Essays on Risk Management and Insurance: Asset Pricing and Consumers’ Preferences

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St.Gallen, May 22, 2018

The President:
Prof. Dr. Thomas Bieger

To my dear parents / Meinen lieben Eltern

&

To Miru, Adi & Lore

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I am also deeply indebted to my parents and family for their unconditional love and support. The example they set for hard work will forever remain the cornerstone of my education. I am also particularly grateful to my friends, near and far, who have accompanied me throughout the journey. A wholehearted thank you goes to Irene, whose devotion and reassurance during challenging times have blurred the line between friendship and family. I hope this dissertation makes all of them proud.

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Daliana Luca

1 Summary

The insurance market in Europe has been undergoing several challenges throughout the last decade. First and foremost, the financial crisis has shed light on the importance of solvency for financial instiutions. Moreover, the regulation that followed the financial crisis does not only focus on the solvency levels and capital requirements for financial institutions, but also on customer protection and product transparency in the European Union.[1] Meanwhile, the low interest rate environment and the increased convergence between insurance companies and financial markets have further strained the profitability of many insurance companies.

This cumulative dissertation contains four articles on risk management and insurance that address some of the challenges currently straining the insurance market. The topic of convergence between financial markets and insurance is addressed in the first paper, which employs an asset pricing model frequently used in the financial markets in order to price insurance contracts. The solvency of insurance companies is addressed in the second paper, whereas the third and fourth papers focus on consumers' preferences and the determinants of intention to purchase interest rate guarantees for life insurance contracts, topics that are important in the light of new regulation regarding consumer protection and the low interest rate environment, which makes financing guarantees for life insurance products difficult for insurers.

[1] One example of such regulation is the European Insurance Distribution Directive (IDD).

2 Zusammenfassung

Der Versicherungsmarkt in Europa steht in den letzten Jahren vor zahlreichen Herausforderungen. Zunächst hat vor allem die Finanzkrise die Wichtigkeit der Solvenz von Finanzinstitutionen aufgezeigt. Die infolge der Finanzkrise eingeführte Regulierung fokussiert allerdings nicht ausschliesslich das Solvenzniveau und die Kapitalanforderungen von Finanzinstitutionen. Vielmehr stehen ebenso Kundenschutz und Produkttransparenz in der Europäischen Union im Mittelpunkt der Betrachtung. Das Niedrigzinsumfeld und die ansteigende Konvergenz zwischen Versicherungsunternehmen und Finanzmärkten belasten die Profitabilität von vielen Versicherungsunternehmen.

Diese kumulative Dissertation beinhaltet vier Artikel über Risikomanagement und Versicherung und befasst sich in diesem Zusammenhang mit den aktuellen Herausforderungen der Assekuranz. Der erste Beitrag thematisiert die Konvergenz zwischen Finanzmärkten und Versicherung. Vor diesem Hintergrund wird ein gängiges Vermögensbewertungsmodell zur Bewertung von Versicherungsverträgen analysiert. Der zweite Beitrag fokussiert die Solvenz von Versicherungsunternehmen. Der dritte Beitrag legt den Fokus auf eine Analyse der Kundenpräferenzen und der vierte Beitrag auf Faktoren, die den Erwerb von Zinsgarantien für Lebensversicherungen beeinflussen. Die beiden zuletzt genannten Themen sind insbesondere hinsichtlich der neuen regulatorischen Vorschriften und des Niedrigzinsumfeldes von essenzieller Bedeutung, da die Finanzierung von Garantien für Lebensversicherungsprodukte durch die regulatorischen Vorschriften und das Niedrigzinsumfeld erschwert werden.

3 Synopsis

Paper I: Consumption-Based Asset Pricing in Insurance Markets: Yet Another Puzzle?
A. Braun, D. Luca, and H. Schmeiser.

The first paper focuses on testing the performance of the consumption-based model (CCAPM) as a pricing model for insurance contracts. The consumption-based model is an attractive theoretical model to determine asset prices, since it establishes a link between the macroeconomic environment and the utility customers get from buying a financial asset. However, the CCAPM has often failed to explain asset prices in ex-post empirical tests: when applied to the equity market, the model gives rise to the equity premium puzzle, which states that equities have delivered an excess premium of 6 percent per annum. Although the model is believed to perform particularly well in the insurance market, no empirical tests have been conducted in order to prove this point. This paper aims to fill this theoretical gap and provides an analysis of the insurance market through a CCAPM lens. Our results show that when applied to insurance markets in various countries, the model requires investors to have higher degrees of risk aversion than what is considered generally acceptable in the literature and that customers are willing to incur high negative expected returns in order to be insured, an anomaly which we entitle the “insurance premium puzzle”. In order to explain this anomaly, we build on concepts existent in the behavioral finance field, such as the loss aversion and narrow framing approach by Barberis and Huang (2001), as well as the second-degree expectation dependence framework by Dionne et al. (2015), with encouraging results.

This paper has been presented at the Jahrestagung des Deutschen Vereins für Versicherungswissenschaft in March 2015, the World Risk and Insurance Economics Congress 2015, the Annual Conference of the Swiss Society for Financial Market Research in April 2016, the Annual Meeting of the Western Risk and Insurance Association in January 2016, as well as the Annual Meeting of the European Group of Risk and Insurance Economists in September 2016.

Paper II: The Impact of Time Discretization on Solvency Measurement
D. Luca and H. Schmeiser.

The second paper studies the impact of the discretization process on the solvency measurement of an insurance company. A theoretical premise already existent in ruin theory states that the probability of ruin of an insurance company measured in continuous time is always greater than the probability of ruin in discrete time. This paper aims to quantify this difference between the probability of ruin in discrete and continuous time. Based on a simple solvency model, we analyze the magnitude of the change in the one year ruin probability when we check the solvency of a company once a year versus every day (daily vs. annual discretization). We complement the analysis by comparing the one year expected policyholder deficit (EPD) checked at daily as opposed to annual frequency. We conclude that by only checking the solvency of the insurance company once a year, we severely underestimate the ruin probability of an insurance company. Results are even more pronounced for the EPD, which is especially important for policyholders. This in turn translates into higher capital requirements for the solvency company. We conclude that in order for an insurance company to have appropriate risk measurement techniques, risk managers need to complement the capital requirements with more frequent observations of the risk measures.

This paper has been presented at the Jahrestagung des Deutschen Vereins für Versicherungswissenschaft in March 2016.

Paper III: Do Consumers Want Investment Guarantees?
D. Luca, H. Schmeiser and F. Schreiber.

The aim of the third paper is to study the customers' preferences for investment guarantees. Investment guarantees are features of products which ensure that at maturity, at least a minimum amount of money is paid back to the purchaser of an investment contract, and are frequently present in life insurance. In the recent macroeconomic environment, insurance companies find it increasingly hard to finance these guarantees because the low interest rate environment makes it difficult to find attractive investment opportunities.

Moreover, insurance companies incur high costs related to the risk management necessary to provide guarantees, which customers are unable to see due to the lack of transparency inherent in these contracts. This translates into an important question, both for practitioners and researchers: does the utility derived by the customer justify the existence of guarantees for investment products? If so, what types of guarantees should insurance companies offer? The third paper addresses these research questions by means of a choice-based conjoint analyis combined with a sociodemographic study which allows us to establish part-worth utility profiles of customer segments and determine shares of preferences in a realistic market environment.

This paper has been presented at the Annual Meeting of the American Risk and Insurance Association in August 2017, the Western Risk and Insurance Association in January 2018 and the Jahrestagung des Deutschen Vereins für Versicherungswissenschaft in March 2018 and the Annual Meeting of the American Risk and Insurance Association in August 2018.

Paper IV: Does Prevention as an Investment Strategy Explain the Intention to Purchase Guarantees for Unit-linked Life Insurance?
D. Luca.

The fourth paper aims to study the decision making process behind the investors' intention to purchase interest rate guarantees for unit-linked life insurance contracts. In particular, the paper examines the relationship between prevention as an investment strategy, the attitudes about unit-linked insurance and the decision to purchase interest rate guarantees, as moderated by the level of financial literacy of the customer. This conceptual framework is theoretically grounded in the regulatory focus theory (see, e.g., Higgins, 1998; Brockner and Higgins, 2001), in which people are motivated either to achieve desired results or to avoid undesired results, which has consequences on their financial decisions (see, e.g., Hamilton and Biehal, 2005). The demand for interest rate guarantees in life insurance products has previously been analyzed in the literature on decision theory. Expected utility theory, prospect theory and multi-cumulative prospect theory have been proposed as theoretical frameworks for the demand of guarantees (see, e.g, Døskeland and Nordahl, 2008; Ebert et al., 2012; Braun et al., 2017; Ruß and Schelling, 2017). In contrast to the existing research, this paper investigates the antecedents of the decision making process and combines elements from previous research in psychology and economics. The paper contributes by investigating the role of the investment strategy, attitudes about unit-linked and the role of financial literacy. To our knowledge, this paper is also the first one to investigate the antecedents of the decision making process for guarantees in long-term saving products such as unit-linked insurance. Our findings reveal that there is a direct positive relationship between having prevention as an investment strategy and the intention to purchase interest rate guarantees. This relationship is mediated by the perceptions about unit-linked insurance and moderated by the role of financial literacy. Based on these results, we derive some practical implications. First, due to the mediating role of perceptions about life insurance, insurers should develop a strategy of enhancing the customers' perceptions about life insurance rather than trying to sell products with guarantees. This would be more beneficial both for customers who would benefit from more upside potential in their retirement accounts and for insurers, who would reduce risk management costs associated with the provision of guarantees. Moreover, due to the mediating role of financial literacy, the intention to purchase guarantees can be influenced by changing the level of financial literacy. By addressing the financial literacy directly through educational programs, customers' intention to purchase interest rate guarantees can be influenced.

This paper has been presented at the Third International Conference for Marketing in the Insurance Industry (ICMI) in October 2017.

Table 1: Tabular Summary of Paper I

Title	Consumption-Based Asset Pricing in Insurance Markets: Yet Another Puzzle?
Authors	Alexander Braun, Daliana Luca, Hato Schmeiser
Published	Journal of Risk and Insurance, forthcoming
Abstract	Although insurance is the typical textbook example for an asset that negatively correlates with consumption, the suitability of the classical consumption-based asset pricing model with power utility to explain historical premiums and claims has not yet been tested. We fill this gap by fitting it to property-casualty market data for Australia, Italy, the Netherlands, the United States, and Germany. In doing so, we reveal yet another asset pricing anomaly. More specifically, the consumption-based model implies even larger relative risk aversion coefficients in the insurance sectors than in the equity markets of the aforementioned countries. To solve this puzzle, we draw on the loss aversion and narrow framing approach by Barberis et al. (2001), as well as the second-degree expectation dependence framework by Dionne (2015), with encouraging results.

Table 2: Tabular Summary of Paper II

Title	The Impact of Time Discretization on Solvency Measurement
Authors	Daliana Luca, Hato Schmeiser
Published	Journal of Risk Finance, Vol. 18 Issue: 1, pp. 2-20
Abstract	We aim to study the difference between the one-year probability of ruin in continuous and discrete time via Monte Carlo simulations. The numerical results show that by checking the solvency of an insurance company only once a year, the ruin probability is consistently underestimated by up to 75 percent of its value observed on an annual basis. We extend the analysis to studying the differences in the expected policyholder deficit (EPD) over a one-year period in discrete and continuous time, which indicate that the observed value of the EPD can be reduced significantly by verifying the available economic capital on a daily basis. Regulators should be aware that when using the discrete time one-year probability of ruin, as done in insurance practice, the true insurer's default risk is often substantially underestimated.

Table 3: Tabular Summary of Paper III

Title	Do Consumers Want Investment Guarantees?
Authors	Daliana Luca, Hato Schmeiser, Florian Schreiber
Published	I.VW-HSG Working Papers on Risk Management and Insurance
Abstract	Drawing on data from a survey among financial decision makers in Germany, we elicit customer preferences for investment guarantees through a choice-based conjoint analysis. In contrast with previous studies which focus on eliciting willingness-to-pay for investment guarantees directly via questionnaires, our methodology is more appropriate for revealing preferences for products whose purchase involve complex cognitive decisions and an infrequent purchase pattern. We start by deriving part-worth utility profiles of customers for different product attributes and continue with simulating shares of preferences in a real market scenario. We then split the sample with the help of eight sociodemographic and psychographic moderators. Thereby, different customer segments are derived for which insurance companies can optimize product designs in order to maximize customers' utility.

Table 4: Tabular Summary of Paper IV

Title	Does Prevention as an Investment Strategy Explain the Intention to Purchase Guarantees for Unit-linked Life Insurance?
Authors	Daliana Luca
Published	I.VW-HSG Working Papers on Risk Management and Insurance
Abstract	The present paper examines the relationship between prevention as an investment strategy and the perceptions about unit-linked insurance and the intention to purchase interest rate guarantees for such products. We propose a framework in which the relationship between adopting prevention as an investment strategy and the intention to purchase interest rate guarantees is moderated by the level of financial literacy of the individual and suggest that this interaction is mediated by the perceptions regarding unit-linked insurance. We find support for our conceptual model by testing it on a sample of 1,017 financial decision makers in Germany using a moderated mediation analysis. The paper therefore offers insights into the decision making process of financial consumers in Germany and presents practical implications for designing products for age old provision.

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Outline

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Part I
Consumption-Based Asset Pricing in Insurance Markets: Yet Another Puzzle?

Abstract

Although insurance is the typical textbook example for an asset that negatively correlates with consumption, the suitability of the classical consumption-based asset pricing model with power utility to explain historical premiums and claims has not yet been tested. We fill this gap by fitting it to property-casualty market data for Australia, Italy, the Netherlands, the United States, and Germany. In doing so, we reveal yet another asset pricing anomaly. More specifically, the consumption-based model implies even larger relative risk aversion coefficients in the insurance sectors than in the equity markets of the aforementioned countries. To solve this puzzle, we draw on the loss aversion and narrow framing approach by Barberis et al. (2001), as well as the second-degree expectation dependence framework by Dionne (2015), with encouraging results.[1]

[1]Braun A., Luca D., and Schmeiser H. (2017). Consumption-Based Asset Pricing in Insurance Markets: Yet Another Puzzle? *Journal of Risk and Insurance*, forthcoming.

