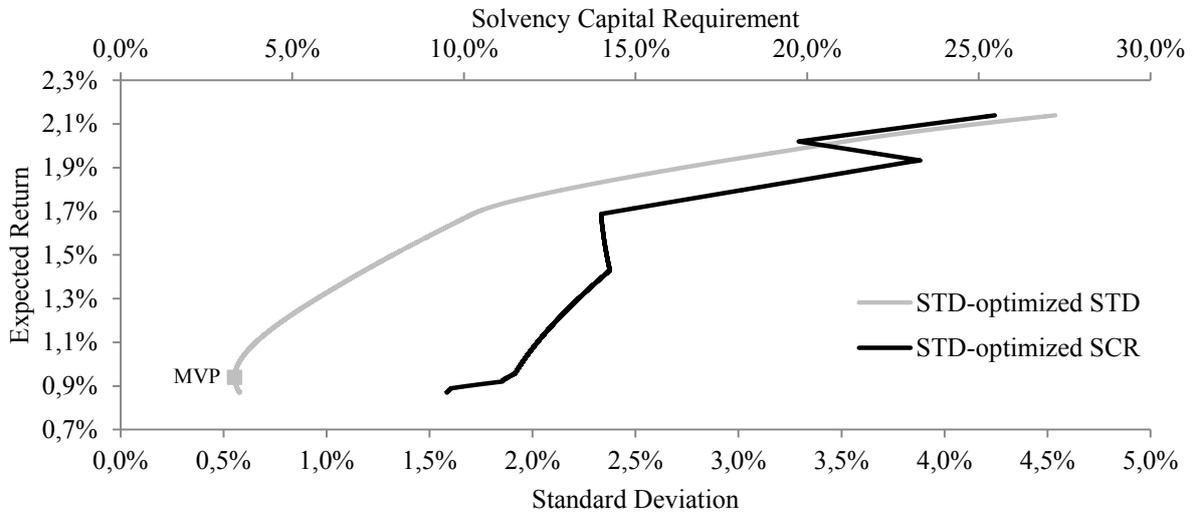
estate assets are only part of high-return portfolios. The results can be explained of course by the relatively high SCR for both asset classes and especially by the high regulatory correlation coefficients. Primarily the latter completely distorts the effect of diversification, which can be already assumed by comparing Panels (a) and (b) in Figure 1. Moreover, infrastructure and real estate assets are not subject to interest rate shocks, according to the Solvency II framework, since they do not exhibit any duration. Those asset classes therefore cannot hedge interest rate shocks on the liability side, so that interest-rate-sensitive corporate and government bonds are even more attractive in a portfolio context. Accordingly, bonds make up the major share of the SCR-efficient portfolios, as they are the only assets that are capable of hedging interest rate risk. These initial results already indicate the incorrect parameterization of the Solvency II standard formula, that may lead to inefficient portfolio allocations and thereby increasing portfolio risk. Interestingly, this contradicts the original purpose of the regulation. To illustrate the potential loss of efficiency between the two optimizations, the next figure shows the respective (in-) efficient frontiers.

Figure 2 is divided into three different sections. Whereas the upper section contains the efficient frontier for the STD-specific optimization, the middle section for the SCR-specific optimization and the lower section for both optimizations are blended. All graphs exhibit two different horizontal axes, which must be interpreted according to the respective variable under consideration.

