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Alexander Braun, Sebastian Utz, Jiahua Xu

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Are insurance balance sheets carbon-neutral? Harnessing asset pricing for climate change policy[†]

Alexander Braun[1] · Sebastian Utz[2] · Jiahua Xu[3]

Abstract
Due to its enormous size and capital base, the insurance industry has the potential to play a key role in countering climate change. To this end, the major capital flows associated with its investment and underwriting businesses would need to be redirected towards carbon-neutral activities. Since insurance companies can be viewed as large portfolios consisting of financial risks (asset side) and underwriting risks (liability side), we suggest an asset pricing approach to detect carbon-intensive positions on their balance sheets. The framework should be accompanied by two simple policy changes to reinforce its effectiveness.

Keywords Climate change · Sustainable insurance · Carbon emissions · Asset pricing

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✉ Alexander Braun
alexander.braun@unisg.ch

Sebastian Utz
sebastian.utz@unisg.ch

Jiahua Xu
jiahua.xu@epfl.ch

[1] Institute of Insurance Economics, University of St. Gallen, Tannenstrasse 19, 9000 St. Gallen, Switzerland

[2] School of Finance, University of St. Gallen, Bodanstrasse 6, 9000 St. Gallen, Switzerland

[3] Ecole polytechnique fédérale de Lausanne (EPFL), UNIL-Extranef 249, 1015 Lausanne, Switzerland

Introduction

Climate change is one of the greatest challenges for humanity (King 2004). According to recent estimates, the global average temperature has already risen by 1 °C compared to pre-industrial levels (see Hawkins et al. 2017). The dominant cause for this development are anthropogenic greenhouse gas (GHG) emissions, which create temperature anomalies for many millennia (see Eby et al. 2009). Should the trend persist, the earth will be faced with catastrophic and irreversible consequences such as ocean acidification, permafrost thawing, desertification, extreme weather, coastal flooding and the extinction of many species. Recent disasters such as hurricanes Harvey, Irma and Maria in 2017 could be harbingers of this development and, alarmingly, research consistently predicts more severe meteorological and hydrological events in the future (see Knutson et al. 2010). The impact of climate change on societies is expected to be devastating, ranging from famines and droughts to the uninhabitability of whole geographic regions.

On the positive side, serious efforts to stabilise carbon emissions are emerging. Since the ratification of the United Nations Framework Convention on Climate Change (UNFCCC) in 1994, 24 Conferences of the Parties (COP) have been held. During the most recent summit of 2018 in Katowice, almost 200 nations agreed on binding rules for the implementation of the 2015 Paris Agreement (see UNFCCC website[1]). The major shift in energy generation and industrial practices associated with the long-term temperature goal of 2 °C will require a significant redirection of global capital flows towards carbon-neutral infrastructure projects and technologies (see, e.g. Schmidt 2014; World Economic Forum 2013). Thus, the insurance industry, as a big contributor to the world's GDP, bears a great responsibility. Recognising their potential to counter climate change, many insurers have committed themselves to a comprehensive, enterprise-wide plan of action. In a detailed survey, Mills (2012) reports 1148 initiatives from 378 institutions in 51 countries, including engagements such as the financing of mangrove reforestation and the promotion of disaster-resilient and energy-efficient building practices. Moreover, 2012 witnessed the introduction of the Principles for Sustainable Insurance (PSI), a voluntary framework supported by 65 entities (see UNEP 2012).

While these are encouraging developments, the actual effectiveness of many of these activities remains unclear. In some cases, companies might merely pursue showcase projects such as investments in emission reduction technologies or environmentally focused funds on a smaller scale, simply because mentioning sustainable business practices resonates well with the public. For a real impact to materialise, however, insurance firms must consistently pursue green policies in their core investment and underwriting portfolios. The potential is enormous: estimates for the global insurance sector indicate around USD 25 trillion in assets under management and almost USD 5 trillion in non-life premium volume (see Mills 2012; Swiss Re 2018b). A reallocation of just a fraction of these capital

[1] https://unfccc.int/.

flows to low-carbon sectors of the economy could be a substantial catalyst for the achievement of climate goals. However, since existing frameworks are not binding, and it is costly for stakeholders to scrutinise the industry, insurers might not be strongly incentivised to extend the green paradigm to their entire balance sheet. Apart from a recent article by Mielke (2018), the literature is astonishingly silent on this issue. We aim to take up the discussion by suggesting a novel policy framework consisting of two main elements.

First, we develop a rapid test for carbon exposure in the investment portfolios of exchange-listed insurance companies, based on asset pricing theory[2]. More specifically, we enrich the 5-factor sector model of Ben Ammar et al. (2018) with an excess return series for traded GHG certificates. Those must be purchased by "polluters" to cover their emissions in a given year, forcing them to internalise externalities associated with climate-wrecking activities. Through this new factor, we aim to capture exposures to the CO_2 price hidden in insurance stock returns, thus unveiling the actual investment practices of the companies. This is important, since the actions of portfolio managers may deviate from their stated intentions, a phenomenon known as "style drift" in the fund industry (see Fung and Hsieh 2002). We empirically implement our approach based on a rolling regression with a 48-month window on the stock return series of 35 European insurance companies from 2008 to 2018 and discuss the time-varying patterns in the carbon factor coefficients. In addition, we illustrate how the model can be extended to capture a broader range of sustainability criteria such as the exclusion of controversial weapons and nuclear energy, as well as the adherence to occupational safety standards and human rights.

Second, we contemplate several complementary regulatory measures. An important question surrounds the institutionalisation of the aforementioned carbon test and the consequences for firms that exhibit a significant exposure to the CO_2 factor. In our view, the most natural way to address these issues is an extension of Solvency II. To begin with, insurers could be mandated to disclose the model's carbon coefficients and corresponding standard errors in both their annual report and their Solvency and Financial Condition Report (SFCR), allowing for a simple and low-cost evaluation of their climate neutrality by stakeholders and the general public. The respective information could then form the basis of an environmental, social and governance (ESG) label for insurance companies. Such signals are already common in the investment fund industry (see, e.g., Ammann et al. 2018; Hartzmark and Sussman 2019). As a further incentive for compliance, a markup (discount) in the capital charges for short (long) carbon exposures could be considered. This idea directly extends to the liability side of the balance sheet, which is not covered by our model. The reason is that technical reserves, even when valued in a market-consistent way, are not sensitive to changes in the price of CO_2. Hence, other measures are needed to discourage firms from insuring carbon-intensive facilities and infrastructures.