1 Introduction

> *"If you buy an asset whose payoff covaries negatively with consumption, it helps to smooth consumption and so is more valuable than its expected payoff might indicate. Insurance is an extreme example. Insurance pays off exactly when wealth and consumption would otherwise be low – you get a check when your house burns down. For this reason, you are happy to hold insurance, even though you expect to lose money – even though the price of insurance is greater than its expected payoff discounted at the risk-free rate."*
>
> – John H. Cochrane

The classical consumption-based model, which was established through the work of Rubinstein (1976), Lucas (1978), Breeden (1979), Grossman and Shiller (1981), as well as Hansen and Singleton (1983), is one of the most influential accomplishments in modern asset pricing theory. Utility-maximizing individuals in a representative-agent economy face the intertemporal choice of either consuming their wealth or investing it in a risky asset. The first-order condition for this tradeoff leads to the central pricing equation of the model: the demand for the asset is adjusted until the loss in utility suffered due to a slightly lower consumption level today equals the gain in expected utility achieved by being able to consume a little more of the future payoff of the asset. Therefore, equilibrium asset prices are expectations of payoffs discounted at the representative agents' marginal rate of substitution. Based on this idea, it is possible to derive risk adjustments that rely on the covariance of payoffs or returns with marginal utility and thus, ultimately, consumption. Assets that perform well when the investor is able to consume abundantly, but pay little in times when his consumption is restrained, are perceived to be risky and sell for prices below their expected payoff discounted at the risk-free interest rate. Insurance policies, in contrast, indemnify their holder after the occurrence of a loss in wealth, thus reducing the volatility of consumption. Hence, individuals are prepared to accept a negative expected return on such contracts.

Despite its theoretical appeal, the consumption-based model repeatedly failed in empirical applications. Its most famous shortcoming is the inability to explain risk premiums observed in postwar stock market data with a reasonable degree of risk aversion. This is the famous equity premium puzzle, which was described by Mehra and Prescott (1985) for the United States and, since then, has received a lot of scholarly attention. Wheatley (1988) as well as Campbell (2003) found evidence for the puzzle in many developed economies, while Donadelli and Prosperi (2012) revealed its existence in a number of emerging markets. Early on, Kandel and Stambaugh (1991) suggested that it might be necessary to contemplate higher values for the risk aversion coefficient. This, however, leads to the emergence of another well-known asset pricing anomaly: the risk-free rate puzzle as constituted by Weil (1989). Given extreme risk aversion, power utility agents are extraordinarily reluctant to engage in intertemporal substitution. This implies that the empirically-observed low and stable risk-free interest rates can only be explained by the consumption-based model if investors exhibit a subjective time discount factor greater than one. Although such a negative time preference is theoretically possible, it is not very plausible as individuals are typically impatient, favoring earlier over later consumption (see, e.g., Kocherlakota, 1996).

Thus, ever since the discovery of the equity premium puzzle, economics and finance researchers have targeted more meaningful risk aversion levels. The dominant strand of literature in this regard centers on model refinements by means of separated time and risk preferences (see, e.g., Epstein and Zin, 1989,9), habit formation (see, e.g., Abel, 1990; Constantinides, 1990; Ferson and Constantinides, 1991; Campbell and Cochrane, 1999), idiosyncratic consumption shocks (see, e.g., Mankiw, 1986; Weil, 1992; Heaton and Lucas, 1996; Constantinides and Duffie, 1996; Gomes and Michaelides, 2008), and rare economic disasters (see, e.g., Rietz, 1988; Barro, 2006,0; Gabaix, 2008,0; Wachter, 2013). However, none of these solutions is considered to be fully satisfactory (see, e.g., Mehra and Prescott, 2003). Other research efforts have focused on long-run persistence in consumption and dividend growth (see, e.g, Bansal and Yaron, 2004; Bansal et al., 2010; Koijen et al., 2010), loss aversion (see, e.g., Benartzi and Thaler, 1995; Barberis et al., 2001; Barberis and Huang, 2001,0), disappointment aversion (see, e.g., Routledge and Zin, 2010), ambiguity aversion (see, e.g., Chen and Epstein, 2002; Gollier, 2011; Rieger and Wang, 2012), and, most recently, higher-order risk preferences (see Dionne et al., 2015). In addition, there have been attempts to improve the model's estimation basis by relying on stockholder samples (see, e.g., Vissing-Jorgensen and Attanasio, 2003), long-run consumption changes (see, e.g., Parker and Julliard, 2005), as well as forward-looking survey and option data (see Söderlind, 2009b). Finally, some authors explored whether factors such as transaction costs (He and Modest, 1995; Luttmer, 1996; Bansal and Coleman, 1996), borrowing constraints (see, e.g., Constantinides et al., 2002), and taxation (see, e.g., McGrattan and Prescott, 2003) drive the equity risk premium.

Apart from equities, the consumption-based model has also been applied to fixed income (see, e.g., Backus et al., 1989; Wachter, 2006), stock options (see, e.g., Liu et al., 2005; Backus et al., 2011), currencies (see Verdelhan, 2010) and even catastrophe bonds (see, e.g., Dieckmann, 2011). Somewhat surprisingly, however, its suitability for insurance contracts has not yet been tested in the financial economics literature, although they are the typical textbook example for an asset that is negatively correlated with consumption and therefore positively correlated with marginal utility. We fill this gap by fitting the classical consumption-based model with power utility to historical property-casualty insurance market data. In doing so, we consider two alternatives for the estimation of the relative risk aversion (RRA) coefficient. First, we apply an extended version of Stein's Lemma introduced by Söderlind (2009a), which builds on a bivariate mixture normal distribution and thus allows for skewed and leptokurtic asset returns, given the log stochastic discount factor (SDF) is Gaussian. Second, we follow Hansen and Singleton (1983) in assuming that consumption growth and asset returns are jointly lognormally distributed as well as homoskedastic. Both approaches are complemented by Hansen and Jagannathan (1991) volatility bounds. Based on aggregate annual premiums and claims for Australia, Italy, the Netherlands, the United States, and Germany we are able to provide evidence of yet another asset pricing anomaly. More specifically, the consumption-based model implies even larger RRA coefficients in the insurance sectors than in the equity markets of the aforementioned countries. To solve this insurance premium puzzle, we draw on the loss aversion and narrow framing approach by Barberis et al. (2001) as well as the second-degree expectation dependence framework by Dionne et al. (2015), with encouraging results.

The rest of the paper is organized as follows: In the next section, we briefly revisit the classical consumption-based model and derive the two procedures that will be employed for its empirical application. The third section contains a discussion on the applicability of asset pricing theory in the insurance context. Furthermore, in the fourth section, we describe our data set, conduct the main empirical analysis for the stock and insurance markets of five countries, and present the RRA estimates that give rise to an insurance premium puzzle. In the penultimate section, we then discuss selected modifications of the consumption-based model and implement the two most promising ones, relying on loss aversion and narrow framing as well as higher-order risk preferences of the representative agent. Finally, in the last section, we summarize our findings and draw our conclusion.

2 The Consumption-Based Model Revisited

2.1 The Basic Asset Pricing Equation

We begin with the core of modern asset pricing theory. Consider a frictionless financial market without arbitrage opportunities. It can be shown that, if these two assumptions hold, there is a stochastic discount factor (SDF) $\tilde{M}_{t+1}$ that prices all random security payoffs $\tilde{X}_{t+1}$:[2]

$$P_t \quad = \quad \mathrm{E}_t\left[\tilde{M}_{t+1}\tilde{X}_{t+1}\right] = \frac{\mathrm{E}_t[\tilde{X}_{t+1}]}{R_f} + cov_t[\tilde{M}_{t+1}, \tilde{X}_{t+1}]. \qquad (1)$$

$\mathrm{E_t}(\cdot)$ denotes the conditional expectation, given all available information at time t, and R_f is the deterministic (gross) return on a riskless investment.[3] $\tilde{M}_{t+1}$ is also called pricing kernel, state price system, or equivalent martingale measure. The first term on the right hand side represents the expected payoff discounted at the risk-free interest rate and the second term is a risk adjustment. In other words, the SDF allows us to determine asset-specific prices and risk adjustments. By writing (1), we have not (yet) made any further assumptions about market completeness, return distributions, investor preferences, or the occurrence of an equilibrium (see, e.g., Cochrane, 2005).

[2] This equation applies to each individual investor and all assets in the economy (see, e.g., Cochrane, 2005).

[3] In line with Cochrane (2005), we denote gross returns with capital letters and define them as payoff divided by price.

2.2 The Stochastic Discount Factor

The consumption-based model is associated with a specific form for the SDF. We employ its common one-period discrete-time version, which is easily extendable to determine the price of any stream of risky future cash flows. A detailed derivation based on Cochrane (2005) can be found in the Appendix. Assume an investor with time-separable utility, driven by his deterministic current and stochastic future levels of consumption, denoted C_t and $\tilde{C}_{t+1}$. By forming the first-order condition for his choice of either consuming his wealth today or investing it in a risky asset and consuming it later, it can be shown that $\tilde{M}_{t+1}$ equals the intertemporal marginal rate of substitution:

$$\tilde{M}_{t+1} \quad = \quad \beta \frac{u'(\tilde{C}_{t+1})}{u'(C_t)}. \tag{2}$$

At this rate, the investor is willing to exchange consumption between times t and $t+1$. To reflect a rational desire for more consumption in combination with decreasing marginal utility, the intra-period utility function needs to be upward-sloping ($u'(\cdot) > 0$) and concave ($u''(\cdot) < 0$). In addition, impatience is captured by the subjective time discount factor β (< 1): people want to consume earlier rather than later.

In combination with (2), (1) states that the equilibrium price P_t we ought to expect for the asset is driven by its random payoff, as well as the investor's intra-period utility function $u(\cdot)$, time preferences β, and consumption levels C_t and C_{t+1}. Assets whose payoffs exhibit a negative covariance (correlation) with the random component of the SDF are positively correlated with consumption and thus make it more volatile.[4] Since investors prefer a steady consumption stream over time, they will only hold such assets if their price is lower than in a risk-neutral world. Insurance, in contrast, indemnifies people after they have suffered a shock to their wealth, which causes their consumption to be low and their marginal utility to be high. In other words, insurance payoffs are negatively correlated with consumption. Their value therefore exceeds the expected payoff

[4]Refer to (2). The random part of the SDF equals marginal utility (of $\tilde{C}_{t+1}$), which is high when $\tilde{C}_{t+1}$ is low.

discounted at the risk-free rate and market participants are prepared to buy insurance policies despite the fact that they expect to lose money on them.

2.3 The Euler Equation for Excess Returns

Applied work usually focuses on returns instead of prices, since the former exhibit well-behaved properties (e.g., stationarity). The stochastic gross return $\tilde{R}_{t+1}$ between times t and $t+1$ is defined as the risky asset's payoff divided by its price: $\tilde{X}_{t+1}/P_t$. To study risk premiums separately from interest rates, we will run our analysis based on (gross) excess returns $\tilde{R}^e_{t+1} = \tilde{R}_{t+1} - R_f$, for which the following Euler equation holds:[5]

$$0 \quad = \quad \mathrm{E}_t[\tilde{M}_{t+1}\tilde{R}^e_{t+1}]. \tag{3}$$

Using the definition of covariance on (3) and rearranging yields an explicit expression for the expected excess return (i.e., the risk premium):[6]

$$\mathrm{E}_t[\tilde{R}^e_{t+1}] \quad = \quad -\frac{cov_t[\tilde{M}_{t+1}, \tilde{R}^e_{t+1}]}{\mathrm{E}_t[\tilde{M}_{t+1}]}. \tag{4}$$

The latter is positive, if the asset's return exhibits a negative covariance with the SDF (marginal utility), i.e., a positive covariance with consumption. Such assets perform badly in those states of the world in which wealth is highly desired by investors. Returns on insurance contracts, in contrast, are negatively correlated with consumption. Due to this hedging property, they may offer negative risk premiums.

2.4 Representative Agent and Constant Relative Risk Aversion

Most empirical applications of the consumption-based model rely on aggregate consumption data. Therefore, they need to assume that markets are complete and that the cumulative behavior of all individual investors in the economy is equivalent to the actions of a single representative agent. The latter commonly

[5] A derivation can be found in the Appendix.

[6] Recall that covariance is defined as $cov_t[\tilde{M}_{t+1}, \tilde{R}^e_{t+1}] = \mathrm{E}_t[\tilde{M}_{t+1}\tilde{R}^e_{t+1}] - \mathrm{E}_t[\tilde{M}_{t+1}] \cdot \mathrm{E}_t[\tilde{R}^e_{t+1}]$.

exhibits constant relative risk aversion (CRRA) preferences as represented by the power utility function, which permit aggregation:

$$u(C_t) = \frac{C_t^{1-\eta}}{1-\eta}, \tag{5}$$

where η equals the relative risk aversion (RRA) coefficient.[7] The corresponding marginal utility is $u'(C_t) = C_t^{-\eta}$, which leads to the SDF:

$$\tilde{M}_{t+1} = \beta \left(\frac{\tilde{C}_{t+1}}{C_t} \right)^{-\eta}. \tag{6}$$

An important property of these preferences are scale invariance, implying that increases in wealth or the size of the economy do not alter risk premiums as long as asset return distributions remain constant (see, e.g., Campbell, 2003).[8] Furthermore, they allow for time-consistent planning in the sense that the optimal allocation to the risky asset determined at the outset does not change when the investor's stochastic future consumption levels turn into realizations (see, e.g., Mehra, 2012).

2.5 Connecting the Stochastic Discount Factor to Data

The Extended Stein's Lemma for Asset Pricing

Through (6), the RRA coefficient η enters the covariance in (4). This complicates an empirical analysis of the risk premium considerably. However, it is possible to analytically access η by means of the extended version of Stein's Lemma introduced by Söderlind (2009a):

Assume (a) the joint distribution of $\tilde{x}$ and $\tilde{y}$ is a mixture of n bivariate normal distributions; (b) the mean and variance of $\tilde{y}$ is the same in each of the n components; (c) $h(\tilde{y})$ is a differentiable function such that $\mathrm{E}[|h'(\tilde{y})|] < \infty$.

[7] For $\eta \to 1$, we have $u(C_t) = \ln(C_t)$. Note that, since the elasticity of intertemporal substitution ψ is the reciprocal of the RRA coefficient η, the standard power utility function does not allow for a disentanglement of time and risk preferences.

[8] This is consistent with empirical findings showing that, despite the strong economic growth over the past century, interest rates and risk premiums did not exhibit a time trend.