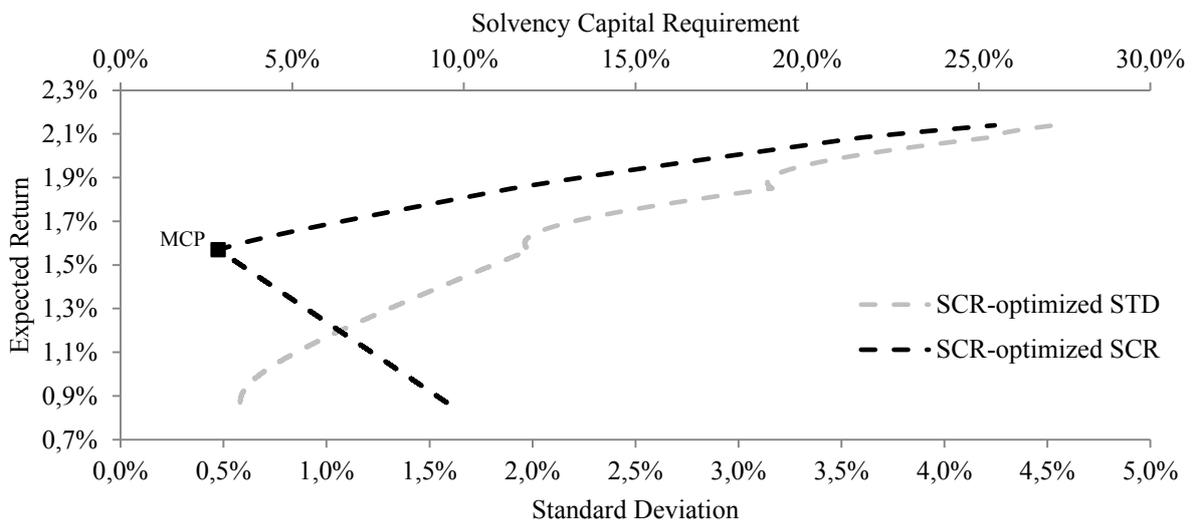
The solid grey line in the upper diagram depicts the efficient frontier for the first optimization problem, using the standard Markowitz approach. It therefore shows the development of portfolio risk depending on the target return (corresponding to Figure 1 a). The solid black line is derived by calculating the SCR for the related STD-efficient portfolios. Note that this line is neither concave nor monotone, thus again indicating the incompatibility between the SCR- and STD-optimization. Hence, the line is not an efficient frontier in the narrow sense. However, in order to judge the degree of incompatibility, it is necessary to calculate the actual SCR-efficient frontier, as shown in the middle section.

Figure 2: Efficient Frontiers

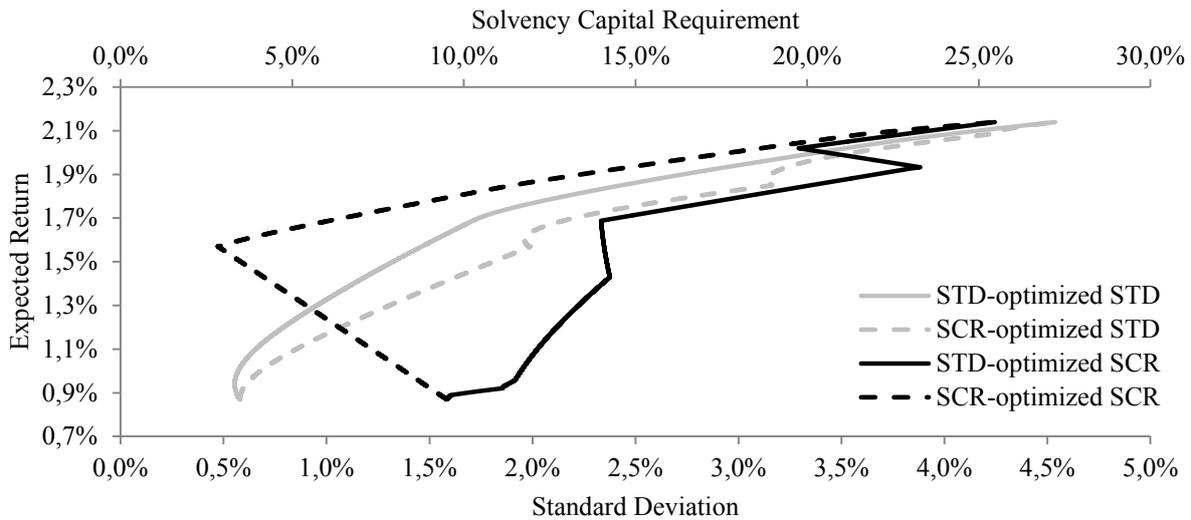
(a) STD-optimized efficient frontier with resulting SCR levels:



(b) SCR-optimized efficient frontier with resulting STD levels:



(c) Deadweight loss between both optimization approaches:



Notes: See text for explanations.