The remainder of this paper is structured as follows. In the second section, we briefly review the advent and dispersion of the sustainability paradigm in the

[2] For mutual insurers, the equity stakes cannot be easily separated from the policyholder stakes and are not traded on an active market (see, e.g., Braun et al., 2015). Thus, our carbon test is unfortunately not applicable to this widespread legal form of insurance companies

insurance industry as well as the known effects of sustainability on asset prices. The linear factor model that we wish to harness for the detection of CO_2 positions in the investment portfolios of insurance companies is introduced in the third section. The fourth section contains an empirical application of our rapid test for carbon exposure. In the penultimate section, we discuss important complementary policy changes. Finally, in the last section, we draw our conclusion.

Background and motivation

Sustainability in insurance

The global insurance industry is home to some of the world's largest institutional investors. With about USD 25 trillion in assets under management, it commands more than 15 times the estimated annual gap (USD 1.6 trillion) that needs to be closed by the private sector to achieve all 17 sustainable development goals (SDGs) by 2030 (see ECOSOC Chamber 2018). Insurers and reinsurers differ from other asset managers such as mutual or hedge funds in that they pursue a liability-driven investment approach. This means that their portfolios are constructed in line with the predicted future insurance liabilities through an overweighting of long-term investment-grade bonds. For the average asset portfolio of the U.S. insurance industry, for example, Wong (2017) reports a 65% share of fixed-income securities compared to 12.5% stocks and only 4.2% cash and short-term investments. Given their long-term investment horizon as well as buy-and-hold strategy, insurers are well positioned to support the transition to the low-carbon economy by funding sustainable projects, particularly related to infrastructure. Due to its stable cash flows and long-term nature, infrastructure is a promising asset class that many insurers have begun to consider in the low interest rate environment of the last decade (see, e.g. Karapiperis 2017).

Despite its overwhelming potential to combat climate change, the global insurance industry has been adopting the sustainability paradigm at a modest speed. Merely 129 insurers worldwide undertook notable measures against global warming between 1995 and 2009, indicating that the majority remained on the sidelines (see Mills 2012). In addition, it is unknown how many of those companies that do pursue green policies actually work with effective levers. More specifically, insurers may pursue several activities against climate change and its consequences, such as science projects, loss prevention, technology investments and new product development, without consistently keeping their core investment and underwriting portfolios carbon-neutral. Reported green investments comprise USD 23 billion in emission reduction technologies and USD 5 billion in environmentally focused funds (see Mills 2012). This is a drop in the bucket compared to the industry's overall assets under management. Hence, for some insurers, green projects may be a fig leaf rather than a real effort to combat global warming.

The Principles for Sustainable Insurance (PSI), launched by the UNEP Finance Initiative in 2012, serves as additional guidance for the industry to address ESG risks and opportunities. Signatories of the PSI represent 25% of the worldwide premium

volume. The four principles are: (i) integrating ESG issues in business decisions; (ii) collaborating with clients and business partners to raise awareness and to develop solutions; (iii) working with governments, regulators, and other stakeholders to promote action; and (iv) disclosing the progress made about the implementation of the principles. Unfortunately, the framework is non-binding, and its implementation does not necessarily result in a reduction of carbon-intensive positions in the industry's investment or underwriting portfolios. In short, while the insurance sector would be capable of a substantial contribution to sustainable development, only a small proportion of its firms have voluntarily committed to explicit goals. For stakeholders, the cost involved in identifying truly sustainable insurers remains high.

From the shareholders' perspective, a lively debate is ensuing on the question of whether sustainability and financial performance are a trade-off. There are theoretical arguments for both a positive and a negative relationship between these goals. Recent empirical studies support the former stance (see, e.g., Dorfleitner et al. 2018; Lins et al. 2017). Moreover, most evidence indicates that sustainable business practices do not result in a significantly reduced profitability but do mitigate risk. In particular, idiosyncratic risk and crash risk (a measure for tail risk) are lower for firms with a high level of ESG activities (see, e.g., Lee and Faff 2009; Kim et al. 2014; Utz 2018).

Sustainability in asset pricing

The risk-return relationship is a long-studied topic in asset pricing, its modern origin being the capital asset pricing model (CAPM) (see Sharpe 1964; Lintner 1965; Mossin 1966; Black et al. 1972). Over the last few decades, several multi-factor augmentations of the CAPM have been proposed (see, e.g., Fama and French 1993; Carhart 1997; Fama and French 2015). Recently, Harvey et al. (2016) presented a list of more than 300 possible factors, and Fama and French (2018) suggested a methodology for factor selection. The fundamental purpose of multi-factor models is to explain the return variation and risk premiums of assets. Applied to whole portfolios, their coefficients indicate the constituent asset classes and investment styles (see Sharpe 1992; Fung and Hsieh 2002).

Extant research has revealed that the sustainability dimensions of a firm have a measurable impact on the performance of its stock and may thus be considered as a risk factor on its own. Khan et al. (2016) document that businesses yield significantly higher financial returns if they exhibit material sustainability aspects. Similarly, Edmans (2011) finds significant positive abnormal returns for companies that treat their staff well and are listed among the best employers. Moreover, Hong and Kacperczyk (2009) provide evidence that norm-constrained institutions such as pension funds shy away from investing in companies with exposure to controversial business activities. Therefore, their stocks offer higher expected returns.[3] Finally, the results of Bernardini et al. (2019) indicate significant alphas for portfolios of low-carbon stocks after the decarbonisation process took off in 2012.

[3] Examples for such "sin stocks" are tobacco, alcohol and gaming enterprises.

We presume it should also be possible to detect CO_2 exposures in portfolios using an adequately configured factor model. The underlying reasoning looks as follows. Through their business model, polluters hold a short position in CO_2, i.e., they benefit (suffer) from falling (rising) carbon certificate prices through lower (higher) operating costs. Increases in the price of CO_2, therefore, make carbon-intensive (green) investments less (more) attractive. Theoretically, this should apply to both equity investments as well as corporate bond investments. We capture the carbon price through actively traded GHG emission certificates. Those certificates need to be acquired by polluters (e.g., coal plant operators) to cover their CO_2 emissions, forcing them to internalise the associated externalities.[4] Intuitively, an insurer can be viewed as a combination of two portfolios, an investment and an underwriting portfolio. Therefore, carbon-intensive positions on the asset side of the balance sheet should leave traces in the returns of its stock, which can be filtered out using a returns-based style analysis (see, e.g., Fung and Hsieh 2002).