Then, $cov[\tilde{x}, h(\tilde{y})] = \mathrm{E}[h'(\tilde{y})] \cdot cov[\tilde{x}, \tilde{y}]$.

Recognizing that $\tilde{x} = \tilde{R}^e_{t+1}$, $\tilde{y} = \ln(\tilde{M}_{t+1})$, and $h(\cdot) = \exp(\cdot)$ and assuming that the log SDF is Gaussian, we can therefore decompose the covariance $cov_t[\tilde{M}_{t+1}, \tilde{R}^e_{t+1}]$ in (4) as follows:

$$cov_t[\exp(\ln(\tilde{M}_{t+1})), \tilde{R}^e_{t+1}] = \mathrm{E}_t[\tilde{M}_{t+1}] \cdot cov_t[\ln(\tilde{M}_{t+1}), \tilde{R}^e_{t+1}]. \quad (7)$$

Furthermore let $\tilde{m}_{t+1} = \ln(\tilde{M}_{t+1})$ and $\Delta\tilde{c}_{t+1} = \ln(\tilde{C}_{t+1}/C_t)$ denote the log SDF and log consumption growth, respectively. Due to the fact that $\tilde{m}_{t+1} = \ln(\beta) - \eta\Delta\tilde{c}_{t+1}$, we have $cov_t[\tilde{m}_{t+1}, \tilde{R}^e_{t+1}] = -\eta cov_t[\Delta\tilde{c}_{t+1}, \tilde{R}^e_{t+1}]$ and may thus employ (7) to rewrite the risk premium (4) in terms of η, the standard deviations $\sigma_t[\Delta\tilde{c}_{t+1}]$ and $\sigma_t[\tilde{R}^e_{t+1}]$, as well the correlation function $\rho_t[\Delta\tilde{c}_{t+1}, \tilde{R}^e_{t+1}]$:

$$\begin{aligned} \mathrm{E}_t[\tilde{R}^e_{t+1}] &= -cov_t[\tilde{m}_{t+1}, \tilde{R}^e_{t+1}] \\ &= \rho_t[\Delta\tilde{c}_{t+1}, \tilde{R}^e_{t+1}] \cdot \sigma_t[\Delta\tilde{c}_{t+1}] \cdot \sigma_t[\tilde{R}^e_{t+1}] \cdot \eta. \quad (8) \end{aligned}$$

The right hand side comprises the four drivers of the risk premium as postulated by the model. Drawing on the law of iterated expectations, it can be shown that this expression also holds for unconditional moments (see, e.g., Söderlind, 2009b). An alternative way of assessing the empirical performance of the consumption-based model are the well-known Hansen and Jagannathan (1991) bounds. The binding lower limit for the volatility of a log SDF that prices a given set of assets can be computed from (8) by setting the correlation $\rho_t[\Delta\tilde{c}_{t+1}, \tilde{R}^e_{t+1}]$ to its maximum of one (minimum of minus one), and solving for the Sharpe ratio:

$$\sigma_t[\tilde{m}_{t+1}] = \eta\sigma_t[\Delta\tilde{c}_{t+1}] \geq \left| \frac{\mathrm{E}_t[\tilde{R}^e_{t+1}]}{\sigma_t[\tilde{R}^e_{t+1}]} \right|. \quad (9)$$

A correlation of one should be used in the context of risky assets such as stocks. Insurance contracts, in contrast, help to smooth consumption and should therefore be evaluated based on a correlation of minus one. Mixture normal distributions can take a wide variety of shapes. Hence, the extended Stein's

Lemma allows us to account for skewness (and kurtosis) in asset returns. At the same time, the necessity to assume a Gaussian log SDF is not much of a sacrifice, since macroeconomic variables such as log consumption growth are typically almost normally distributed (see, e.g. Söderlind, 2009a).

Jointly Lognormally-Distributed Asset Returns and Consumption Growth

Apart from the aforementioned solution, we will also follow Hansen and Singleton (1983) in assuming that the joint conditional distribution of gross returns and consumption growth is lognormal as well as homoskedastic. Although this approach is not particularly realistic, it has been widely used in empirical research on the consumption-based model and is thus well-suited to ensure the comparability of our results. Consider the following definition (see, e.g., Campbell, 2003):

Any lognormally-distributed random variable $\tilde{x}$ exhibits the property: $\ln(\mathrm{E}_t[\tilde{x}]) = \mathrm{E}_t[\ln(\tilde{x})] + \frac{1}{2}var_t[\ln(\tilde{x})]$, *with* $var_t[\ln(\tilde{x})] = \mathrm{E}_t[\ln(\tilde{x})^2] - \mathrm{E}_t[(\ln(\tilde{x})]^2$. *If, moreover, $\tilde{x}$ is homoskedastic, then* $var_t[\ln(\tilde{x})] = \sigma^2[\ln(\tilde{x})]$.

This means that given joint conditional lognormality and homoskedasticity of $\tilde{M}_{t+1}$ and $\tilde{R}^e_{t+1}$, the following relationship applies:[9]

$$\begin{aligned} \mathrm{E}_t[\tilde{r}^e_{t+1}] + \frac{1}{2}\sigma^2[\tilde{r}^e_{t+1}] &= -cov[\tilde{m}_{t+1}, \tilde{r}^e_{t+1}] \\ &= \rho[\Delta\tilde{c}_{t+1}, \tilde{r}^e_{t+1}] \cdot \sigma[\Delta\tilde{c}_{t+1}] \cdot \sigma[\tilde{r}^e_{t+1}] \cdot \eta \quad (10) \end{aligned}$$

Since $\tilde{m}_{t+1} = \ln(\beta) - \eta\Delta\tilde{c}_{t+1}$, we can conclude that

$$cov[\tilde{m}_{t+1}, \tilde{r}^e_{t+1}] = -\eta cov[\Delta\tilde{c}_{t+1}, \tilde{r}^e_{t+1}].$$

Consequently, as in (8), we are able to express the risk premium in terms of η, the standard deviations $\sigma[\Delta\tilde{c}_{t+1}]$ and $\sigma[\tilde{r}^e_{t+1}]$, as well as the correlation

[9]For a detailed derivation, please refer to the Appendix.

function $\rho[\Delta\tilde{c}_{t+1}, \tilde{r}^e_{t+1}]$.[10]

Again, the Hansen and Jagannathan (1991) volatility bound for the log SDF can be derived by acknowledging that the absolute value of the correlation $\rho[\Delta\tilde{c}_{t+1}, \tilde{r}^e_{t+1}]$ may not exceed one. Rearranging for the (logarithmic) Sharpe ratio leads to:

$$\sigma[\tilde{m}_{t+1}] = \eta\sigma[\Delta\tilde{c}_{t+1}] \geq \left| \frac{\mathrm{E}_t[\tilde{r}^e_{t+1}] + \frac{1}{2}\sigma^2[\tilde{r}^e_{t+1}]}{\sigma[\tilde{r}^e_{t+1}]} \right|. \tag{11}$$

3 Financial Pricing of Insurance

3.1 Asset Pricing Theory and Insurance Markets

The price of an insurance policy under classical actuarial theory equals the present value of its future cash flows, calculated with actuarial probabilities and discount rates. In other words, insurance risk is treated as purely idiosyncratic in nature. Yet, insurance payoffs are nowadays frequently linked to the developments in the capital markets. This can either be through products that comprise both actuarial and financial risk, such as participating life insurance, or due to the fact that an insurer's ability to settle claims hinges on security prices via the asset side of the balance sheet. Consequently, central ideas from asset pricing theory are increasingly applied to insurance markets (see, e.g., Bauer et al., 2013). In contrast to financial markets, however, the latter are known to lack a complete set of Arrow-Debreu securities. Hence, additional assumptions are required to determine the pricing kernel $\tilde{M}_{t+1}$ in (1).

Bauer et al. (2013) discuss various settings in which the complete market argument carries over to insurance pricing. An important question in this regard is whether the financial and the insurance risk affecting a contract's payoff are stochastically independent and therefore separable. If this is the case and the insurance risk is also fully diversifiable, a unique $\tilde{M}_{t+1}$ arises via replication. The overall contract price is then obtained by weighting the replication price with

[10] The Jensen's Inequality term $\frac{1}{2}\sigma^2[\tilde{r}^e_{t+1}]$ arises due to the fact that we consider the expected value of a log return.

actuarial probabilities (see, e.g., Brennan and Schwartz, 1976).[11] In practice, however, there are limits to diversification, because the number of independent and identically-distributed risk units is finite. Despite this fact, one may still rely on a coherent choice of $\tilde{M}_{t+1}$ or on utility-indifference pricing (see, e.g., Schweizer, 2001; Carmona, 2008). Moreover, an almost-complete market setup prevails for most insurance contracts, meaning that the inherent insurance risk is too small to affect security prices. In this specific situation, the complete financial market model is merely inflated by an orthogonal risk and replication once more delivers a unique $\tilde{M}_{t+1}$ (see, e.g., Pham et al., 1998; Moller, 2001).[12]

Given financial and insurance risks are nonseparable, it is possible to empirically determine their dependence structure by means of a factor model for $\tilde{M}_{t+1}$, such as the Insurance CAPM (see, e.g., Biger and Kahane, 1978).[13] This implies that insurance contracts contain a risk premium associated with systematic financial market risk. Furthermore, the work of Mitchell et al. (1999) and Froot (2001) provided indications for risk premiums stemming from large systematic insurance risks such as longevity and natural catastrophes. One way to capture those is to select a parametric form for the pricing kernel and estimate it using observable prices of insurance-linked securities (see, e.g., Wang, 2004; Bauer et al., 2010).[14] The insurance contracts themselves do not need to be marketable for this purpose. Hence, just as for the above-mentioned approaches, the idea is to link up the prices of insurance contracts with those of traded financial instruments. In doing so, however, we do not learn how the underlying security prices are formed in equilibrium. Exactly this question has been proposed by Bauer et al. (2013) and others as a key direction for future research.

[11] The combination of risk-neutral and actuarial probabilities is called the "product measure" (see Bauer et al., 2013).

[12] Diversification is then achieved through an atomically-granular distribution of the insurance risk across market participants. This is consistent with the seminal result of Arrow (1971), who proved the risk-neutrality of expected utility maximizers for infinitesimally small stakes.

[13] Major disasters, e.g., may have a notable impact on security prices (Bauer et al., 2013). An example is the massive negative reaction of Japan's Nikkei index after the Kobe earthquake in 1995.

[14] Well-known approaches in this context are the Esscher transform and the Wang transform. Apart from those, many actuarial premium principles can be translated into a change of measure (see, e.g., Schweizer, 2001).

3.2 Risk Premiums for Systematic Insurance Risk

We aim to provide new insights in this regard by means of the classical consumption-based asset pricing model. More specifically, we consider the case in which insurance risk is severe enough to directly enter into the marginal utility of the the representative-agent via consumption, giving rise to a stochastic dependence between $\tilde{M}_{t+1}$ and the insurance payoff $\tilde{X}_{t+1}$. Two earlier attempts have been made in a similar setting: Friedberg and Webb (2007) as well as Dieckmann (2011) apply the consumption-based model to aggregate mortality risk and catastrophe bonds, respectively. The presence of risk premiums for systematic insurance risk in the property-casualty insurance market, in contrast, has not been examined yet. This is surprising, given the fact that loss accumulation due to extreme events is very common in most of the corresponding business lines. Ibragimov and Walden (2007), e.g., show that there are limits to diversification in insurance markets in the presence of tail risks. An important phenomenon in this regard is the impact of severe droughts, thunderstorms, or earthquakes on fire insurance. According to a joint evaluation by the Association of Dutch Insurers and the Fire Department of the Netherlands, summer storms that hit the province of North Holland in 2015 resulted in a substantial surge in fire insurance claims. One of the main causes was heavy rainfall, which short-circuited electrical installations in gardens. Similarly, fires started by broken gas lines are the most common side effect of earthquakes. The famous 1906 San Francisco earthquake caused most of its overall damage through fire (see website of the Insurance Information Institute). Even the frequency and severity of casualty (or liability-based) “catastrophes” has increased considerably over the past decade (see website of Guy Carpenter). Insured losses associated with compensation and legal costs in asbestos litigation cases, e.g., typically turn out much higher than for natural catastrophes such as Hurricane Katrina or the Northridge Earthquake.

3.3 Insurance Stocks vs. Insurance Contracts

At this point, a brief note is due on how our analysis of insurance contracts is going to differ from a test of the representative-agent consumption-based model on insurance stock returns. Evidently, the latter are well-suited to empirically determine the stochastic dependence between insurance risk and systematic financial risk. This is because they are influenced by general stock market movements, but essentially represent an amalgamation of the different exposure types (underwriting risk, market risk, operational risk etc.) inherent in the balance sheet of an insurance company. By means of adequately-designed factor models such as the Insurance CAPM, e.g., it is thus possible to apply relative pricing, i.e., to estimate an underwriting beta and, in turn, derive a risk premium for insurance contracts from the financial markets. However, to develop an understanding of the underlying fundamental sources of risk that drive insurance premiums, we have to embark upon the much more challenging task of absolute pricing (see, e.g., Cochrane, 2005). In this context, the focus lies on macroeconomic magnitudes such as consumption, implying that insurance stocks are not instrumental for the derivation of expected excess returns on insurance contracts. Testing the consumption-based model on insurance stocks reveals the equity premium puzzle for a special sector of the equity market.[15] Our analysis, in contrast, contributes to the literature by directly considering the relationship between the payoff on an insurance contract and the consumption stream of the investor.

3.4 Excess Returns on Insurance Contracts

Before we begin the empirical analysis, we still need to determine how excess returns should be measured in our context. From the perspective of the policyholder, the price of a property-casualty policy is the insurance premium and its payoff is the indemnification paid by the insurance company to cover a loss. There are no additional return components, since most property-casualty policies such as fire insurance are single-period contracts, subject to annual renewals. They do not pay any interim cash flows and cannot be sold before the expiry date.[16] Hence, they naturally lend themselves to test the consumption-based model. We estimate the gross return $\tilde{X}_{t+1}/P_t$ on the representative agent's policy by means of the loss ratio: $\tilde{X}_{t+1}$ for a given year will be represented by the aggregate claims and P_t by the overall premium volume. Since both magnitudes include the number of contracts, $\tilde{X}_{t+1}/P_t$ can also be interpreted

[15] Results for the equity premium puzzle in the context of insurance stocks can be found in the Appendix.