It is obvious that the minimum SCR portfolio (MCP) on the black dashed line – unlike the MVP in the first optimization – is located significantly above the minimum achievable target portfolio return. This point represents the basis for further interpretation of the results. Recalling the descriptive statistics and regulatory requirements in Table 1, the MCP should consist solely of government bonds that are not subject to any SCR and are additionally dominating money market instruments (which are also free of capital charge) in terms of the return-SCR relationship. Moreover, it is evident that the course of the frontier below and above the MCP is almost linear (with concave tendency only), which is due to the very high regulatory correlation figures as well as the monotonously relationship between SCR and returns above the MCP. Note that this does not hold true for infrastructure and real estate assets, which are (most of the time) not part of the SCR-efficient portfolios. Interestingly, the byproduct of the SCR-optimal portfolios (gray dashed line), the STD-return line, is monotonously and segmentally concave. Hence, there is at least a monotonous relationship between the STD and the return. To conclude, there is no homomorphic relationship between the STD-return concept and the SCR-return concept, which is one major explanation of the incompatibility of the standard formula in the Solvency II Directive. This issue is even exacerbated by the incompatible correlation figures in the case of a SCR-optimization, as well as the neglect of the duration gap in the case of the STD-optimization. [8] To quantify the extent of the incompatibility in terms of portfolio risk, we blend the results of the upper and middle graph into one in Figure 2 (c).

As mentioned, neither the course of the two black lines nor that of the two gray lines in the figure are homomorphic or even congruent. The striking significant deviation between the black lines in the SCR-case can be explained by the strong regulatory preference for government

bonds compared to other asset classes. However, one must bear in mind that part of this deviation is due to the scaling of the two different horizontal axes. Ultimately, it is not the area between the two gray or the two black lines that is essential; it is only the horizontal distance between the lines that needs to be interpreted. For instance, given a target portfolio return of 1.8%, the STD-optimal standard deviation is 88 basis points below the corresponding standard deviation according to the SCR-optimization. Using two standard deviations as the relevant measure for quantifying risk, the short fall risk of the portfolio would increase decisively by 176 basis points per annum. [9]

Whether the above mentioned theoretical impact of Solvency II on the portfolio weights of real estate and infrastructure is also relevant in practice depends on the overall capital budget of an individual insurance company and hence, on whether the insurer is forced to minimize the capital requirements at all. While some insurers will certainly be under-capitalized after Solvency II comes into effect, other insurers may already be well-provided with capital. To gain a more realistic picture of the potential practical influence of Solvency II, in the next step, we do not minimize the SCR, but introduce different upper boundaries of given capital budget levels. Depending on the capital budget, we derive optimal portfolios with corresponding efficient frontiers, which are located between the dashed and solid lines in Figure 2. Hence, each given capital budget yields a separate optimization output, i.e. the portfolio weights and corresponding efficient frontiers. For the sake of brevity and with regard to our research objective, we focus on the resulting optimal real estate and infrastructure weights. The results of the optimization are depicted in Figure 3 below.

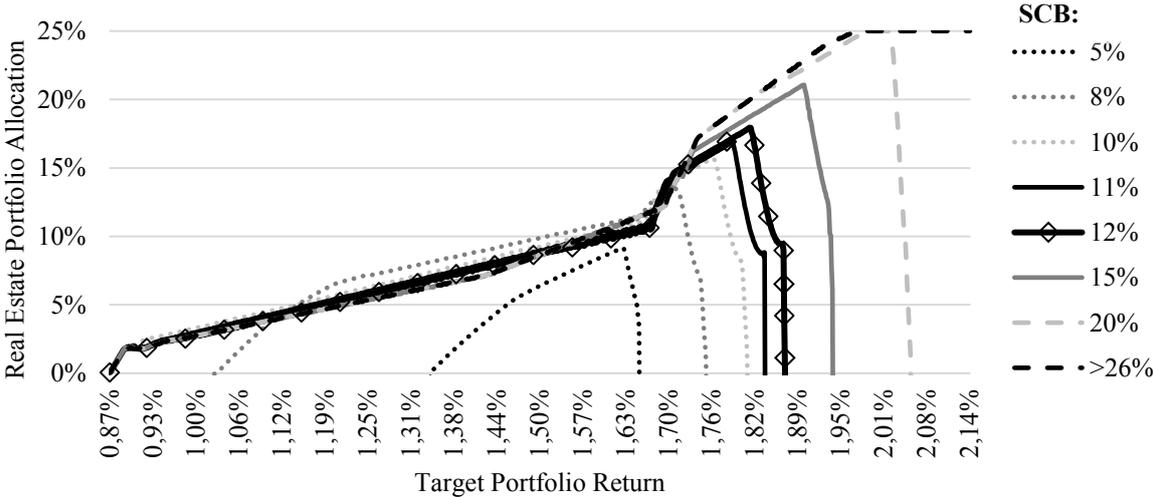
The two diagrams show the efficient portfolio weights for real estate and infrastructure investments corresponding to the respective capital budget, ranging from 5% to 26%, as indicated in the legend of the graphic. Note that not the maximum achievable portfolio weights (given a certain target return and capital budget) for both asset classes are shown, but the optimal portfolio weights (still minimizing risk). The area alongside the return-axis thereby indicates the return spectrum, which is reachable for the individual solvency capital. Hence, assuming a capital budget of 5%, only target returns between approximately 1.31% and 1.61% are attainable. On the other hand, the allocations for capital budgets >26% correspond directly to the efficient portfolios as presented in Figure 1 (STD-optimization), i.e. the unrestricted case.