European Union Emission Trading Scheme

The prices for CO_2 that we use in this paper are drawn from the European Union Emissions Trading System (EU ETS), the oldest and largest emission trading system worldwide. Its first phase was launched in January 2005 to achieve the climate targets established in the Kyoto Protocol, which contains explicit limits for the emission of climate-damaging gases, such as CO_2, per country. The EU ETS contributes to the reduction of such gases by turning the ability to emit them into a scarce resource. More specifically, it caps the emissions of entire economies at a specified level of tons of CO_2 in a certain period. The trading system focuses on carbon-intensive industries responsible for approximately 50% of the European CO_2 emissions. These comprise, for instance, power generation, iron and steel, paper and cellulose, chemistry, and refineries. All registered facilities have to prove that they own enough allowances to cover their emissions on April 30 each year. In case of a shortfall, the operator of the facility has to pay EUR 100 per ton of extra emitted CO_2 and additionally has to deliver the missing number of emission allowances. The prosecution of such a misdemeanour is based on national legislation transposing the pertinent EU directive (Directive 2003/87/EC).

To prevent a price shock in the first (test) period from 2005 to 2007, governments distributed the emission allowances[5] following a grandfathering mechanism. This means that a certain amount of CO_2 was allocated to each of the 11,000 facilities registered in the EU ETS based on their past emissions (including some reduction targets). If a facility was able to reduce its CO_2 emissions to a greater extent than

[4] In 2005, the European Union Emissions Trading System (EU ETS) was launched as the first GHG trading scheme in the world. Although the EU ETS was initially criticised for its large number of emission certificates, market fundamentals changed and prices have increased notably in recent years.

[5] One CO_2 emission certificate permits the owner to emit one ton of CO_2 or other gases that damage the climate with the same intensity.

expected, the operator was allowed to trade the free allowances. With the beginning of the third period (2013–2020), the distribution of emission allowances changed. Thereafter, the EU only provided about 60% of the certificates, whereas the additional 40% could be purchased by firms causing pollution. Coal power stations are an exception, since they have to purchase all necessary emission allowances through the trading system at market prices.[6] During this third period, prices for emission allowances substantially increased from EUR 6.50 in January 2013 to EUR 25 in June 2019. The current price translates into a CO_2-induced cost pressure for the operator of an average coal plant of about 10% of the market price per kilowatt hour (kWh) of produced electricity and is therefore significant.[7]

Model framework

To isolate the impact of CO_2 price exposure and avoid omitted variable bias, our model needs to control for key factors that are known to explain the return time series of insurance stocks. We therefore adopt the insurance-specific five-factor asset pricing model (INS5) of Ben Ammar et al. (2018) and extend it by our carbon factor (CO_2):

$$\begin{aligned} R^e_{i,t} = \alpha_i + \beta_{i,MKT} MKT_t + \beta_{i,HMLINS} HMLINS_t + \beta_{i,PRETINS} PRETINS_t \\ + \beta_{i,ROEINS} ROEINS_t + \beta_{i,SPREADINS} SPREADINS_t + \beta_{i,CO2} CO2_t + \epsilon_{i,t}, \end{aligned} \tag{1}$$

where $R^e_{i,t}$ denotes the excess return of stock i in period t; α_i is the intercept for stock i; $\beta_{i,F}$ represents the loading on factor F; and $\epsilon_{i,t}$ is the idiosyncratic error term. The original INS5 model comprises the following factors: the market index (MKT); a zero-investment portfolio sorted by the book-to-market (b/m) ratio of insurance stocks (HMLINS); a zero-investment portfolio sorted by prior month return of insurance stocks (PRETINS); a zero-investment portfolio sorted by the return on equity (ROE) of insurance stocks (ROEINS); and the return difference between insurance stocks and the entire market (SPREADINS).[8] We add the carbon factor to capture GHG exposures on the asset side of the insurers' balance sheets. Positive β_{CO2} (carbon betas) indicate net long positions in green assets since the portfolio value increases when GHG emission certificates become more expensive. Conversely,

[6] Exceptions existed for coal plants in Eastern European countries.

[7] An average brown coal power station can produce one kWh of electricity through the emission of 1.1 kg of CO_2. The current market price for one kWh on the German electricity market is approximately EUR 0.3, and the cost for the emission allowances per kWh is approximately EUR 0.03.

[8] We construct HMLINS, ROEINS, and PRETINS slightly differently from Ben Ammar et al. (2018), who developed their model for U.S. property-liability insurers, since we work with European data. More specifically, we sort the sample insurance stocks by the respective characteristics (previous year b/m ratio, previous year ROE, previous month return) and form equally weighted tercile portfolios. The risk factors are then derived by subtracting the last tercile (lowest value) from the first tercile (highest value) portfolio.

negative coefficients point towards polluters whose profitability is negatively affected by rising CO_2 prices.[9] All factors are measured in excess returns.

In a second analysis, we further extend the INS5 model by a broad sustainability factor (FNGO):

$$\begin{aligned} R^e_{i,t} = \alpha_i &+ \beta_{i,MKT} MKT_t + \beta_{i,HMLINS} HMLINS_t + \beta_{i,PRETINS} PRETINS_t \\ &+ \beta_{i,ROEINS} ROEINS_t + \beta_{i,SPREADINS} SPREADINS_t + \beta_{i,CO2} CO2_t \\ &+ \beta_{i,FNGO} FNGO_t + \epsilon_{i,t}. \end{aligned} \tag{2}$$

To construct FNGO, we first form a factor FNG, which reflects the excess returns of an equally weighted portfolio of 88 mutual funds with FNG label. The abbreviation FNG stands for "Forum Nachhaltige Geldanlagen" (see FNG website[10]), an initiative that awards its sustainability label to fund managers in German-speaking Europe, given that they satisfy a transparent set of minimum criteria such as the exclusion of weapons manufacturers and coal plant operators. It signals to investors that the funds consistently pursue a rigorous sustainability strategy in line with internal standards. Since the excess return series of FNG is influenced by general stock market movements and likely includes a high concentration of green businesses, we orthogonalise on MKT and CO2 through the following regression:

$$FNG_t = \gamma + \delta_{MKT} MKT_t + \delta_{CO2} CO2_t + u_t. \tag{3}$$

FNGO is obtained by adding up γ and u_t. In other words, we strip FNG of the variance that is explained by the market and the carbon factor, thereby exclusively leaving those parts that are neither attributable to general stock market or carbon allowance volatility. Thus FNGO should separately detect exposures to further sustainability dimensions. Equations (1) to (3) are estimated by means of OLS and Newey-West HAC standard errors with lags of four.