[16] This is different from stocks, for which dividends $\tilde{D}_{t+1}$ also need to be accounted for in the gross return: $(\tilde{X}_{t+1} + \tilde{D}_{t+1})/P_t$.

as the return on the average insurance policy in the economy or business line. The excess return $\tilde{R}^e_{t+1}$ equals the difference between the loss ratio $\tilde{X}_{t+1}/P_t$ and the gross risk-free rate R_f.

4 Empirical Analysis

4.1 Data, Sample Selection, and Descriptive Statistics

Our empirical analysis is based on historical time series of aggregate annual premium volumes and claims for fire insurance in Australia (1992–2012), Italy (1973–2011), and the Netherlands (1986–2011), which have been provided by Swiss Re. This data set has been complemented by direct premiums earned and direct losses incurred for U.S. fire insurance between 1989 and 2012 as recorded by A.M. Best. Finally, we obtained annual premiums and claims data from the German Insurance Association (GDV) in the period from 1974 to 2012. The latter is available for the following business lines: fire, casualty, household, and homeowners insurance. As explained in the previous section, the excess return $\tilde{R}^e_{t+1}$ equals the difference between the loss ratio $\tilde{X}_{t+1}/P_t$ and the gross risk-free rate R_f. A timing convention is needed as both premiums and claims are flows over the year instead of point-in-time observations. In line with common practice in the insurance industry, we calculate the loss ratios based on contemporaneous premiums and claims, thus implicitly assuming that the former are measured at the beginning and the latter at the end of the year. To fit the model to real returns, we additionally adjust the loss ratios for inflation.

Furthermore, we draw on an updated version of the macroeconomic data set used in Campbell (1999) and Campbell (2003), which can be downloaded from the International Financial Statistics (IFS) website and comprises time series of consumption, consumer price indices, short-term interest rates, population, and GDP deflator.[17] Data on non-durables and services consumption is only available for the United States. Consequently, we need to work with total household consumption expenditure for Australia, Italy, the Netherlands, and

[17] The pre-Euro consumption figures for Italy, the Netherlands, and Germany have been converted by means of the fixed exchange rates between the Euro and the former domestic currencies of those countries.

Germany. The time frames of the macroeconomic series are matched to those of the premiums and claims figures for each country. In line with the empirical literature on the equity premium puzzle, we compute log consumption growth based on real per capita consumption, which is defined as the overall level of consumption divided by the population and the GDP deflator.[18] Finally, we follow Campbell (2003) and draw on stock market returns from Morgan Stanley Capital International (MSCI), which we have downloaded from the Wharton Research Data Services website and adjusted for inflation using the consumer price index of each country. This will enable us to benchmark our RRA coefficient estimates for the insurance sector with the values that constitute the classical equity premium puzzle. Due to the restricted availability of insurance data, we are in fact looking at shorter time horizons than most of the earlier empirical asset pricing literature. For comparison purposes, we have included an exact replication of the Campbell (2003) results in the Appendix.

Country	Period	$\overline{r}^s$	$\sigma[r^s]$	$\gamma[r^s]$	$\overline{r}^i$	$\sigma[r^i]$	$\gamma[r^i]$	$\overline{r}_f$	$\overline{\Delta c}$	$\sigma[\Delta c]$	$\gamma[\Delta c]$
AUL	1992-2012	6.06%	17.83%	–1.58	–52.63%	41.85%	0.55	2.78%	1.73%	1.84%	–0.98
ITA	1973-2011	1.33%	28.83%	–0.12	–45.73%	17.19%	0.34	2.02%	1.54%	2.19%	–0.42
NL	1986-2011	6.24%	23.57%	–1.26	–57.97%	14.11%	1.24	2.40%	1.25%	1.84%	0.17
USA	1989-2012	6.44%	17.73%	–1.62	–71.93%	29.93%	1.15	1.02%	1.61%	1.78%	–1.68
GER	1974-2011	7.18%	25.77%	–0.68	–30.64%	14.75%	0.08	2.36%	1.63%	1.46%	–0.02

Table 5: International Equity Returns, Insurance Returns, Risk-Free Rates, and Consumption Growth

This table shows the average annual log returns of the equity market (column three), fire insurance market (column six), and risk-free asset (column nine), as well as the corresponding standard deviations (columns four and seven) and skewnesses (columns five and eight) for all countries in our sample. The last three columns contain the average annual log growth rates of (per capita) consumption, its standard deviations, and its skewnesses. The time period for each country is determined by the availability of insurance premiums and claims data. All figures are reported in real terms.

[18] Just as premiums and claims, consumption is a flow measure and thus requires a timing convention. Campbell (2003) advocates that the latter should be determined so as to generate the highest possible contemporaneous correlation between consumption growth and stock returns. Accordingly, we resort to a beginning-of-year timing convention for Germany, Italy, the Netherlands and the United States, meaning that consumption growth in a specific year is calculated as per capita consumption in the next year divided by per capita consumption in the current year. By contrast, an end-of-year timing convention is adopted for Australia. In this case, current consumption growth equals this year's per capita consumption divided by last year's per capita consumption.

Table 5 contains some descriptive statistics. We see that the stock markets in all countries apart from Italy have delivered average log returns ($\overline{r}^s$) in excess of six percent per annum over the considered time periods. The corresponding volatilities ($\sigma[r^s]$) range between 17 and 29 percent and the distributions exhibit a negative skewness ($\gamma[r^s]$). Campbell (2003) suggests that the relatively poor performance of the Italian stock market can be attributed to its small size in percent of GDP. Moreover, the average annual log returns ($\overline{r}^i$) on fire insurance in all five countries lie below –30 percent. Hence, as implied by asset pricing theory, individuals are prepared to accept a significant negative return on their insurance contracts, because the latter represent a consumption hedge. Three of the five insurance market return volatilities ($\sigma[r^i]$) are smaller than the corresponding stock market return volatilities. This could be due to the fact that insurance sector fundamentals and actuarial premium drivers are quite stable over time and insurance prices generally display a relatively low sensitivity to short-term changes in market sentiment. Moreover, all insurance return distributions in our sample are positively skewed ($\gamma[r^i]$). Their long right tail is generated by loss accumulations due to systematic insurance risk as discussed in the previous section. Put differently, there are certain states of the world in which the representative agent realizes a very high positive return on his policy. Turning to the average log return ($\overline{r}_f$) of the risk-free asset, we notice that short-term government debt yielded less than three percent per annum in all of the five countries.[19] Finally, the last three columns show the average log consumption growth rates ($\overline{\Delta c}$) as well as their standard deviations ($\sigma[\Delta c]$) and skewnesses ($\gamma[\Delta c]$). With one exception (Italy), the first two measures lie consistently below two percent. The skewnesses, however, are negative in four cases, implying that the representative agent may face severe drops in consumption. In combination with the skewnesses of the insurance returns, this is an indication for a potential tail dependence of consumption growth and the returns on property-casualty policies. We will return to this finding later on, when looking for suitable extensions of the classical consumption-based model. Overall, Table 5 underlines that high single-digit average equity returns, large

[19]Our values are slightly lower than those reported in Campbell (2003), because the low-interest rate environment after the millennium forms a larger part of the sample. For a comparison please refer to the Appendix.

negative average insurance returns, and a low consumption growth volatility characterize many developed countries, including the United States.

4.2 The Equity Premium Puzzle: A Brief Review

We begin our empirical analysis with a brief review of the classical equity premium puzzle. Estimates of the relevant variables for our sample countries and time periods can be found in Table 6. In line with Table 5, all figures are reported in real terms. Panel A is based on the extended Stein's Lemma and Panel B relies on the lognormality assumption. Accordingly, the estimated annual equity risk premium in column three is represented by expected excess returns ($\mathrm{E}[\tilde{R}^e_{t+1}]$) in the first case as well as adjusted expected log excess returns ($a\mathrm{E}[\tilde{r}^e_{t+1}] = \mathrm{E}_t[\tilde{r}^e_{t+1}] + \frac{1}{2}\sigma^2[\tilde{r}^e_{t+1}]$) in the second case.[20] Columns four, five, and six contain the corresponding standard deviations ($\sigma[\tilde{R}^e_{t+1}]$ and $\sigma[\tilde{r}^e_{t+1}]$), skewnesses ($\gamma[\tilde{R}^e_{t+1}]$ and $\gamma[\tilde{r}^e_{t+1}]$), and the Hansen-Jagannathan bounds for the log SDF ($\sigma[\tilde{m}_{t+1}]$) as defined in Equations (9) and (11). Furthermore, in columns seven and eight, we have provided the volatilities of log consumption growth ($\sigma[\Delta\tilde{c}_{t+1}]$) and the correlations of log consumption growth with the equity risk premium ($\rho[\Delta\tilde{c}_{t+1}, \tilde{R}^e_{t+1}]$ and $\rho[\Delta\tilde{c}_{t+1}, \tilde{r}^e_{t+1}]$). In order to evaluate the risk aversion of the representative agent, we employ Equations (8) and (34) in combination with two different inputs for the correlation: (a) the empirically estimated correlation coefficient in column seven and (b) a correlation of one. The latter is consistent with the definition of the Hansen-Jagannathan bounds and allows us to differentiate between the impact of the SDF volatility as well as the correlation of the SDF with excess returns.[21] We have included the respective estimates in the last two columns labeled $\eta(1)$ and $\eta(2)$. All time periods are determined by the availability of insurance data.

The figures in Panels A and B are very similar. Apart from common sampling-related deviations, our findings are largely consistent with earlier research (see Appendix). Turning to the Hansen-Jagannathan bounds, we realize

[20] The adjustment is Jensen's Inequality, i.e., half a sample variance of the log excess return (see Equation 34).

[21] Recall that a perfect positive correlation between excess returns and consumption growth implies a perfect negative correlation between excess returns and the SDF. This is characteristic for portfolios on the mean-variance frontier, which are maximally risky and thus earn the highest expected returns for a given standard deviation (see, e.g., Cochrane, 2005).

that pricing kernels which are capable of explaining historical asset prices in these five countries would need to exhibit a minimum volatility of between 11 and 38 percent. Yet, all log consumption growth volatilities are around two percent or lower. Thus, Equations (9) and (11) tell us that the model will only fit, if the RRA coefficient η is large. This can be seen explicitly when considering the values of $\eta(1)$, which have been calculated based on the empirical correlation coefficients in column seven.[22] Most authors, including Mehra and Prescott (1985), deem RRA values of between one and ten to be acceptable. Our estimates, in contrast, lie all considerably above this range. Even after setting the correlation to one, only the $\eta(2)$ value for Italy drops below the theoretical RRA threshold of ten. Therefore, the empirically observed stock market returns can only be reconciled with the theoretical model on the basis of implausibly high RRA coefficients. This phenomenon, which holds consistently across countries, is the equity premium puzzle.[23]

4.3 Consumption-Based Asset Pricing in Insurance Markets

In the next step, we fit the consumption-based asset pricing model to inflation-adjusted excess returns on insurance policies. The respective results can be found in Table 7, which exhibits the same structure as Table 6. Once more, the estimates in column three of Panel A are based on the extended Stein's Lemma and expected excess returns, whereas column three of Panel B relates to the lognormality assumption and adjusted expected excess returns. The associated volatilities and skewnesses are reported in columns four and five, respectively. Columns six to eight contain the Hansen-Jagannathan bounds for the log SDF, the volatility of consumption growth, and the correlations of log consumption growth with the insurance market risk premium. The last two columns present the RRA coefficients $\eta(1)$ and $\eta(2)$, which have been estimated using (a) the

[22] The correlation estimates tend to increase with the interval of the underlying time series (see, e.g., Campbell and Cochrane, 1999). Thus, our results of between 0.3 and 0.6 are somewhat higher than those reported in earlier studies, since we work with annual rather than quarterly data (see Appendix). As a corollary, we obtain smaller values for $\eta(1)$.

[23] Brown et al. (1995) suggested that the high ex-post equity premiums in the United States may be caused by a survivor bias of stock exchanges. Their hypothesis, however, is contradicted by the fact that the puzzle also exists in other countries.

Panel A: Extended Stein's Lemma

Country	Period	$\mathrm{E}[\tilde{R}^e_{t+1}]$	$\sigma[\tilde{R}^e_{t+1}]$	$\gamma[\tilde{R}^e_{t+1}]$	$\sigma[\tilde{m}_{t+1}]$	$\sigma[\Delta\tilde{c}_{t+1}]$	$\rho[\Delta\tilde{c}_{t+1}, \tilde{R}^e_{t+1}]$	$\eta(1)$	$\eta(2)$
AUL	1992-2012	4.91%	16.95%	–0.81	28.95%	1.84%	+0.3667	43.00	15.77
ITA	1973-2011	3.34%	29.39%	0.70	11.38%	2.19%	+0.3702	14.02	5.19
NL	1986-2011	6.62%	22.65%	–0.59	29.24%	1.84%	+0.6101	25.98	15.85
USA	1989-2012	7.09%	16.87%	–1.03	42.03%	1.78%	+0.6321	37.30	23.58
GER	1974-2011	8.38%	26.68%	0.08	31.41%	1.46%	+0.2884	74.41	21.46

Panel B: Lognormality Assumption

Country	Period	$a\mathrm{E}[\tilde{r}^e_{t+1}]$	$\sigma[\tilde{r}^e_{t+1}]$	$\gamma[\tilde{r}^e_{t+1}]$	$\sigma[\tilde{m}_{t+1}]$	$\sigma[\Delta\tilde{c}_{t+1}]$	$\rho[\Delta\tilde{c}_{t+1}, \tilde{r}^e_{t+1}]$	$\eta(1)$	$\eta(2)$
AUL	1992-2012	4.82%	17.57%	–1.58	27.43%	1.84%	+0.4358	34.28	14.94
ITA	1973-2011	3.19%	27.84%	–0.12	11.44%	2.19%	+0.4186	12.46	5.22
NL	1986-2011	6.59%	23.44%	–1.23	28.13%	1.84%	+0.6249	24.40	15.25
USA	1989-2012	6.96%	17.57%	–1.65	39.61%	1.78%	+0.6578	33.77	22.22
GER	1974-2011	8.13%	25.74%	–0.77	31.61%	1.46%	+0.3441	62.74	21.59

Table 6: Evidence for the Equity Premium Puzzle

This table illustrates the equity premium puzzle based on the extended Stein's Lemma (Panel A) and the lognormality assumption (Panel B). It contains the annual equity market risk premiums (column three), the corresponding standard deviations (column four) and skewnesses (column five), as well as the resulting Hansen-Jagannathan bounds (column six) for all countries in our sample. In addition, it shows the volatilities of consumption growth (column seven) and its correlations with excess returns (column eight). The last two columns labeled $\eta(1)$ and $\eta(2)$ display the RRA coefficient estimates for (a) the empirical correlation in column seven and (b) a correlation of one. The time period for each country is determined by the availability of insurance premiums and claims data. All figures are reported in real terms.

empirical correlation and (b) a correlation of minus one.[24] In the upper part of each panel, we have summarized the results for the fire insurance markets in Australia, Italy, the Netherlands, and the United States, while the lower part is dedicated to our four property-casualty business lines in the German market.