It is striking that, regardless of the individual capital budget, most of the risk-efficient portfolios in the computable return spectrum exhibit a significant share of real estate. Considering the

distance between the different capital budgets in the case of high target-portfolio returns, one can observe the development of decreasing optimal real estate weights, with a decreasing capital budget and vice versa. This effect diminishes for medium to low target returns, as the efficient real estate weights are almost congruent, irrespective the budget level. However, it is noticeable that the optimal real estate weights for a capital budget of 8% even exceed the allocations for higher capital budgets. This can be explained by the fact that investments in stocks and infrastructure are not affordable for this particular capital budget, due to the high regulatory capital charges. Accordingly, real estate investments replace these two assets in order to achieve the target returns. However, in terms of portfolio risk, it is crucial that the standard deviation of all portfolios for a capital budget of 8% exceeds the standard deviation of portfolios with a higher capital budget over the entire return spectrum.

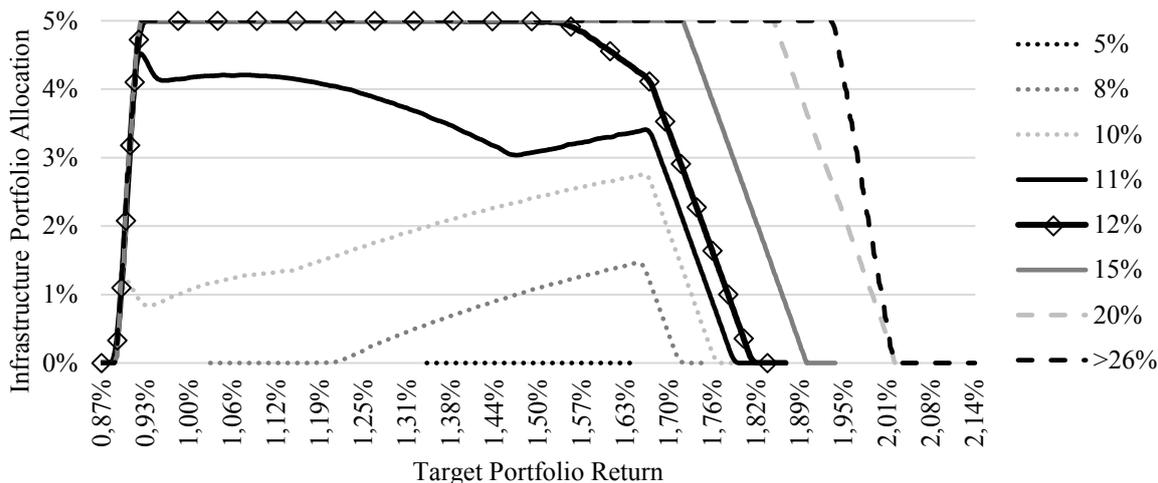
Figure 3: Optimal Real Estate and Infrastructure Portfolio Allocation for Different Levels of Solvency Capital Budget (SCB)

(a) Real Estate:



(b) Infrastructure:

SCB:



Notes: Figure 3 illustrates the STD optimal portfolio weights for real estate and infrastructure assets for different given levels of Solvency Capital Budget. The marked line thus represents the average capitalization of European insurers.