Empirical analysis

Data and descriptive statistics

Our sample consists of 35 European insurance companies included in the STOXX Europe 600 Insurance index as of February 2019. For each company, we collect monthly returns as well as year-end b/m ratios and ROEs spanning the period from

[9] To validate this effect, we collected monthly stock return data over the period January 2017 to December 2018 from two types of companies based in Europe: (i) "green" business models (e.g. from the renewable energy sector), and (ii) carbon-intensive business models (e.g. from the fossil fuel power industry). Subsequently, we regressed the excess return time series of each company on the European five-factor asset pricing model of Fama and French (2015) plus the CO_2 factor. The excess return series for the five European Fama-French factors were obtained from Ken French's library. In line with those factors, the excess returns of the European stocks and the CO_2 factor were converted to USD. We found the average β_{CO2} of "green" companies (0.16) to be higher than the average β_{CO2} of carbon-intensive companies (-0.11), on a statistically significant level ($p = 0.01$). The respective results are available from the authors upon request.

[10] https://www.fng-siegel.org/en/siegelkriterien-en.html.

Table 1 Descriptive statistics

	Mean	Volatility	Median	Min.	Max.	Skewness	Kurtosis	Obs.
MKT	−0.379	4.930	0.136	−24.996	9.840	−1.379	4.308	129
HMLINS	0.210	1.319	0.247	−3.415	6.211	0.705	3.203	129
PRETINS	−0.104	1.732	−0.266	−9.998	6.904	−0.272	10.238	129
ROEINS	0.257	1.891	0.172	−8.782	9.559	0.174	9.068	129
SPREADINS	0.196	3.473	0.746	−11.044	12.968	−0.228	1.495	129
CO2	0.847	16.552	1.690	−50.796	57.052	0.044	1.184	129
FNGO	0.080	0.509	0.063	−1.601	1.015	−0.702	1.547	36

The table presents the mean, volatility, median, minimum, maximum, skewness, kurtosis, and number of observations for the monthly excess return series of each factor. The data for MKT, HMLINS, PRETINS, ROEINS, SPREADINS and CO2 cover the period from April 2008 to December 2018. The FNGO series is available from January 2016 to December 2018

December 2007 to January 2019 from Datastream. Furthermore, we proxy the risk-free interest rate between January 2008 and December 2018 through the one-month Euribor (Euro Interbank Offered Rate). The latter was obtained from Bloomberg together with returns of the STOXX All Europe Total Market index, which we use as the market factor MKT. To construct HMLINS, PRETINS and ROEINS, we sort the 35 insurance stocks according to their b/m ratios (annual basis), prior month returns (monthly basis) as well as ROEs (annual basis), and group them into terciles for each month. The return time series of the zero-investment portfolios that constitute the factors are obtained by subtracting the equally weighted excess returns of the lowest from those of the highest tercile portfolio. Finally, we construct SPREADINS by subtracting MKT from the monthly excess returns of the STOXX Europe 600 Insurance index. All price and accounting data are denominated in EUR.

Carbon prices are measured through the European Climate Exchange EU Allowances (ECX EUA) futures contract. For a gapless time series from April 2008 to December 2018, we merge data of investing.com and quandl.com and calculate the associated excess returns for CO2. In addition, we consult the FNG website[11] for the list of funds that have received the FNG label since 2016. We collect the monthly returns of those funds for the period January 2016 to January 2019 from Datastream, form an equally weighted portfolio and subtract the risk-free rate series to obtain the excess returns for FNG. Those are then orthogonalised on MKT and CO2 as described in the previous section, leaving us with FNGO. Table 1 presents descriptive statistics for the factors.

The MKT series exhibits a negative mean of −0.379% (−4.54% p.a.) because the sample includes extreme observations from the global financial crisis in 2008 and the dramatic price decline in December 2018 that marked the worst week in a decade. HMLINS and ROEINS show positive means of 0.210% (2.55% p.a.) and 0.257% (3.084% p.a.), respectively. In contrast, the average excess return of PRETINS is −0.104% (−1.248% p.a.). These figures are consistent with those of Ben

[11] https://www.fng-siegel.org/en/.

Ammar et al. (2018) for the INS5 factors in the U.S. stock market. The mean of 0.196% (2.352% p.a.) for SPREADINS indicates a positive historical return spread of the European insurance sector over the main market. Turning to our carbon and sustainability factors CO2 and FNGO, we find average excess returns of 0.847% (10.164% p.a.) and 0.080% (0.960% p.a.), respectively. The former mirrors the substantial increase in the price of GHG certificates during the past decade, putting pressure on polluter business models. The relatively low mean of FNGO, in contrast, suggests that adherence to a broad range of sustainability dimensions has not been associated with high excess returns in the European market.

A rapid test of carbon exposure

Below we discuss our main empirical analysis. For all 35 insurance[12] stock return time series in our sample, we run a rolling regression with 48-month window, repeatedly estimating Model (1) over the period from April 2008 to December 2018. This results in a sequence of carbon betas for each insurer, reflecting the time-varying CO_2 price exposure of its investment portfolio. We exclude three insurers with short time series, leaving us with a remaining sample of 32 firms that exhibit regression results for at least 50 subsequent estimation windows. The entire analysis relies on publicly available excess return data for the insurance companies and the risk factors, but it does not require any labour-intensive manual analysis of annual reports or investor relations releases. Hence, it is a "rapid test" of carbon exposure in the asset allocations of insurers. The corresponding results are depicted in Fig. 1.

The majority of insurers in our sample show a more or less pronounced increase in the carbon beta in 2018. This consistently mirrors the many recent declarations of well-known industry constituents to explicitly pursue decarbonisation strategies. For example, in 2018, *Insurer 20* (*Insurer 14*) announced the termination of investments in companies gaining more than 30% (25%) of their revenues from coal mining or coal-based energy production. Any such remaining assets were meant to be sold by the end of the year. Similarly, following the adoption of ESG benchmarks in 2017, *Insurer 33* reported in June 2018 that it applied the corresponding criteria to close to 100% of its asset portfolio. The most striking effect, however, is associated with the climate change strategy of *Insurer 6*, developed in the firm's Responsible Investment Guideline in 2015. Significantly positive carbon betas for 2018 indicate that this insurance group not only withdrew from carbon-intensive assets but seems to have reallocated a non-negligible quantity of the respective funds to green investments. Together with *Insurer 26*, *Insurer 6* is the only European insurance company for which we document such results. Another special case is *Insurer 4*, which, as a real pioneer, adopted an explicit climate change strategy as early as 2012. According

[12] For the purpose of anonymisation, the names of the insurers have been redacted. The anecdotal evidence mentioned in the sections "A rapid test of carbon exposure" and "Detecting further sustainability dimensions" can be found in Allianz (2018), Generali (2018), Aviva (2018), Buthelezi (2019), Storebrand (2018), Swiss Re (2018a), on the Munich Re website, and on the Reuters website.