In contrast to Table 6, we now observe considerable differences between Panels A and B. This is a clear indication that the widespread lognormality assumption in asset pricing does not fit the typical shape of loss ratio distributions. The extended Stein's Lemma, on the other hand, is much better suited for the analysis of insurance data, since it accounts for skewness (and kurtosis). As an example consider the United States, whose insurance risk premium distribution in Panel A is characterized by a skewness ($\gamma[\tilde{R}^e_{t+1}]$) of 2.81 compared to –1.03 for the distribution of the equity risk premium (see Table 6). In Panel B, in contrast, we obtain a skewness of merely 1.20 for the U.S. insurance risk premium. Thus, the lognormality assumption does not properly capture the long right tail, representing systematic insurance risk. We therefore decide to focus our subsequent interpretation efforts on Panel A. As expected, the insurance risk premiums are highly negative, ranging from around –28 percent for German fire insurance down to almost –50 percent for U.S. fire insurance. Only one of the corresponding volatilities exceeds 30 percent (Australia), while the majority lies under ten percent. Hence, insurance risk premiums seem to be generally more stable than equity risk premiums (cf. Table 6). Furthermore, the Hansen-Jagannathan bounds vary between 124 and 853 percent. This means that we need an excessively volatile SDF to explain the average historical excess returns, a condition which is clearly not fulfilled by log consumption growth. Consistent with the model predictions, most correlation coefficients between log consumption growth and insurance risk premiums are negative. Yet, they exhibit very small absolute values, leading to absurdly high $\eta(1)$-estimates of between 360 and 9500. Although setting the correlation to minus one causes a substantial decrease, the $\eta(2)$ of between 67 and 584 still remain way beyond any reasonable threshold. More specifically, they equal between 4 and 37 times their equity counterparts. Overall, our results support the theory insofar as

[24] Since asset pricing theory assumes a negative covariance of insurance returns with consumption growth (refer to the second section), both the Hansen-Jagannathan bounds for the log SDF and $\eta(2)$ now require a perfect negative correlation.

individuals are indeed prepared to accept negative excess returns on insurance contracts to smooth consumption over time. However, to fit the insurance data, we need extreme levels of risk aversion, which are even higher than in the stock markets. This phenomenon will be subsequently referred to as the insurance premium puzzle.

At first glance, the insurance premium puzzle comprises two baffling aspects: the very high RRA coefficients implied by the consumption-based model and the fact that individuals seem to be more risk averse in the insurance market than for stock investments.[25] The latter can be plausibly explained with the latest insights in economics and psychology. Both disciplines have long been dominated by the notion that attitude towards risk is a stable personality trait over time and across contexts. More recent work, however, calls this assumption into question (see, e.g., Weber et al., 2002; Soane and Chmiel, 2005; Hanoch et al., 2006; Riddel, 2012). Instead of categorizing individuals as being risk taking or risk averse, decision researchers have begun to adopt a domain-specific approach. There are many domains in which people are confronted with choices over risky outcomes, including finance, insurance, sports, leisure, health, career, and the environment. Experiments and surveys show that the preferences of most subjects display a substantial domain heterogeneity. Against this background, we view the observed discrepancy in the RRA coefficients between equity and insurance markets as a contribution to the literature on domain-specific risk aversion and focus our subsequent efforts on understanding the actual level of η.

5 Tackling the Puzzle

5.1 A Discussion of Selected Model Extensions

As indicated at the outset of this paper, the literature on the equity premium puzzle is abundant in modifications of the consumption-based model. In this section, we consider a number of the most influential approaches as natural candidates for tackling the insurance premium puzzle. Epstein and Zin (1989,9)

[25] Note that the second aspect of the puzzle can also be illustrated by applying the RRA coefficients that have been estimated using equity market data (see Table 6) in order to predict the risk premiums on insurance contracts. In this case, the difference between the observed and the model-generated risk premiums would indicate the need for further investigations.

Panel A: Extended Stein's Lemma

Country	Period	$\mathrm{E}[\tilde{R}^e_{t+1}]$	$\sigma[\tilde{R}^e_{t+1}]$	$\gamma[\tilde{R}^e_{t+1}]$	$\sigma[\tilde{m}_{t+1}]$	$\sigma[\Delta\tilde{c}_{t+1}]$	$\rho[\Delta\tilde{c}_{t+1}, \tilde{R}^e_{t+1}]$	$\eta(1)$	$\eta(2)$
AUL (Fire)	1992–2012	–38.27%	30.72%	1.63	124.60%	1.84%	–0.1862	364.52	67.86
ITA (Fire)	1973–2011	–37.89%	9.11%	0.62	415.78%	2.19%	–0.0298	6370.89	189.56
NL (Fire)	1986–2011	–45.87%	8.40%	1.82	545.88%	1.84%	–0.0313	9466.93	295.87
USA (Fire)	1989–2012	–49.94%	17.90%	2.81	279.05%	1.78%	+0.0983	<0	156.53
GER (Fire)	1974–2011	–28.01%	11.20%	0.63	250.14%	1.46%	–0.1188	1438.36	170.88
GER (Casualty)	1974–2011	–51.34%	6.01%	0.32	853.68%	1.46%	+0.0624	< 0	583.16
GER (Household)	1974–2011	–46.54%	6.54%	0.13	711.32%	1.46%	+0.3013	< 0	485.91
GER (Homeowners)	1974–2011	-31.84%	19.05%	0.87	167.10%	1.46%	–0.0590	1935.72	114.15

Panel B: Lognormality Assumption

Country	Period	$\mathrm{aE}[\tilde{r}^e_{t+1}]$	$\sigma[\tilde{r}^e_{t+1}]$	$\gamma[\tilde{r}^e_{t+1}]$	$\sigma[\tilde{m}_{t+1}]$	$\sigma[\Delta\tilde{c}_{t+1}]$	$\rho[\Delta\tilde{c}_{t+1}, \tilde{r}^e_{t+1}]$	$\eta(1)$	$\eta(2)$
AUL (Fire)	1992-2012	–46.58%	42.03%	0.58	110.82%	1.84%	–0.1984	304.25	60.36
ITA (Fire)	1973-2011	–46.66%	14.76%	0.31	316.00%	2.19%	–0.0270	5332.66	144.06
NL (Fire)	1986-2011	–59.43%	13.63%	1.12	435.90%	1.84%	–0.0321	7363.56	236.26
USA (Fire)	1989-2012	–68.79%	28.88%	1.20	238.18%	1.78%	+0.0202	<0	133.61
GER (Fire)	1974–2011	–31.91%	14.76%	–0.03	216.23%	1.46%	–0.1677	880.66	147.71
GER (Casualty)	1974–2011	–69.44%	10.38%	0.17	668.90%	1.46%	+0.0426	< 0	456.93
GER (Household)	1974–2011	–60.63%	12.35%	–0.26	490.88%	1.46%	+0.2608	< 0	335.32
GER (Homeowners)	1974–2011	–37.07%	27.22%	–0.24	136.22%	1.46%	–0.0413	2252.45	93.05

Table 7: Evidence for the Insurance Premium Puzzle

This table illustrates the insurance premium puzzle based on the extended Stein's Lemma (Panel A) and the lognormality assumption (Panel B). It contains the annual insurance market risk premiums (column three), the corresponding standard deviations (column four) and skewnesses (column five), as well as the resulting Hansen-Jagannathan bounds (column six) for all countries and insurance business lines in our sample. In addition, it shows the volatilities of consumption growth (column seven) and its correlations with excess returns on insurance policies (column eight). The last two columns labeled $\eta(1)$ and $\eta(2)$ display the RRA coefficient estimates for (a) the empirical correlation in column seven and (b) a correlation of one. All figures are reported in real terms.

introduced a recursive utility function, which disentangles risk aversion from the elasticity of intertemporal substitution and thus allows for a high expected excess return and a low risk-free interest rate.[26] While being key in overcoming the risk-free rate puzzle, this refinement on a stand-alone basis is known to capture only a third of the historical equity premium when calibrated with reasonable values for the RRA coefficient (see, e.g., Siegel and Thaler, 1997).[27] Hence, it will be insufficient to match the, in absolute terms, even larger average excess returns on insurance policies. Moreover, we could turn to the habit persistence frameworks of Abel (1990), Constantinides (1990), and Campbell and Cochrane (1999), under which utility depends on the difference between current consumption and a benchmark level. Unfortunately, they come with undesirable side effects regarding consumption volatility and fiscal policy (see, e.g., Lettau and Uhlig, 2000; Ljungqvist and Uhlig, 2000). Another potential remedy is the rare disaster hypothesis as coined by Rietz (1988) and Barro (2006), suggesting that major economic crises or wars are an important driver of asset prices. It seems consequential that the demand for insurance might depend on such event risks, too.[28] More recently, however, several objections have been raised. Julliard and Ghosh (2012), e.g., point out that both the empirical frequency and magnitude of economic disasters are too small to rationalize the equity premium puzzle and that the rare events hypothesis actually deteriorates the model's ability to explain the cross-sectional variation in risk premiums. The next category of refinements to be considered is based on the work of Mankiw (1986) and Weil (1992), who abandoned the representative-agent economy

[26]Note that this class of preference functionals is irreconcilable with expected utility theory (see, e.g., Weil, 1990).

[27]Also, it lacks time-varying risk aversion to match empirically-observed equity volatilities (see, e.g., Barberis et al., 2001).

[28]Barro (2009) estimates that society would be prepared to forgo 20 percent of GDP each year to eliminate rare disasters.

to account for heterogeneous investors, facing idiosyncratic shocks.[29] Consequently, consumption growth, and hence the stochastic discount factor, are more volatile on the individual than on the aggregate (or per capita) level. Meanwhile, however, it has been shown that the historical equity premium can hardly be generated by realistically calibrated model of this type (see, e.g., Lettau, 2002; Heaton and Lucas, 2008).

More plausible explanations for the equity and the insurance premium puzzle include the potential discrepancy between ex ante beliefs and ex post realizations, behavioral economic phenomena, as well as the role of higher-order risk preferences. It is certainly conceivable that distributional moments estimated from historical data do not reflect ex ante expectations of economic agents. In other words, the magnitude of claims ratios (or insurance risk premiums) may be a surprise for most policyholders, since they experience difficulties in accurately assessing loss frequencies and severities before purchasing insurance. Support for the argument is provided by Söderlind (2009b), who finds that the equity premium puzzle can be reduced when calibrating the consumption-based model based on survey answers and option-implied volatilities. Testing this hypothesis, however, is beyond the scope of our paper, since it would require a full-scale psychometric study.

The first attempt to overcome the equity premium puzzle with ideas from behavioral economics, particularly the prospect theory of Kahneman and Tversky (1979), has been made by Benartzi and Thaler (1995), who employ loss aversion together with a myopic evaluation horizon of one year for gains and losses. Following their article, several studies have established similar concepts in asset pricing (see, e.g., Barberis et al., 2001; Barberis and Huang, 2001; Barberis et al., 2006; Barberis and Huang, 2008a,0,0). One achievement in

[29]This approach ties in with the literature on background risk, which examines decision making under uncertainty in incomplete markets. A number of studies in this area have illustrated that the presence of uninsurable exogenous risks can increase the risk aversion of individuals and trigger more cautious behavior elsewhere (see, e.g., Eeckhoudt et al., 1996; Franke et al., 2006; Lee, 2008). A direct consequence of this "risk vulnerability effect" is a reduction of the demand for risky investments (see, e.g., Kimball, 1990; Gollier and Pratt, 1996). Hence, models that do not account for background risks may underestimate expected excess returns. Apart from asset pricing, insights on background risk have been applied in the context of portfolio selection (see, e.g., Heaton and Lucas, 2000; Jiang et al., 2010; Baptista, 2008,0) and optimal insurance decisions (see, e.g., Doherty and Schlesinger, 1983; Dana and Scarsini, 2007; Fei and Schlesinger, 2008).

this strand of the literature is the inclusion of loss aversion and narrow framing into the Euler equations of the consumption-based model. By means of such modifications, it is possible to explain several characteristics found in aggregate data with sensible levels of risk aversion. In particular, the approach of Barberis et al. (2001) is able to reconcile a low volatility of consumption growth with a high equity premium, a low risk-free interest rate, a high equity volatility, and a low correlation of excess returns with consumption growth. Due to its success in addressing the equity premium puzzle, we will consider this approach in the context of the insurance premium puzzle, too. Yet, an important critique is that the model essentially relies on a set of additional parameters, whose values can be chosen quite flexibly from a wide range with the goal of lowering the RRA coefficient to acceptable levels.

Another, more recent, refinement of the consumption-based model has been developed by Dionne et al. (2015), who suggest that, apart from the covariance between consumption growth and excess returns, investors also care about extreme downside risk in their consumption levels. Accounting for prudence through an explicit second-order expectation dependence term, their reformulated approach is able to fit empirical equity premiums with RRA coefficients of less than ten. Since our insurance risk premiums are characterized by positive skewness (cf. Table 7) and we have already conjectured a potential tail dependence of log consumption growth and insurance returns (cf. Table 5), we deem the Dionne et al. (2015) modification to be the most promising direction that can be investigated to solve the insurance premium puzzle, at least partially. Hence, the latter will be at the heart of our further considerations.