Concerning infrastructure investments, the results yield a comparably similar picture at first glance. However, it is not possible to include infrastructure in the efficient portfolios is not possible for all target-portfolio return's, given a capital budget of 5%. Moreover, infrastructure is not necessarily allocated over the whole computable return spectrum for different capital budgets. This is particularly the case for high target-portfolio returns, irrespective of the relevant capital budget and for low target returns in low-capital budget portfolios (5% and 8%). Furthermore, in contrast to the results for real estate, there is a clear monotonous relationship between the capital budget and the efficient infrastructure allocation. That is, a higher capital budget results in a higher infrastructure weight for any target portfolio return and vice versa. This is due to the fact that infrastructure is subject to the highest capital requirements and therefore it is not capable of replacing any other asset class. The results suggest that the individual capital budget of an insurer determines the optimal real estate and infrastructure allocation. To consider the practical relevance and implications, we discuss the obtained findings in the next section with respect to the average capitalization prevailing in the European insurance market.

7 Discussion and Practical Implications

According to Braun *et al.* (2014), the average capitalization of Swiss insurance companies ranges from approximately 5-12%. Taking into account the information provided by the German Federal Financial Supervisory Authority (BaFin) and the results of the QIS5 released by EIOPA (2011), the average European insurer's capitalization is located at the high end of the range and generally amounts to 12%. Henceforth, in the spirit of Braun *et al.* (2013) and Hoering (2013), we use this figure as the basis for our further interpretation. In addition, it is

necessary to determine the most relevant target portfolio returns prevailing in the insurance industry, in order to be able to interpret the results meaningfully. Taking into account the actual average European insurer's asset allocation (cf. e.g. Fitch, 2011; Insurance Europe and Oliver Wyman, 2013) and the empirical asset returns, the most realistic portfolio compositions and therefore the relevant section to be interpreted lies between target returns of 1.7-1.8%. This would result in an annual return of around 7%, which is sufficient to cover the overhead costs and meet the obligations to policyholders.

Recalling Figure 3, the optimal real estate portfolio weights are well above the average current insurer's real estate allocation of 5% for the majority of combinations of target returns and capital budget. Hence, the introduction of Solvency II does not impact on the current trend of increasing real estate allocations, at least not for the average insurer. Considering a specific target return of 1.75% for instance, the risk-optimal real estate weight for 12% SCB amounts to exactly 16%, with rather moderate shifts when varying target return and/or budget within reasonable intervals. It is particularly noticeable that for high target returns, real estate weights are increased to their investment limit once the capital budget allows this. This is due to the risk-reducing properties (i.e. low correlation) which are explicitly accounted for in the optimization problem, since the objective function itself contains the empirical covariance matrix. Real estate therefore proves to be an attractive complement to stocks for sufficiently capitalized insurers.

On the other hand, the optimal infrastructure weight for the mentioned return of 1.75% and SCB of 12% is exactly 1.87%. Other than for real estate, this allocation is extremely sensitive to variations in capital budget or target return. While reducing the SCB constraint to 11% leads to an allocation of only 1.11%, increasing it to 13% leads one of 2.61%. Variation in the target return has an even more severe impact, since the slope of the allocation function is very steep in the relevant section for all relevant SCBs. Interestingly, the average SCB of 12% yields almost exactly the current infrastructure allocation of insurance companies in Europe within the relevant return spectrum. Moreover, at first glance, the sensitivity of infrastructure weights of only 1.11% to 2.61% seems quite insignificant. However, given the average lot size for European infrastructure investment deals of approximately €400 mm, with notable deals well exceeding €1 bn (Preqin, 2013), this difference could account for just one single investment in practice. Again, for high target returns, infrastructure weights are increased to their investment limit once the capital budget allows for it. However, the amount of capital needed to ensure the

full risk-optimal allocation is much than for real estate. Also bear in mind that very high target-return portfolios do not contain infrastructure investments, simply due to their relatively low expected return.