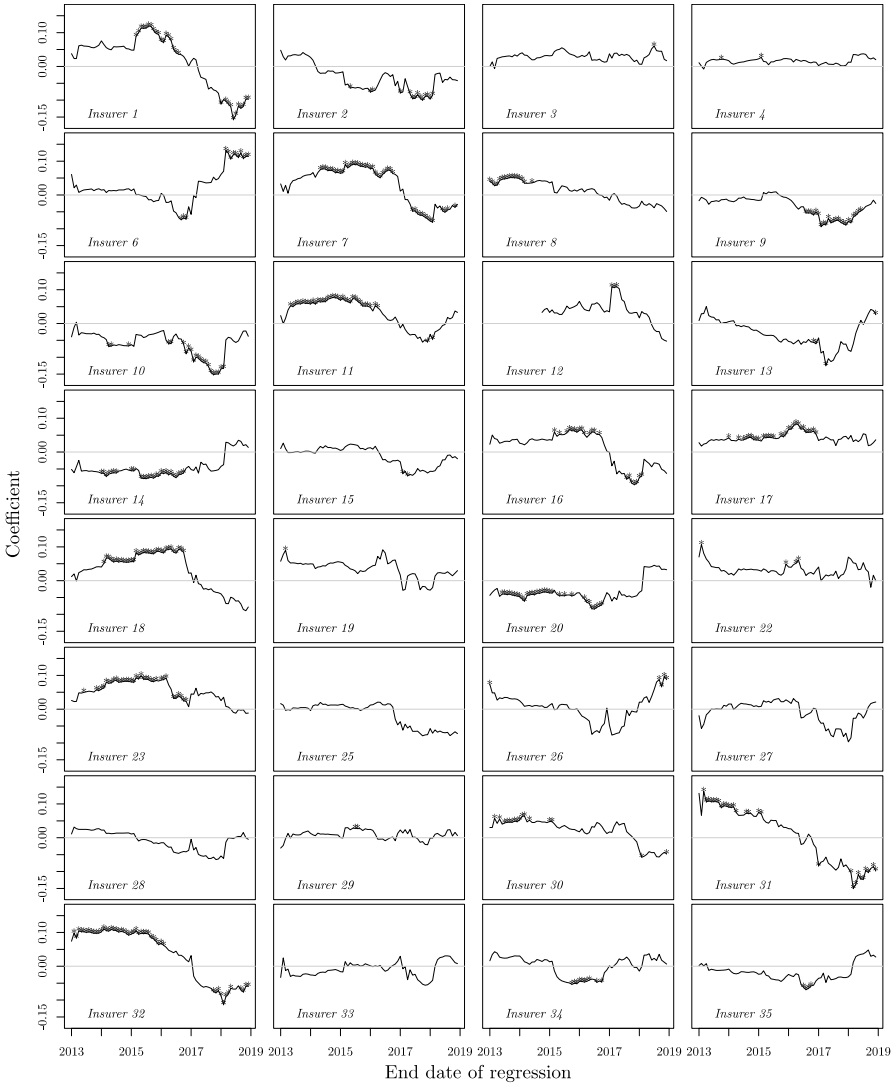

Fig. 1 Time series of coefficients (betas) for the factor CO_2. This figure displays each insurer's coefficient to the factor CO_2 as a function of time. The coefficients are estimated by means of Model (1) and a 48-month rolling window. The first set of 48 monthly return observations ends in January 2013, the last set ends in December 2018. Standard errors are based on the Newey-West HAC covariance matrix with lags of four. Coefficients with a significance level of 0.1 or below are marked by "*". We exclude insurers with shorter times series than 50 rolling windows (*Insurer 5, Insurer 21* and *Insurer 24*) from this analysis

to our estimates, it has indeed been running a CO_2-neutral investment portfolio ever since.

Against the general societal trend towards sustainability, several insurers still exhibited significantly negative carbon betas at the end of 2018. In this group are

firms such as *Insurer 1, Insurer 7, Insurer 30, Insurer 31* and *Insurer 32*.[13] Consider *Insurer 7*, e.g., which declared itself the first carbon-neutral international insurer in 2006 and contributed over GBP 500 million of investments to the wind, solar, biomass and other renewable energy projects. Despite these efforts, large parts of its investment portfolio seem to be allocated to CO_2-intensive assets. These results illustrate the importance of a transparent approach and the superiority of a returns-based style analysis over the manual screening of financial statements. The fact that we pick up a carbon exposure in these insurers' investment portfolios indicates a discrepancy between their affirmations and actual behaviour.

Detecting further sustainability dimensions

We continue our analysis with the estimation of Model (2) for each of the 35 European insurance companies. As explained above, the time series of excess returns for FNGO was derived from the returns of funds that exhibit the FNG sustainability label. Those funds are free of assets that are at odds with the ten norms of the UN Global Compact. Moreover, their portfolios do not include investments in the anti-human weapons sector, coal and nuclear plant power operators, as well as oil sand quarries. To avoid multicollinearity issues among MKT, CO2 and FNGO, we apply the orthogonalisation explained in the section "Model framework". Since FNG launched its fund label in 2016, the returns of the sustainability factor are available for 3 years ranging from 2016 to 2018.

Table 2 includes the results of this analysis. The carbon beta of each firm in Table 2 is generally consistent with the estimate of the carbon beta for the latest period in our rolling window approach displayed in Fig. 1. This indicates robustness of the results, since neither the modification in the length of the time series nor the integration of an additional sustainability factor substantially changes the results of Model 1. *Insurer 1* and *Insurer 31* are examples of significantly negative carbon betas in both models, *Insurer 6* and *Insurer 13* of positive carbon betas.