5.2 Loss Aversion and Narrow Framing

Before considering high-order risk preferences, however, we embark upon an excursus to the work of Barberis et al. (2001) and Barberis and Huang (2001), who enrich the consumption-based model with two key experimental insights from the literature on decision making under risk. Firstly, they argue that loss aversion should be incorporated in the representative investor's preferences. Rather than focusing on his or her absolute wealth level, a loss-averse agent evaluates the corresponding changes relative to a reference point, thereby reacting more severely to losses than to similarly-sized gains. Since we examine excess returns on insurance contracts, our reference point is the risk-free interest rate. This intuitively makes sense, because the latter represents the investor's opportunity cost for the insurance premium. Hence, all returns below the risk-free rate are considered to be a loss.[30] Secondly, they draw on the phenomenon of narrow framing as demonstrated by Tversky and Kahneman (1981).[31] In the classical model setup discussed above, utility is defined over consumption. Accordingly, individuals assess stocks or insurance contracts in combination with other wealth risks that they face, such as the stochasticity of labor income or house prices. Narrow framing, in contrast, means that the decision to engage in a gamble is taken in isolation, i.e., people act as if they receive utility directly from variations in their financial wealth, although it is only one element of their total net worth. Barberis and Huang (2008b) offer two plausible explanations for narrow framing that are directly applicable to our insurance context. On the one hand, investors suffer regret about poor financial decisions, which constitutes a form of nonconsumption disutility. Many policyholders regularly feel that they pay a lot of premiums but hardly ever get a payoff from their insurance company. On the other hand, individuals tend to frame narrowly whenever they rely on intuition instead of consequential reasoning. Intuitive actions are spontaneous and strongly driven by the information that is most accessible in a given situation. Evidently, return information for single insurance policies is more readily available and easier to understand than the distribution of outcomes that arises from the combination of an insurance contract with all other wealth components of the decision maker.

The early framework of Benartzi and Thaler (1995) already assumed that individuals are loss averse and narrowly frame equity returns, which they evaluate at a myopic horizon of one year.[32] Barberis et al. (2001) and Barberis

[30] Alternatively, one could set the representative agent's reference point to zero instead of the risk-free rate. In that case, positive and negative returns would be perceived as "gains" and "losses", respectively.

[31] Following the extant literature, we treat loss aversion and narrow framing as separate concepts. Nevertheless, they are closely linked and in many cases they naturally occur together (see, e.g., Kahneman, 2003; Barberis et al., 2006).

[32] It appears quite natural to assume that investors focus on annual gains and losses, since media coverage, fund performance reports, tax filings etc. are all centered around one-year returns (see, e.g., Barberis and Huang, 2008b).

and Huang (2001) ensure that investors additionally receive direct utility from consumption, thus enabling empirical tests of the model's predictions for the distributional moments of consumption growth and stock market excess returns. We take their reasoning one step further by proposing that both loss aversion and narrow framing are likely to play a central role in the insurance context as well. In other words, a negative excess return on the property-casualty policy of the representative agent should have a stronger impact on his utility than a positive excess return of the same size. Similarly, he should regret the decision to purchase coverage he did not need, since he would have been better off not paying the premium. Below, we fit a parsimonious version of the consumption-based model with loss aversion and narrow framing as proposed by Barberis and Huang (2008b) to our insurance market data.[33]

The following extensions of the Euler equations for returns and excess returns (3) apply:[34]

$$
\begin{aligned}
1 &= \mathrm{E}_t[\tilde{M}_{t+1}\tilde{R}_{t+1}] + b_0\beta\mathrm{E}[\overline{v}(\tilde{R}_{t+1} - R_f)] \\
0 &= \mathrm{E}_t[\tilde{M}_{t+1}\tilde{R}^e_{t+1}] + b_0\beta\mathrm{E}[\overline{v}(\tilde{R}^e_{t+1})].
\end{aligned}
\tag{12}
$$

We now have a second term reflecting the idea that, apart from consumption, the investor also gets utility directly from changes in his financial wealth, represented by the excess returns on the risky insurance contract. The constant b_0 controls the degree of narrow framing, i.e., the prominence of utility derived from gains and losses in financial wealth relative to consumption utility. Choosing $b_0 = 0$ results in the classical model. The additional preference function $\overline{v}$ captures loss aversion as suggested by prospect theory. It exhibits

[33] Barberis et al. (2001) and Barberis and Huang (2001) additionally allow for time-varying loss aversion in line with prior gains or losses. Under their approach, losses are more painful if they follow earlier losses and less so, if they occur after prior gains. This feature is of subordinate importance to our analysis of asset risk premiums, since it is mainly needed to generate empirically observed equity volatilities and long-term return predictability (see Barberis and Huang, 2008b).

[34] Please refer to Barberis and Huang (2008b) for a detailed representation of the utility maximization problem faced by the representative agent. A proof of optimality can be found in Barberis et al. (2001).

a piecewise-linear form kinked at the origin and overweighs negative excess returns through the parameter λ:

$$\overline{v}(x) = \begin{cases} x & \text{for } x \geq 0 \\ \lambda x & \text{for } x < 0, \text{ where } \lambda > 1. \end{cases} \tag{13}$$

Employing the definition of covariance to (12) and rearranging, we obtain an expression for the risk premium as in (4):

$$\begin{aligned} 0 &= \mathrm{E}_t[\tilde{M}_{t+1}] \cdot \mathrm{E}_t[\tilde{R}^e_{t+1}] + cov_t[\tilde{M}_{t+1}, \tilde{R}^e_{t+1}] + b_0\beta\mathrm{E}[\overline{v}(\tilde{R}^e_{t+1})] \\ \mathrm{E}_t[\tilde{R}^e_{t+1}] &= -\frac{cov_t[\tilde{M}_{t+1}, \tilde{R}^e_{t+1}]}{\mathrm{E}_t[\tilde{M}_{t+1}]} - \frac{b_0\beta\mathrm{E}[\overline{v}(\tilde{R}^e_{t+1})]}{\mathrm{E}_t[\tilde{M}_{t+1}]}. \end{aligned} \tag{14}$$

Furthermore, we resort to the extended version of Stein's Lemma and break down the covariance in terms of $\rho_t[\Delta\tilde{c}_{t+1}, \tilde{R}^e_{t+1}]$, $\sigma_t[\Delta\tilde{c}_{t+1}]$, $\sigma_t[\tilde{R}^e_{t+1}]$, and the RRA coefficient η:

$$\begin{aligned} \mathrm{E}_t[\tilde{R}^e_{t+1}] &= -cov_t[\tilde{m}_{t+1}, \tilde{R}^e_{t+1}] - \frac{b_0\beta\mathrm{E}[\overline{v}(\tilde{R}^e_{t+1})]}{\mathrm{E}_t[\tilde{M}_{t+1}]} \\ &= \rho_t[\Delta\tilde{c}_{t+1}, \tilde{R}^e_{t+1}] \cdot \sigma_t[\Delta\tilde{c}_{t+1}] \cdot \sigma_t[\tilde{R}^e_{t+1}] \cdot \eta - \frac{b_0\beta\mathrm{E}[\overline{v}(\tilde{R}^e_{t+1})]}{\mathrm{E}_t[\tilde{M}_{t+1}]} \end{aligned} \tag{15}$$

Finally, use $R_f = 1/\mathrm{E}_t[\tilde{M}_{t+1}]$ (see Appendix) to get:

$$\mathrm{E}_t[\tilde{R}^e_{t+1}] = \rho_t[\Delta\tilde{c}_{t+1}, \tilde{R}^e_{t+1}] \cdot \sigma_t[\Delta\tilde{c}_{t+1}] \cdot \sigma_t[\tilde{R}^e_{t+1}] \cdot \eta - b_0\beta\mathrm{E}[\overline{v}(\tilde{R}^e_{t+1})] \cdot R_f. \tag{16}$$

In contrast to the original framework, the consumption-based model with loss aversion and narrow framing is only testable once we have fixed values for the three additional parameters b_0, β, and λ, that cannot be estimated from the data. Consistent with Barberis et al. (2001) and Barberis and Huang (2001), we pick $\beta = 0.98$ and $\lambda = 2.25$. The latter has been proposed by Tversky and Kahneman (1992) based on a comprehensive analysis of human behavior in gambling experiments. Unfortunately, determining a reasonable b_0 is not as straightforward as it may seem. At the same time, this parameter has a key impact on the results, as it governs the relative importance of nonconsumption utility. Barberis et al. (2001) stress that there are no strong clues for the choice of b_0 and employ a wide range of positive values. Ruling out the possibility of a negative b_0, however, implies that the model can, in many cases, no longer accommodate assets with negative risk premiums.[35] To see this, consider (16): unless the second term on the right hand side is smaller than the first one, $\mathrm{E}_t[\tilde{R}^e_{t+1}] < 0$ requires $\rho_t[\Delta\tilde{c}_{t+1}, \tilde{R}^e_{t+1}] < 0$ and $b_0 < 0$, since loss aversion (13) with $\lambda = 2.25$ almost surely leads to $\mathrm{E}[\overline{v}(\tilde{R}^e_{t+1})] < 0$. Consequently, we suggest that the degree of narrow framing should be represented by the absolute size of b_0 and, in line with our insurance context, allow for negative values. Against this background, b_0 will be determined separately for each country and business line by decreasing its value in increments of 0.01 until the RRA coefficient drops below the theoretically acceptable value of ten for the first time. In line with many extant studies in the asset pricing literature, we now exclusively focus on $\eta(2)$, which assumes a perfect negative correlation between consumption growth and excess returns on insurance. Table 8 summarizes our results.

Columns three to seven comprise the estimates for the insurance market risk premiums, excess return volatilities, skewnesses, consumption growth volatilities, expected nonconsumption utilities, and the average gross risk-free rate over the considered time horizons. The last two columns present the narrow framing coefficient b_0 and the RRA coefficient $\eta(2)$, which have been estimated based on (16) in combination with the aforementioned assumptions. As targeted, all values for $\eta(2)$ now lie between two and ten. This considerable reduction compared to Table 7 has been achieved with narrow framing parameters of between –0.44 and –0.36. To assess whether these values are reasonable, we turn to Barberis and Huang (2001), who note that *"one way to think about b_0 is to compare the disutility of losing a dollar in the stock market with the disutility of having to consume a dollar less"*. They argue that the ratio of these two disutilities in equilibrium can be expressed as $b_0\beta\lambda$ and set $b_0 = 0.45$ so that the

[35] Apart from insurance contracts, such assets are plentiful in modern financial markets. Obvious examples include exchange-traded funds (ETF) that offer the buyer a short position in a stock market index. If the risk premium of the long ETF is positive, that of the short ETF must be negative.

Country	Period	$\mathrm{E}[\tilde{R}^e_{t+1}]$	$\sigma[\tilde{R}^e_{t+1}]$	$\gamma[\tilde{R}^e_{t+1}]$	$\sigma[\Delta\tilde{c}_{t+1}]$	$\mathrm{E}[\overline{v}(\tilde{R}^e_{t+1})]$	R_f	b_0	$\eta(2)$
AUL (Fire)	1992–2012	–38.27%	30.72%	1.63	1.84%	–0.9054	102.83%	–0.36	9.61
ITA (Fire)	1973–2011	–37.89%	9.11%	0.62	2.19%	-0.8526	102.13%	–0.43	6.01
NL (Fire)	1986–2011	–45.87%	8.40%	1.82	1.84%	–1.0321	102.45%	–0.43	8.46
USA (Fire)	1989–2012	–49.94%	17.90%	2.81	1.78%	–1.1345	101.05%	–0.42	8.64
GER (Fire)	1974–2011	–28.01%	11.20%	0.63	1.46%	–0.6317	102.41%	–0.42	8.45
GER (Casualty)	1974–2011	–51.34%	6.01%	0.32	1.46%	–1.1551	102.41%	–0.44	3.76
GER (Household)	1974–2011	–46.54%	6.54%	0.13	1.46%	–1.0472	102.41%	–0.44	3.13
GER (Homeowners)	1974–2011	–31.84%	19.05%	0.87	1.46%	–0.7285	102.41%	–0.40	9.30

Table 8: Consumption-Based Insurance Pricing with Loss Aversion and Narrow Framing

This table illustrates the effect of the loss aversion and narrow framing modification with $\beta = 0.98$ and $\lambda = 2.25$ on the consumption-based model's ability to explain our insurance market data. It contains the annual risk premiums on insurance policies (column three), the corresponding excess return standard deviations (column four), and the skewnesses (column five) for all countries and insurance business lines in our sample. In addition, it shows the volatilities of consumption growth (column six), the expected prospect (nonconsumption) utility (column seven), and the average gross risk-free interest rate (column eight). The last two columns labeled b_0 and $\eta(2)$ display the narrow framing coefficient and the RRA coefficient, which have been estimated using the extended version of Stein's Lemma and a perfect negative correlation between consumption growth and excess returns. All figures are reported in real terms.

loss of one dollar on a stock investment causes approximately the same reduction in utility as foregoing one dollar of consumption ($0.45 \times 0.98 \times 2.25 = 0.99$). Hence, our b_0 estimates in absolute terms imply that the disutility of a one dollar loss on an insurance contract equals the disutility of a consumption decline between 0.79 ($|-0.36| \times 0.98 \times 2.25$) and 0.97 ($|-0.44| \times 0.98 \times 2.25$) dollars. Put differently, the representative agent attributes a somewhat higher importance to consumption utility than to nonconsumption utility. This seems to be an economically reasonable outcome. Nevertheless, it would be false to conclude that the loss aversion and narrow framing approach fully solves the insurance premium puzzle. The reason is that we essentially tweaked the RRA coefficients by fixing three out of four parameters. While our choice of β and λ was based on experimental evidence, there is no such guidance with regard to b_0. Against this background, a broad range of values seems tolerable. We cannot tell, e.g., whether a more extreme b_0 in absolute terms of 0.2 (0.6) might still be valid, implying that the representative agent suffers the same disutility from a dollar loss on an insurance contract as from a 0.44 (1.32) dollar reduction in consumption. Further research is necessary in this regard.