While the previous passages focus solely on the situation of average- and overcapitalized insurance companies, the situation may turn out differently for undercapitalized market participants. According to the QIS5 results of EIOPA (2011), 23.2% of European insurers are at risk of not fulfilling the SCR imposed by Solvency II (i.e. their SCR coverage is below 1.2). Putting aside operational risks (e.g. insufficient reinsurance or high concentration risk), it is likely that these insurers exhibit a SCB below 12%. As a result, these insurers need to act in order to minimize their SCR, e.g. by reducing the allocation of alternative assets. Focusing on the 5%, 8% and 10% SCB-level's real estate and infrastructure allocations, three findings are notable. First, given the attainable target return spectrum, real estate weights of well above 5% are still risk-optimal. Second, risk optimal infrastructure weights are below 2% in the vast majority of cases. Third, the maximum attainable target return is very sensitive to the SCB level. Hence, the capital burden imposed by the Solvency II standard formula creates a competitive disadvantage for already undercapitalized market participants. Compared to overcapitalized competitors, this is likely to force them into a less efficient asset allocation, i.e. limiting infrastructure allocations and also limiting the expansion of real estate allocations. Furthermore, it forces them into low target-return portfolios, i.e. limiting both stock allocations and the expansion of real estate allocations. Both disadvantages might lead to more consolidation among European insurance companies and therefore to further declining competition. Taken together, all these effects undermine the original purpose of Solvency II.

8 Conclusion

The forthcoming Solvency II Directive introduces a risk-based model for insurers to derive their capital requirements, and thereby changes the set of rules prevailing in the past years. Henceforth, especially undercapitalized insurers might be forced to minimize their economic capital in order to remain competitive in the industry. In addition, even for sufficiently capitalized insurance companies, the Directive might create incentives to reduce capital requirements and potentially lead to a change in the investment patterns. During recent years, especially alternative assets, such as real estate and infrastructure, drew more attention from investors as an alternative source for adequate returns in the current low-interest-rate environment. However, Solvency II might constrain this very development.

To empirically investigate the raised questions, we conduct several portfolio optimizations with respect to the given regulatory requirements of the Solvency II standard formula. The results confirm the current investment trends; real estate and infrastructure investments should play a significant role in the mixed asset portfolio of a representative European insurance company, when the aim of the optimization is to minimize portfolio standard deviation. By contrast, in capital-efficient optimizations, for which the aim of the optimization is to minimize the overall SCR, infrastructure is completely removed from the portfolios over the whole spectrum of target returns and real estate weights are reduced substantially. However, accounting for the actual (not minimum) capitalization of European insurers again yields a different picture. We show that, although the calibration of the capital requirements for alternative assets are obviously inadequate in terms of the risk and SCR relationship, real estate as well as infrastructure investments are still allocated in the risk optimal portfolios, even if realistic capital budgets are considered. In the case of well-capitalized insurance companies, the derived optimal portfolio weights even exceed the observable allocations in practice, which indicates that the introduction of Solvency II is not likely to affect the investment policy with respect to real estate and infrastructure assets. As a consequence, if at all, only small and undercapitalized insurers may be forced to reduce their exposure to alternative investments. Hence, this paper hopefully helps to evaluate the potential effects of Solvency II on a more meaningful basis than in the current and ongoing debates prevailing both in academia and practice. In addition, the paper offers further explanations of the disparity between theoretical optimal and actual alternative asset allocation in practice.

Ultimately, we open up several avenues for further research on related topics. First, the methodology can be used as a basic framework for dealing with capital requirements in portfolio optimization. Further research could, for instance, examine different capital requirement regimes for insurance companies, such as the Standard & Poor's Rating model or the Swiss Solvency Test. Second, there is an ongoing research stream on whether real estate investments exhibit any duration. The same should hold true for infrastructure, as it is also seen as a supposedly interest-rate-sensitive asset. Hence, further studies could account for the respective duration of both assets within the interest rate risk sub-module in the relevant capital charge framework. Lastly, this paper focuses solely on the effects on direct real estate and infrastructure investments. However, more and more capital now flows into debt-like investment vehicles, such as real estate debt funds, which in turn are treated differently under the Solvency II regime. Further research could incorporate these investments instruments in a similar setting.