For several companies, only one of the two factors (CO2, FNGO) is significant. Moreover, we observe cases in which the carbon betas and sustainability coefficients exhibit opposite signs. This indicates that examining the carbon factor is not sufficient for a comprehensive analysis of the extent to which insurance companies align their investment portfolios with ESG criteria beyond the carbon intensity. The inclusion of FNGO provides more insights on how a company rooted the broader sustainability paradigm in its asset allocation. *Insurer 22*, e.g., shows little green exposure, yet it is identified as having a significantly positive loading on the FNGO factor. This can be explained by investments that focus on sustainability dimensions other than carbon intensity. In November 2018, *Insurer 22* launched South Africa's first ESG index unit trust funds that "exclude alcohol, gambling, tobacco, nuclear power and weapons".

Other insurers such as *Insurer 5, Insurer 7* and *Insurer 18* turn out to have significantly negative loadings on the FNGO factor, indicating non-compliance with

[13] The carbon beta of *Insurer 18* displays a similar evolution over time, but it ends up insignificant in 2018.

Table 2 Regression analysis

Company name	Intercept	MKT	HMLINS	PRETINS	ROEINS	SPREAD-INS	CO2	FNGO
Insurer 1	1.443**	0.501**	−3.785***	1.094	−1.466	0.747***	−0.079**	1.373
	(0.026)	(0.028)	(0.002)	(0.186)	(0.200)	(0.000)	(0.011)	(0.166)
Insurer 2	−0.283	1.246***	3.296**	−0.135	−0.866	0.995***	−0.049	−1.527
	(0.776)	(0.000)	(0.025)	(0.902)	(0.512)	(0.003)	(0.521)	(0.381)
Insurer 3	−0.153	0.949***	0.890	−0.994	0.682	0.912***	0.015	−0.759
	(0.708)	(0.000)	(0.294)	(0.235)	(0.508)	(0.000)	(0.623)	(0.428)
Insurer 4	−0.075	1.246***	2.343***	0.924	0.762	0.761***	0.013	1.031*
	(0.866)	(0.000)	(0.006)	(0.160)	(0.125)	(0.000)	(0.723)	(0.070)
Insurer 5	1.307***	0.928***	4.046***	0.439	0.959***	0.125	−0.015	1.688***
	(0.001)	(0.000)	(0.000)	(0.245)	(0.001)	(0.185)	(0.492)	(0.000)
Insurer 6	−0.610	1.559***	1.492*	0.530	1.598*	1.040***	0.081**	−2.559**
	(0.205)	(0.000)	(0.056)	(0.457)	(0.073)	(0.000)	(0.020)	(0.050)
Insurer 7	−1.038*	1.119***	−0.120	−2.151***	−0.402	0.656***	−0.012	−1.511**
	(0.090)	(0.000)	(0.891)	(0.001)	(0.587)	(0.000)	(0.586)	(0.028)
Insurer 8	−1.032**	1.566***	4.100***	−0.159	1.988**	1.166***	−0.063	0.538
	(0.022)	(0.000)	(0.000)	(0.802)	(0.016)	(0.000)	(0.123)	(0.391)
Insurer 9	−0.074	1.058***	2.011***	0.868*	0.853	0.176	−0.027	1.470*
	(0.847)	(0.000)	(0.008)	(0.071)	(0.179)	(0.306)	(0.294)	(0.095)
Insurer 10	0.977	0.679**	−3.796**	−1.770**	−1.209	0.470	−0.005	2.140*
	(0.228)	(0.020)	(0.017)	(0.023)	(0.413)	(0.101)	(0.942)	(0.072)
Insurer 11	1.072**	1.096***	2.261**	1.958*	−0.443	0.080	−0.002	0.778
	(0.032)	(0.000)	(0.031)	(0.055)	(0.550)	(0.780)	(0.958)	(0.438)
Insurer 12	−0.425	0.984***	−0.934	1.071	−0.245	0.409	−0.018	−2.979**
	(0.489)	(0.000)	(0.472)	(0.324)	(0.830)	(0.237)	(0.667)	(0.047)
Insurer 13	−0.166	0.054	−0.781	0.851	0.506	−0.087	0.076***	1.643**
	(0.720)	(0.786)	(0.236)	(0.264)	(0.594)	(0.479)	(0.005)	(0.045)
Insurer 14	0.094	0.509**	0.744	1.132*	−0.401	0.557***	0.061**	2.561***
	(0.808)	(0.029)	(0.293)	(0.058)	(0.567)	(0.000)	(0.013)	(0.000)
Insurer 15	0.197	0.186	0.256	−0.357	−0.579	0.070	0.012	0.609
	(0.635)	(0.394)	(0.710)	(0.421)	(0.380)	(0.702)	(0.560)	(0.331)
Insurer 16	1.400**	0.756***	−2.981***	0.105	−0.482	0.493***	−0.019	1.672
	(0.012)	(0.003)	(0.009)	(0.873)	(0.651)	(0.006)	(0.717)	(0.102)
Insurer 17	2.419*	0.789**	−2.737	−0.286	−1.312	0.738**	0.012	−1.285
	(0.085)	(0.032)	(0.147)	(0.781)	(0.533)	(0.018)	(0.844)	(0.397)
Insurer 18	0.134	1.541***	−1.594*	−1.555*	−0.119	1.039***	−0.079	−3.156**
	(0.876)	(0.000)	(0.072)	(0.087)	(0.904)	(0.006)	(0.302)	(0.046)
Insurer 19	0.174	0.981***	1.337	0.417	−1.364	0.725**	0.015	1.054
	(0.792)	(0.000)	(0.395)	(0.667)	(0.287)	(0.033)	(0.801)	(0.333)
Insurer 20	0.141	0.645***	0.328	1.137	−0.304	0.409	0.059	0.075
	(0.730)	(0.003)	(0.787)	(0.300)	(0.677)	(0.116)	(0.207)	(0.940)
Insurer 21	0.228	1.047***	1.846	−0.689	0.543	0.951***	0.013	−1.306
	(0.705)	(0.000)	(0.121)	(0.369)	(0.530)	(0.000)	(0.696)	(0.321)
Insurer 22	0.443	0.552**	−1.455	2.104*	−3.217***	−0.108	0.047	3.653***
	(0.525)	(0.015)	(0.464)	(0.066)	(0.000)	(0.665)	(0.161)	(0.005)

Table 2 (continued)