5.3 Higher-Order Risk Preferences

The second promising refinement of the consumption-based model that we consider has been brought forward by Dionne et al. (2015). Motivated by the work of Kraus and Litzenberger (1976), Harvey and Siddique (2000), Ang et al. (2006) and others, they assume that a rational investor will exhibit higher-order risk attitudes. Therefore, he not only cares about the covariance of consumption with an asset's (excess) returns, but also about downside risk. Dionne et al. (2015) capture downside risk through second-degree expectation dependence (SED), which they define as follows:

$$SED(\tilde{R}^e_{t+1}|C^*_{t+1}) \geq 0 \Leftrightarrow -cov\left(\tilde{R}^e_{t+1}, (C^*_{t+1} - \tilde{C}_{t+1})_+\right) \geq 0, \tag{17}$$

with C^*_{t+1} denoting some shortfall threshold for the individual's random consumption level $\tilde{C}_{t+1}$. Hence, positive SED is equivalent to the negative covariance of excess returns with the payoff of a European put option on consumption, struck at C^*_{t+1}. They then show that the risk premium in a consumption-based framework can be approximated by means of two components, namely a covariance effect and an integrated SED effect:[36]

$$
\begin{aligned}
\mathrm{E}_t[\tilde{R}^e_{t+1}] \approx \lambda cov_t[\Delta\tilde{C}_{t+1}, \tilde{R}^e_{t+1}] + \lambda^2 \int_{\underline{C}}^{\overline{C}} SED[\tilde{R}^e_{t+1}|C^*_{t+1}]\,\mathrm{d}C_{t+1} \\
\approx & \lambda\left(\rho_t[\Delta\tilde{C}_{t+1}, \tilde{R}^e_{t+1}] \cdot \sigma_t[\Delta\tilde{C}_{t+1}] \cdot \sigma_t[\tilde{R}^e_{t+1}]\right) \\
& + \lambda^2 \int_{\underline{C}}^{\overline{C}} SED[\tilde{R}^e_{t+1}|C^*_{t+1}]\,\mathrm{d}C^*_{t+1}.
\end{aligned} \tag{18}
$$

It is important to point out that, in contrast to the classical setup, the pricing kernel is now based on absolute changes in consumption $\Delta\tilde{C}_{t+1} = \tilde{C}_{t+1} - C_t$ instead of log consumption growth $\Delta\tilde{c}_{t+1}$. Apart from that, the RRA coefficient does no longer appear directly. The risk premium is now a function of the Arrow-Pratt measure of constant absolute risk aversion (CARA) λ as well as a coefficient of constant absolute prudence (CAP) λ^2, introduced by Modica and Scarsini (2005), Crainich and Eeckhoudt (2008), and Denuit and Eeckhoudt (2010):

$$
\lambda = -\frac{u''(C_t)}{u'(C_t)} \qquad\qquad \lambda^2 = \frac{u'''(C_t)}{u'(C_t)}
$$

Correspondingly, Dionne et al. (2015) abandon the power utility function in favor of exponential utility:

$$
u(C_t) = -\exp(-\lambda C_t) \tag{19}
$$

[36]For an extensive derivation, including proofs, refer to Dionne et al. (2015).

To estimate the model, they rely on an approximation for the integrated SED term in (18):[37]

$$\int_{\underline{C}}^{\overline{C}} SED[\tilde{R}^e_{t+1}|C^*_{t+1}]\,\mathrm{d}C^*_{t+1} \approx \sum_{i=2}^{n} cov_t[\tilde{R}^e_{t+1}, \Delta\tilde{C}_{t+1}|\tilde{C}_{t+1} \leq C^{(i)}]\cdot \cdot \left(C^{(i)} - C^{(i-1)}\right), \tag{20}$$

which can be computed based on the following algorithm (see Dionne et al. (2015)):

(i) Sort the elements of the consumption level time series in ascending order ($\underline{C} = C^{(1)} \leq ... \leq C^{(i)} \leq ... \leq C^{(n)} = \overline{C}$) and find the corresponding excess returns as well as differenced consumption levels.

(ii) Calculate $n-1$ successive lower partial covariances between the sorted sequences of excess returns and differenced consumption levels (starting with the ones that pertain to $C^{(1)}$ and $C^{(2)}$).

(iii) Now, integrated consumption SED can be evaluated as the sum of the products of the $n-1$ lower partial covariances and the differences between the sorted consumption levels.

(iv) Finally, solve (18) for λ and compute the RRA coefficient as follows: $\eta = \lambda \cdot \mathrm{E}[\tilde{C}_{t+1}]$.

Once more, the model is fitted to our insurance market data. As in the previous section, we exclusively report $\eta(2)$, thus assuming a perfect negative correlation between the absolute consumption changes and excess returns on property-casualty insurance policies. The results can be found in Table 9. Columns three to seven comprise the estimates for the insurance market risk premiums, excess return volatilities, skewnesses, average per capita consumption levels, volatilities of consumption changes, and integrated SED terms. The last two columns present the CARA coefficient λ and the associated RRA coefficient $\eta(2)$, which have been estimated based on (18) as well as the methodology outlined by Dionne et al. (2015). Although, the $\eta(2)$ are now substantially

[37] It should be noted that Dionne et al. (2015) derive their model in terms of net returns, while, for comparison purposes, our presentation is based on excess returns.

smaller than in Table 7, their sizes still remain between 15 and 43. Hence, embracing higher-order risk preferences does alleviate but not eliminate the insurance premium puzzle.

Country	Period	$\mathrm{E}[\tilde{R}^e_{t+1}]$	$\sigma[\tilde{R}^e_{t+1}]$	$\gamma[\tilde{R}^e_{t+1}]$	$\mathrm{E}[\tilde{C}_{t+1}]$	$\sigma[\Delta\tilde{C}_{t+1}]$	$\int SED\, dC$	λ	$\eta(2)$
AUL (Fire)	1992–2012	–38.27%	30.72%	1.63	304.15	566.84	–39.5116	0.08	23.97
ITA (Fire)	1973–2011	–37.89%	9.11%	0.62	128.78	279.28	–11.7528	0.17	21.77
NL (Fire)	1986–2011	–45.87%	8.40%	1.82	145.88	270.97	–7.6610	0.23	33.59
USA (Fire)	1989–2012	–49.94%	17.90%	2.81	287.43	498.93	–23.0150	0.13	37.13
GER (Fire)	1974–2011	–28.01%	11.20%	0.63	142.77	196.48	–15.7597	0.13	18.06
GER (Casualty)	1974–2011	–51.34%	6.01%	0.32	142.77	196.48	–5.4112	0.30	42.44
GER (Household)	1974–2011	–46.54%	6.54%	0.13	142.77	196.48	–6.8733	0.25	35.84
GER (Homeowners)	1974–2011	–31.84%	19.05%	0.87	142.77	196.48	–23.8887	0.11	15.40

Table 9: Consumption-Based Insurance Pricing with Second-Degree Expectation Dependence

This table illustrates the ability of the consumption-based model's SED modification to explain our insurance market data. It contains the annual risk premiums on insurance policies (column three), the corresponding excess return volatilities (column four), and the skewnesses (column five) for all countries and insurance business lines in our sample. In addition, it shows estimates of the average per capita consumption level (column six), the volatility of absolute consumption changes (column seven), and the integrated SED of excess returns and consumption. The last two columns labeled λ and $\eta(2)$ display the Arrow-Pratt measure of CARA as well as the RRA coefficient. The latter has been derived assuming a perfect negative correlation between excess returns and absolute consumption changes. All figures are reported in real terms.

6 Summary and Conclusion

Motivated by the fact that insurance is the typical textbook example for an asset whose payoff negatively correlates with consumption, we fit the classical CRRA-utility consumption-based model to an international property-casualty market data set. In doing so, we are able to provide evidence for another asset pricing anomaly, which we dub the insurance premium puzzle. More specifically, due to the low volatility of consumption growth, the highly-negative empirically-observed excess returns on the representative agents' policies can only be explained with absurdly large RRA coefficients. Those even exceed their counterparts implied by stock market data from the analyzed countries by far. We attribute this difference to the fact that agents are known to exhibit domain-specific risk aversion and continue our analysis of the insurance setting with a focus on two promising model refinements. In particular, we implement the loss aversion and narrow framing approach brought forward by Barberis et al. (2001) as well as the SED framework of Dionne et al. (2015). Although the former allows us to lower the RRA coefficients to acceptable levels, it falls short of an empirical reference point for one of its key parameters. Thus, at this stage it would be premature to conclude that it solves the insurance premium puzzle. The Dionne et al. (2015) model, in contrast, offers at least a partial solution. Due to its theoretical appeal, as well as its solid empirical performance, this approach is a natural direction for the further development of asset pricing theory in the context of insurance claims.

Throughout the course of this paper, we were able to identify a whole slew of avenues for future research. Firstly, more work is necessary to confirm the viability of the Barberis et al. (2001) extension. Without reliable experimental evidence on the actual size of the narrow framing parameter, one must be careful not to leap to unsustainable conclusions regarding the considered asset pricing puzzles. Secondly, it might be possible to improve the fit of the Dionne et al. (2015) model by considering higher-order risk attitudes beyond prudence. The authors in fact propose a further model refinement, including an n-th order expectation dependence term. When testing for temperance (kurtosis aversion), however, they do not find a notable impact on the risk premiums, most likely due to the properties of their data. The latter are a major limitation of our analysis as well. Although we documented that the insurance excess return distributions are generally positively skewed, the respective time series are clearly too short to capture the true tail. The problem is that extreme systematic insurance risk events such as super cyclones or megathrust earthquakes have recurrence periods of 100 years or even longer. Hence, the associated contract payoffs are not covered by historical observations but have to be simulated using catastrophe risk models. The latter could therefore be employed for a further assessment of the prudence or temperance extensions. Thirdly, the absence of more comprehensive premiums and claims data prevents us from performing additional robustness checks with regard to aggregation level, geographical scope, and time frame. As a consequence, sampling error remains an issue to be addressed. Fourthly, a modification of the consumption-based model by means of ambiguity aversion might help to explain the observed risk premiums on insurance contracts. The difference between risk and uncertainty seems relevant since individuals do not know the exact statistical distribution of the claims. Therefore, part of the expected excess returns may arise due to uncertainty avoidance. Finally, apart from risk premiums as conjectured by classical asset pricing theory, insurance prices are probably also driven by frictions, such as search costs, financial distress costs, and costs of capital. Thus, future work could aim at breaking down the expected excess returns on insurance contracts in order to estimate the size of frictional elements relative to systematic insurance risk premiums.

7 Appendix

7.1 A Detailed Derivation of The Consumption-Based Model

Below, we provide a detailed derivation of the consumption-based model. Consider a random payoff $\tilde{X}_{t+1}$ at time $t+1$.[38] In order to determine what $\tilde{X}_{t+1}$ is worth to an investor at time t, we draw on the time-separable utility $U(\cdot)$ that he derives from his deterministic current and stochastic future levels of consumption, denoted C_t and $\tilde{C}_{t+1}$:

$$U(C_t, \tilde{C}_{t+1}) \quad = \quad u(C_t) + \beta \mathrm{E}_t \left[u(\tilde{C}_{t+1}) \right]. \tag{21}$$

$\mathrm{E}_t[\cdot]$ is the conditional expectation, given all information available at time t. The intra-period utility function $u(\cdot)$ is upward-sloping ($u'(\cdot) > 0$) and concave ($u''(\cdot) < 0$). Thus, it reflects a rational desire for more consumption in combination with decreasing marginal utility.[39] The curvature of $u(\cdot)$ also governs aversion to risk and to intertemporal substitution: the more stable consumption is across states of the economy and over time, the better. Furthermore, impatience is captured by the subjective time discount factor β (< 1): people want to consume earlier rather than later. Given the investor possesses the endowments E_t and $\tilde{E}_{t+1}$ and has complete flexibility in buying or selling an amount ξ of the asset at a price P_t, he faces the following optimization problem:

$$\begin{aligned} \max_{\xi} \quad u(C_t) \quad &+ \quad \beta \mathrm{E}_t \left[u(\tilde{C}_{t+1}) \right] \qquad s.t. \\ C_t \quad &= \quad E_t - P_t \xi, \\ \tilde{C}_{t+1} \quad &= \quad \tilde{E}_{t+1} + \tilde{X}_{t+1} \xi. \end{aligned} \tag{22}$$

We now insert the constraints into the target function and form the first-order derivative:

$$\frac{\partial U(C_t, \tilde{C}_{t+1})}{\partial \xi} \quad = \quad -u'(C_t) P_t + \beta \mathrm{E}_t \left[u'(\tilde{C}_{t+1}) \tilde{X}_{t+1} \right]. \tag{23}$$

[38] For stocks, $\tilde{X}_{t+1}$ consists of the price ($\tilde{P}_{t+1}$) and the dividend ($\tilde{D}_{t+1}$): $\tilde{X}_{t+1} = \tilde{P}_{t+1} + \tilde{D}_{t+1}$.

[39] Returns are only an intermediate objective. Ultimately, utility is driven by consumption (see, e.g., Cochrane, 2005).