Endnotes

- [1] In line with Braun *et al.* (2014), we do not account for the possible “symmetric adjustment mechanism” of -7% and use the base levels of the two stresses (cf. SCR 5.37 in EIOPA (2012)).
- [2] The data frequency and sample period is limited to quarterly observations, due to the frequency of the benchmark index of infrastructure performance.
- [3] The IPD U.K. Property Total Return Index covers one of the most transparent and liquid real estate markets in the world. Data is available in high frequency and for a sufficiently long time period. For these reasons, the regulator also decided to use exactly this index in order to map real estate performance in Europe. We deem the simple unsmoothing technique to be sufficient for our research purposes.
- [4] The index covers transactions in all economic and social infrastructure sectors, i.e. transportation, energy (oil, water, gas), communication, waste recycling, healthcare and education. All included sectors are in accordance with the definition of infrastructure from Wagenvoort *et al.* (2010) and Weber and Alfen (2010).
- [5] We use this index to enhance the sample period, as there is no other European corporate bond index with a comparably long history. The European corporate bonds index provided by BofA Merrill Lynch (Code: MLEXPEE) only dates back to 1996, but shows very similar risk/return profile and correlation patterns. Therefore, our results are unlikely to be affected by the choice of data set. In addition, other studies have also chosen this index for similar research purposes (cf. e.g. Braun *et al.*, 2013)
- [6] We thank William le Noble from Citigroup for providing the information.
- [7] Strictly speaking, one should differentiate between the free and restricted assets of the insurance company. The free assets thereby equal the firms’s equity capital and are not subject to regulatory investment limits. These limits are only relevant for the restricted assets, which back the insurer’s technical provisions. For reasons of simplicity, we assume the free assets to be allocated in the same manner as restricted assets.
- [8] However, negative interest rate shocks, as prescribed by the regulator, are not expected during the current structural low-interest-rate environment and are therefore not accounted

for in the Markowitz-optimization. In addition, to reliably incorporate interest rate risk into the optimization algorithm would require detailed assumptions about the balance sheet of the respective insurance company.

[9] This corresponds to a Value-at-Risk of approximately 95% assuming normal i.i.d. returns.

Appendix

Appendix 1: Altered Term Structure for Interest Rate Risk

Maturity t (years)	Relative Change $s^{up}(t)$	Relative Change $s^{down}(t)$
0,25	70 %	-75 %
0,5	70 %	-75 %
1	70 %	-75 %
2	70 %	-65 %
3	64 %	-56 %
4	59 %	-50 %
5	55 %	-46 %
...
20	26 %	-29 %
90	20 %	-20 %

Notes: This table shows the relevant stress factors s^{down} for individual maturities t

Appendix 2: Spread Risk Factors for Bonds

Credit Quality Step								
	0	1	2	3	4	5	6	Unrated

Duration (years)	< 5	0.9% × D	1.1% × D	1.4% × D	2.5% × D	4.5% × D	7.5% × D	7.5% × D	3.0% × D
	5-10	4.50% +	5.50% +	7.00% +	12.50% +	22.50% +	37.50% +	37.50% +	15.00% +
		0.53% × (D-5)	0.58% × (D-5)	0.58% × (D-5)	1.50% × (D-5)	2.51% × (D-5)	4.20% × (D-5)	4.20% × (D-5)	1.68% × (D-5)
	10-15	7.15% +	8.40% +	10.50% +	20.00% +	35.05% +	58.50% +	58.50% +	23.40% +
		0.50% × (D-10)	0.50% × (D-10)	0.50% × (D-10)	1.00% × (D-10)	1.80% × (D-10)	0.50% × (D-10)	0.50% × (D-10)	1.16% × (D-10)
	15-20	9.65% +	10.90% +	13.00% +	25.00% +	44.05% +	61.00% +	61.00% +	29.20% +
0.50% × (D-15)		0.50% × (D-15)	0.50% × (D-15)	1.00% × (D-15)	0.50% × (D-15)	0.50% × (D-15)	0.50% × (D-15)	1.16% × (D-15)	
>20	12.15% +	13.40% +	15.50% +	30.00% +	46.55% +	63.50% +	63.50% +	35.00% +	
	0.50% × (D-20)								

Notes: This table presents the spread risk factors for bonds and loans, depending on individual credit quality and duration.

Appendix 3: Solvency II Market Risk Correlation Matrix

	Interest	Equity	Property	Spread
Interest	1			
Equity	0 / 0.5	1		
Property	0 / 0.5	0.75	1	
Spread	0 / 0.5	0.75	0.5	1

Notes: The table depicts the regulatory correlation figures for the upward (left) and downward (right) scenario

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