Company name	Intercept	MKT	HMLINS	PRETINS	ROEINS	SPREAD-INS	CO2	FNGO
Insurer 23	−0.855	0.786***	−0.456	−1.781**	−0.025	0.360*	−0.001	−0.320
	(0.138)	(0.000)	(0.645)	(0.013)	(0.977)	(0.057)	(0.970)	(0.752)
Insurer 24	0.167	0.644**	−1.255	0.865	−2.370**	0.468**	0.148***	−1.227
	(0.785)	(0.019)	(0.110)	(0.472)	(0.041)	(0.013)	(0.000)	(0.275)
Insurer 25	−0.236	1.741***	−0.042	−0.481	0.412	0.755*	−0.087	−0.053
	(0.785)	(0.000)	(0.974)	(0.592)	(0.684)	(0.068)	(0.396)	(0.971)
Insurer 26	0.317	1.048**	3.032***	3.059**	3.160**	0.299	0.030	1.624
	(0.731)	(0.019)	(0.005)	(0.015)	(0.011)	(0.390)	(0.477)	(0.202)
Insurer 27	0.605	0.634***	−2.386**	1.057*	−2.398***	0.087	0.034	1.071
	(0.369)	(0.000)	(0.010)	(0.090)	(0.002)	(0.706)	(0.124)	(0.108)
Insurer 28	−0.531	0.666***	0.520	−0.095	0.884	0.596***	0.017	0.462
	(0.178)	(0.000)	(0.524)	(0.874)	(0.133)	(0.000)	(0.480)	(0.343)
Insurer 29	0.359	0.710**	1.269	0.472	−0.319	0.516**	0.031	0.957
	(0.708)	(0.011)	(0.250)	(0.601)	(0.790)	(0.041)	(0.481)	(0.380)
Insurer 30	−0.329	1.432***	−1.602*	−1.744**	0.536	0.816***	−0.025	1.019
	(0.389)	(0.000)	(0.059)	(0.039)	(0.494)	(0.000)	(0.339)	(0.189)
Insurer 31	1.117	0.968***	5.376***	−0.159	1.885	0.503	−0.089*	3.231**
	(0.161)	(0.002)	(0.001)	(0.913)	(0.218)	(0.161)	(0.079)	(0.024)
Insurer 32	0.966*	0.686***	1.435*	−0.930	1.418**	0.505**	−0.041	−0.174
	(0.079)	(0.001)	(0.078)	(0.176)	(0.025)	(0.035)	(0.151)	(0.851)
Insurer 33	−0.080	0.187	−0.467	1.571**	−0.583	0.581***	0.070***	0.355
	(0.862)	(0.276)	(0.576)	(0.015)	(0.342)	(0.003)	(0.006)	(0.616)
Insurer 34	0.631	0.481**	−0.331	0.413	0.623	0.143	0.035	0.215
	(0.166)	(0.017)	(0.631)	(0.577)	(0.283)	(0.425)	(0.357)	(0.789)
Insurer 35	0.144	0.645**	0.680	0.016	0.200	0.142	0.046	1.040
	(0.874)	(0.037)	(0.508)	(0.979)	(0.799)	(0.535)	(0.250)	(0.439)

This table reports the results of the time series regressions (monthly excess returns) using Model (2) for each of the 35 European insurance companies in the period from January 2016 to December 2018. The columns contain the estimates of the coefficients labeled in the heading, i.e., the first column ("Intercept") shows the abnormal return of each insurance company, the second column shows the market beta ("MKT") and the remaining columns show the coefficients of the additional risk factors. We also report Newey-West adjusted *p*-values in parentheses below each coefficient. The significance level of 0.1, 0.05 and 0.01 is denoted by *, ** and *** respectively

sustainability aspects. Some insurance firms are compliant with either the carbon or the FNGO factor. For example, as already mentioned, *Insurer 6* is one of the pioneers in focusing on green assets, indicated by a significantly positive carbon beta. However, it shows a negative exposure to the FNGO factor. The pattern for *Insurer 31* is inverse. Through a proprietary Sustainability Investment Policy, *Insurer 31* commits itself to ethical investment, excluding companies that are heavily engaged in businesses ranging from tobacco to gambling.

Furthermore, *Insurer 31* admits that it is holding carbon-associated funds and subtly insinuates that for some of those funds the carbon footprint might be high

from time to time. Instead of divesting, the insurer promises to "engage with and encourage" those investees "to improve to reduce their carbon footprint." Hence, *Insurer 31's* FNGO compliance ($\beta_{FNGO} > 0$) and high exposure to carbon prices ($\beta_{CO_2} < 0$) is consistent with the results of our rapid test.

Complementary policy changes

Disclosure requirements and ESG label

To reinforce its effectiveness, the rapid test for carbon exposure presented above needs to be embedded in a policy framework. According to Mills (2012), "insurance regulators and investors are seeking climate risk disclosure, compelling insurers to formally consider climate change in operational, business, and investment practices […]." In line with this view, we advocate mandatory disclosure requirements. Two obvious conduits are the annual report as well as the SFCR governed by Pillar 3 of Solvency II, which insurers must regularly publish according to strict guidelines (see EIOPA 2015). Either one could be extended by carbon betas, their standard errors, and an interpretation of the results, including their historical evolution. Complementary lists of carbon-intensive and green assets could be provided in an online appendix. In contrast to lengthy verbal explanations, this would offer stakeholders and regulators a quantified, reliable and easily verifiable assessment of the degree to which insurers' investment portfolios are climate compliant. The idea is naturally extendable to the broader set of sustainability dimensions that can be tested with our FNGO model. Recent advances of the European regulator EIOPA indicate that such a solution has the potential to find majorities among policymakers (see EIOPA 2018, 2019). Even without a regulatory obligation, signatories of the PSI initiative discussed in the second section should be pursuing such a heightened degree of transparency themselves.

Another consideration is the introduction of an ESG label for insurers to further increase transparency regarding climate risks. In the mutual fund space, such signals are already common (see Hartzmark and Sussman 2019). An example is the FNG label that we employed to construct our sustainability factor in the previous section. Clearly, insurers cannot simply be deemed low-carbon based on an assessment of their own emissions. Instead, as outlined in previous sections of this paper, the most important climate levers are their investment and underwriting activities. Hence a transparent approach is key, taking into account the CO_2 exposures in the companies' core portfolios. Based on the output of our carbon test for the asset side, an efficient climate label could be designed with three different ranks or badges: polluting (significantly negative carbon betas), climate-neutral (insignificant carbon betas) and green investment portfolios (significantly positive carbon betas). Naturally, the same idea would work for a full sustainability label, using the FNGO-extended factor model. An ESG label established on the quantitative basis of our asset pricing approach should be a strong signal, allowing stakeholders to reliably identify climate-friendly and sustainable insurers. Interestingly, first industry pioneers are arguing that a common classification system for sustainable insurers is needed and

that policymakers should consider the inclusion of ESG criteria in regulatory frameworks (see Sheehan 2019).

Capital charges

While the disclosure requirements for climate risks in their balance sheets can generally lessen the attractiveness of carbon-intensive investments for insurance companies, a current study by Mielke (2018) shows that, on their own, they have only moderate potential to bias insurers' investment decisions towards green assets. An adjustment of the Solvency II capital charges, in contrast, is considered to be more promising. However, instead of performing a costly and intricate analysis of the carbon intensity of each individual position in an insurer's investment portfolio, we suggest considering a modification of the overall Solvency Capital Requirement (SCR) on the company level. More specifically, given our carbon test for listed insurance companies, it would be straightforward to introduce a regulatory capital discount for green (positive carbon betas) and a markup for polluting investment portfolios (negative carbon betas). Inspiration can be drawn from the EU's Capital Markets Union Initiative, under which high-quality infrastructure assets obtain favourable Solvency II capital treatment. Braun et al. (2017, 2018, 2019) have shown that capital charges can have a major influence on the asset allocation of insurance companies. Hence, the inclusion of climate or even ESG considerations in the first pillar of Solvency II should be a strong lever for the redirection of the investment flows in the European insurance sector. Clearly, this would constitute quite a far-reaching extension of the main objective of Solvency II, i.e., the protection of the policyholders. Whether the protection of the climate should be added as an additional goal must be determined through an intensive political discussion among the EU member states. One consequence that needs to be taken into account is the likely rise in premiums for customers of insurers with negative carbon betas due to their increased capital requirements. While this appears to be an undesired effect at first glance, the associated declines in demand experienced by carbon-intensive insurers could even further accelerate the industry's transition to carbon neutrality.

Conclusion

Owing to its enormous size and capital base, the insurance industry should occupy a key role in the achievement of the UNFCCC climate goals. If only a fraction of the sector's USD 25 trillion in investments worldwide could be directed away from carbon-intensive assets, this would constitute a substantial contribution to the efforts against global warming. It is doubtful, however, whether voluntary initiatives will be enough to genuinely implant the sustainability paradigm in the industry DNA.

Since insurance companies can be viewed as large portfolios consisting of financial risks (asset side) and underwriting risks (liability side), we suggest an asset pricing approach to detect carbon-intensive positions on their balance sheets. Our

model extends the insurance-specific five-factor framework of Ben Ammar et al. (2018) by the excess returns on GHG allowances. Owing to the long (short) position in the price of CO_2 implied by their business fundamentals, green (polluter) firms can be expected to exhibit a positive (negative) carbon factor beta. As these effects feed through to the portfolio level, they should be measurable in the excess return time series of the insurers' stocks. We empirically implement the model based on rolling regressions and illustrate the evolution of the carbon footprint of 35 European insurance companies over the past few years. Also, we test a further specification, including the carbon factor and a proxy for a broad range of other sustainability dimensions. Finally, we discuss two straightforward policy measures that could be pursued to reinforce the effectiveness of the CO_2 test. On the one hand, regulators and investors should aim for a new set of disclosure requirements, compelling insurers to factor the climate perspective into their investment decisions. Those could be complemented by a new ESG label, either for green or even for fully sustainable insurers. On the other hand, we enrich the debate by a potential modification of the Solvency II capital requirements, taking into account the outcome of the carbon test.

Further analyses are required to tackle the limitations of our work. First, the suspected link between the carbon price and stock returns needs to be better understood. Similarly, more research is needed regarding the relationship with bond returns. The question is to what extent our model picks up non-green fixed income positions in investment portfolios. This is a key issue, since the asset allocation of insurance companies comprises around 60% to 70% of government and corporate debt. Second, one should not forget the liability side of the balance sheet. The market value of insurance contracts only reacts to shifts in risk fundamentals but not to changes in the price of CO_2. Thus our model cannot detect GHG exposures in the insurers' underwriting business. This may result in a situation in which firms appear to be climate compliant, because they run a low-carbon asset portfolio while they still write coverage for coal plants. The introduction of an ESG label for insurance companies only makes sense if it also covers their liability side. Although there are no straightforward solutions to these issues, considering the high stakes associated with climate change, their further consideration will be well worth the effort.

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About the authors

Alexander Braun is a Member of the Executive Board of the Institute of Insurance Economics (I.VW-HSG) and Adjunct Professor of Risk Management at the University of St. Gallen (HSG). Before joining HSG, he worked in the Capital Markets Division of Lehman Brothers in London. Mr. Braun studied Business Administration at the University of Mannheim (Germany) and Monash University (Australia). In addition, he obtained a PhD in Finance at the University of St. Gallen (Switzerland), where he was also awarded the Venia Legendi. Mr. Braun has published in renowned scientific journals such as The Journal of Risk and Insurance, Journal of Banking and Finance, European Journal of Operational Research, and The Geneva Papers on Risk and Insurance-Issues and Practice. His research and teaching activities have been awarded, amongst others, by the American Risk and Insurance Association (ARIA), the Asia-Pacific Risk and Insurance Association (APRIA), The Geneva Association, and the Casualty Actuarial Society (CAS). For further information please refer to https://www.alexandria.unisg.ch/persons/2621.

Sebastian Utz is an Assistant Professor at the School of Finance of the University of St. Gallen. He holds a master's degree in mathematics from the University of Augsburg, he obtained his PhD in business administration from the University of Regensburg, and he was a visiting research scholar at the Department of Banking and Finance at the Terry School of Business at the University of Georgia. Sebastian's focus research areas are impact investing, sustainable finance, and multi-criteria decision-making. His research has been published in leading international journals such as Operations Research, the European Journal of Operational Research, Review of Managerial Science, and the Review of Financial Economics.

Jiahua Xu is a postdoctoral researcher at the Swiss Federal Institute of Technology in Lausanne (EPFL), as well as a research associate at the University College London Centre for Blockchain Technologies. Her research interests cover insurance economics, machine learning and cryptocurrency. She received her PhD from the University of St. Gallen in Switzerland, MSc from the University of Mannheim in Germany, and BA from Fudan University in China. She works pro bono at a not-for-profit organisation, Development International e.V., specialising in labour rights research.