The corresponding first-order condition for a maximum is:

$$0 \overset{!}{=} -u'(C_t)P_t + \beta \mathrm{E}_t \left[u'(\tilde{C}_{t+1})\tilde{X}_{t+1}\right]$$

$$u'(C_t)P_t = \beta \mathrm{E}_t \left[u'(\tilde{C}_{t+1})\tilde{X}_{t+1}\right]. \tag{24}$$

Here, $u'(C_t)P_t$ equals the loss in utility caused by having to pay the asset's purchase price and $\beta \mathrm{E}_t \left[u'(\tilde{C}_{t+1})\tilde{X}_{t+1}\right]$ is the increase in discounted expected utility generated by its payoff. The investor adjusts ξ until this first-order condition holds, i.e., marginal utility loss must equal marginal utility gain. Rearranging (24) yields the central asset pricing formula of the consumption-based model, which states that the price we ought to expect for the asset is driven by the payoff $\tilde{X}_{t+1}$, the investor's utility function, as well as his time preferences (β) and consumption levels (C_t and $\tilde{C}_{t+1}$):

$$P_t = \mathrm{E}_t \left[\beta \frac{u'(\tilde{C}_{t+1})}{u'(C_t)} \tilde{X}_{t+1}\right]. \tag{25}$$

7.1.1 Risk Adjustments and the Stochastic Discount Factor

We define the SDF $\tilde{M}_{t+1}$ (pricing kernel) as the intertemporal marginal rate of substitution:[40]

$$\tilde{M}_{t+1} = \beta \frac{u'(\tilde{C}_{t+1})}{u'(C_t)}. \tag{26}$$

Substituting (26) into (25), gives a more convenient expression for the pricing equation:

$$P_t = \mathrm{E}_t[\tilde{M}_{t+1}\tilde{X}_{t+1}]. \tag{27}$$

Due to their well-behaved properties (e.g., stationarity), many empirical applications draw on returns instead of prices. To obtain the gross return $\tilde{R}_{t+1}$, we need to divide the payoff by the price: $\tilde{R}_{t+1} = \tilde{X}_{t+1}/P_t$. Therefore, (27)

[40] At this rate the investor is willing to forgo consumption at time t for additional consumption at time $t+1$.

can be rearranged into an Euler equation that accounts for $\tilde{R}_{t+1}$ as a special payoff with a price of one:[41]

$$1 = \mathrm{E}_t[\tilde{M}_{t+1}\tilde{R}_{t+1}]. \tag{28}$$

Since the (gross) risk-free rate R_f is, by definition, deterministic, it should equal the inverse of the conditional expectation of the SDF:

$$R_f = \frac{1}{\mathrm{E}_t[\tilde{M}_{t+1}]}. \tag{29}$$

Recalling $cov_t[\tilde{M}_{t+1}, \tilde{X}_{t+1}] = \mathrm{E}_t[\tilde{M}_{t+1}\tilde{X}_{t+1}] - \mathrm{E}_t[\tilde{M}_{t+1}] \cdot \mathrm{E}_t[\tilde{X}_{t+1}]$ on (27) and exploiting the relationship in (29), we can derive an explicit expression for the risk premium:

$$\begin{aligned} P_t &= \mathrm{E}_t[\tilde{M}_{t+1}] \cdot \mathrm{E}_t[\tilde{X}_{t+1}] + cov_t[\tilde{M}_{t+1}, \tilde{X}_{t+1}] \\ &= \frac{\mathrm{E}_t[\tilde{X}_{t+1}]}{R_f} + cov_t[\tilde{M}_{t+1}, \tilde{X}_{t+1}]. \end{aligned} \tag{30}$$

The first term represents the expected payoff discounted at the risk-free rate and the second term is a risk adjustment. Hence, Equation (30) states that it is possible to determine asset-specific risk adjustments by means of a unique SDF. Assets whose payoffs exhibit a negative covariance (correlation) with the random component of the SDF are positively correlated with consumption and thus make it more volatile.[42] Since investors prefer a steady consumption stream over time, they will only hold such assets if their price is lower than in a risk-neutral world. Insurance, in contrast, indemnifies people after they have suffered a shock to their wealth, which causes their consumption to be low and their marginal utility to be high. Its value therefore exceeds the expected payoff discounted at the risk-free rate. In other words, market participants are prepared to buy insurance policies despite the fact that they expect to lose money on

[41] An Euler equation represents the necessary condition for optimality in an intertemporal choice problem.

[42] Recall from (26) that the random part of the SDF equals marginal utility (of $\tilde{C}_{t+1}$), which is high when $\tilde{C}_{t+1}$ is low.

them, because their payoff is negatively correlated with consumption. The same economic idea can be expressed by means of the return representation (28):

$$\begin{aligned} 1 &= \mathrm{E}_t[\tilde{M}_{t+1}] \cdot \mathrm{E}_t[\tilde{R}_{t+1}] + cov_t[\tilde{M}_{t+1}, \tilde{R}_{t+1}] \\ \mathrm{E}_t[\tilde{R}_{t+1}] &= R_f - \frac{cov_t[\tilde{M}_{t+1}, \tilde{R}_{t+1}]}{\mathrm{E}_t[\tilde{M}_{t+1}]}. \end{aligned} \tag{31}$$

According to (31), the expected return of an asset is composed of the risk-free rate and a risk premium. The latter is positive, if the asset's return exhibits a negative covariance with the SDF (marginal utility), i.e., a positive covariance with consumption. This type of asset performs badly in those states of nature where wealth is highly desired by investors. Returns on insurance, in contrast, are negatively correlated with consumption. Due to this hedging property, such contracts may offer expected gross returns below the risk-free rate or even negative expected net returns. Finally, to derive the Euler equation for excess returns, which underlies our empirical analysis, rearrange (28) as follows: $1 = \mathrm{E}_t[\tilde{M}_{t+1}(\tilde{R}_{t+1} - R_f + R_f)] = \mathrm{E}_t[\tilde{M}_{t+1}\tilde{R}^e_{t+1}] + \mathrm{E}_t[\tilde{M}_{t+1}]R_f$, and insert (29).

7.1.2 A Brief Excursus to the Risk-Free Rate Puzzle

Given joint conditional lognormality and homoskedasticity of $\tilde{M}_{t+1}$ and $\tilde{R}_{t+1}$, we may log (28) and drop the time subscript on the variance to obtain the following relationship:

$$\ln(1) = \ln(\mathrm{E}_t[\tilde{M}_{t+1}\tilde{R}_{t+1}])$$

$$0 = \mathrm{E}_t[\ln(\tilde{M}_{t+1}\tilde{R}_{t+1})] + \frac{1}{2}var_t[\ln(\tilde{M}_{t+1}\tilde{R}_{t+1})]$$

$$= \mathrm{E}_t[\ln(\tilde{M}_{t+1}) + \ln(\tilde{R}_{t+1})] + \frac{1}{2}var[\ln(\tilde{M}_{t+1}) + \ln(\tilde{R}_{t+1})]. \tag{32}$$

Defining the log return as $\tilde{r}_{t+1} = \ln(\tilde{R}_{t+1})$ and rearranging yields:

$$\mathrm{E}_t[\tilde{r}_{t+1}] = -\mathrm{E}_t[\tilde{m}_{t+1}] - \frac{1}{2}(\sigma^2[\tilde{m}_{t+1}] + \sigma^2[\tilde{r}_{t+1}] + 2cov[\tilde{m}_{t+1}, \tilde{r}_{t+1}]). \quad (33)$$

Now note that the log risk-free rate is $r_f = -\mathrm{E}_t[\tilde{m}_{t+1}] - \frac{1}{2}\sigma^2[\tilde{m}_{t+1}]$ because both its own variance and its covariance with the log SDF must be zero. This expression can be used to illustrate the risk-free rate puzzle. By inserting the log SDF $\tilde{m}_{t+1} = \ln(\beta) - \eta\Delta\tilde{c}_{t+1}$, we get $r_f = -\ln(\beta) + \eta\mathrm{E}_t[\Delta\tilde{c}_{t+1}] - \frac{1}{2}\eta^2\sigma^2[\Delta\tilde{c}_{t+1}]$. Ignoring the variance term, it is easy to see that a high RRA coefficient η can only be reconciled with low interest rates, if the time discount factor β exceeds one (see Campbell, 2003). Subtracting r_f from (33) and substituting $\sigma[\tilde{r}_{t+1}] = \sigma[\tilde{r}^e_{t+1}]$ as well as $cov[\tilde{m}_{t+1}, \tilde{r}_{t+1}] = cov[\tilde{m}_{t+1}, \tilde{r}^e_{t+1}]$ allows us to switch to log excess returns $\tilde{r}^e_{t+1} = \tilde{r}_{t+1} - r_f$ and obtain

$$\begin{aligned}
\mathrm{E}_t[\tilde{r}^e_{t+1}] + \frac{1}{2}\sigma^2[\tilde{r}^e_{t+1}] &= -cov[\tilde{m}_{t+1}, \tilde{r}^e_{t+1}] \\
&= \rho[\Delta\tilde{c}_{t+1}, \tilde{r}^e_{t+1}] \cdot \sigma[\Delta\tilde{c}_{t+1}] \cdot \sigma[\tilde{r}^e_{t+1}] \cdot \eta \quad (34)
\end{aligned}$$

Country	Period	$\overline{r}^s$	$\sigma[r^s]$	$\overline{r}_f$	$\sigma[r_f]$	$\overline{\Delta c}$	$\sigma[\Delta c]$
AUL	1970.1-1999.1	3.540%	22.699%	2.054%	2.528%	2.099%	2.056%
ITA	1971.2-1998.2	3.168%	27.039%	2.371%	2.847%	2.200%	1.700%
NL	1977.2-1998.4	14.070%	17.228%	3.377%	1.591%	1.841%	2.619%
USA	1947.2-1998.4	8.085%	15.645%	0.891%	1.746%	1.964%	1.073%
GER	1978.4-1997.4	9.838%	20.097%	3.219%	1.152%	1.681%	2.431%

Table 10: Equity Returns, Risk-Free Rates, and Consumption Growth as Employed by Campbell (2003)

This table shows the average annual log return of the equity market (column three) and risk-free asset (column seven) as well as the corresponding standard deviations (columns four and six) for all countries in our sample. In addition, the last two columns contain the average annual log growth rates of per capita consumption and the standard deviations of log consumption growth. The time period for each country has been chosen in line with Campbell (2003). All figures are reported in real terms.

Country	Period	$a\mathrm{E}[\tilde{r}^e_{t+1}]$	$\sigma[\tilde{r}^e_{t+1}]$	$\sigma[\tilde{m}_{t+1}]$	$\sigma[\Delta\tilde{c}_{t+1}]$	$\rho[\Delta\tilde{c}_{t+1}, \tilde{r}^e_{t+1}]$	$\eta(1)$	$\eta(2)$
AUL	1970.1–1998.4	3.885%	22.403%	17.342%	2.059%	+0.1439	58.51	8.42
ITA	1971.2–1998.1	4.687%	27.068%	17.315%	1.665%	–0.0056	< 0	10.40
NL	1977.2–1998.3	11.421%	16.901%	67.576%	2.510%	+0.0317	849.98	26.92
USA	1947.2–1998.3	8.074%	15.272%	52.867%	1.071%	+0.2050	240.67	49.34
GER	1978.4–1997.3	8.669%	20.196%	42.922%	2.447%	+0.0293	599.60	17.54

Table 11: Evidence for the Equity Premium Puzzle as Provided by Campbell (2003)

This table illustrates the equity premium puzzle based on the joint lognormality assumption of Hansen and Singleton (1983). It contains the annual equity market risk premiums (column three), the corresponding excess return standard deviations (column four), and the resulting Hansen-Jagannathan bounds (column five) for all countries in our sample. In addition, it shows the volatilities of consumption growth (column six) and its correlations with excess returns (column seven). The last two columns labeled $\eta(1)$ and $\eta(2)$ display the RRA coefficient estimates for (a) the empirical correlation in column seven and (b) a correlation of one. The time period for each country has been chosen in line with Campbell (2003). All figures are reported in real terms.

Panel A: Insurance Stocks Indices

Index	Period	$a\mathrm{E}[\tilde{r}^e_{t+1}]$	$\sigma[\tilde{r}^e_{t+1}]$	$\sigma[\tilde{m}_{t+1}]$	$\sigma[\Delta\tilde{c}_{t+1}]$	$\rho[\Delta\tilde{c}_{t+1}, \tilde{r}^e_{t+1}]$	$\eta(1)$	$\eta(2)$
S&P 500 Insurance	1990–2012	3.59%	25.82%	13.89%	1.82%	+0.7160	10.65	7.62
Nasdaq Insurance	1972–2012	4.60%	15.89%	28.95%	1.83%	+0.4536	34.91	15.83
Dow Jones P&C	1993-2012	4.61%	20.18%	22.83%	1.59%	+0.2530	56.64	14.33

Panel B: General Stocks Indices

Index	Period	$a\mathrm{E}[\tilde{r}^e_{t+1}]$	$\sigma[\tilde{r}^e_{t+1}]$	$\sigma[\tilde{m}_{t+1}]$	$\sigma[\Delta\tilde{c}_{t+1}]$	$\rho[\Delta\tilde{c}_{t+1}, \tilde{r}^e_{t+1}]$	$\eta(1)$	$\eta(2)$
S&P 500	1990-2012	4.23%	18.74%	22.59%	1.82%	+0.6828	18.16	12.40
Nasdaq	1972-2012	5.72%	26.05%	21.96%	1.83%	+0.5112	23.50	12.01
Dow Jones	1993-2012	4.87%	19.63%	24.82%	1.59%	+0.7036	22.15	15.58

Table 12: Insurance vs. General Stock Returns

This table illustrates the equity premium puzzle for insurance stocks (Panel A) and the general stock market (Panel B) based on the the joint lognormality assumption of Hansen and Singleton (1983). It contains the annual equity risk premiums (column three), the corresponding excess return standard deviations (column four), and the resulting Hansen-Jagannathan bounds (column five) for all indices in our sample. In addition, it shows the volatilities of consumption growth (column six) and its correlations with excess returns (column seven). The last two columns labeled $\eta(1)$ and $\eta(2)$ display the RRA coefficient estimates for (a) the empirical correlation in column seven and (b) a correlation of one. The time period for each index has been determined by the longest available time series. All figures are reported in real terms.

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Part II
The Impact of Time Discretization on Solvency Measurement

Abstract

We aim to study the difference between the one-year probability of ruin in continuous and discrete time via Monte Carlo simulations. The numerical results show that by checking the solvency of an insurance company only once a year, the ruin probability is consistently underestimated by up to 75% of its value observed on an annual basis. We extend the analysis to studying the differences in the expected policyholder deficit (EPD) over a one-year period in discrete and continuous time, which indicate that the observed value of the EPD can be reduced significantly by verifying the available economic capital on a daily basis. Regulators should be aware that when using the discrete time one-year probability of ruin, as done in insurance practice, the true insurer's default risk is often substantially underestimated. [1]

[1]Luca D. and Schmeiser H. (2017). The Impact of Time Discretization on Solvency Measurement. *Journal of Risk Finance*, 18(1):2-20.

1 Introduction

The main objective of ruin theory is to determine the ruin probability, the likelihood that an insurance company faces ruin over a defined period of time. In the light of recent regulatory changes, the probability of ruin is becoming an increasingly important metric for insurance companies. In Europe, Solvency II requires insurance companies to maintain Solvency Capital Requirement (SCR) so that the probability of liabilities exceeding assets during the following year is lower than 0.5%. The traditional approach of risk theory has been to treat the probability of ruin as an exogenous variable provided by regulators. Otherwise stated, the regulators check that the discrete time one-year probability of ruin does not exceed a certain threshold. However, from ruin theory it is well known[2] that both the planning horizon and the frequency with which we check the solvency of an insurance company have an impact on the probability of ruin.

In this paper, we inspect how the time discretization affects the one-year ruin probability. We aim to quantify the difference between the ruin probability measured in (approximately) continuous time and the ruin probability measured in discrete time. We check whether a higher frequency of observation of the probability of ruin implies substantially higher estimates of the ruin probability than annual observations. Therefore, we move from the discrete case one-year horizon, as done, for example, in Solvency II (see, e.g., EC, 2009; EIOPA, 2014) and the Swiss Solvency Test (SST) (see, e.g., FOPI, 2004; FOPI, 2006) to a (approximately) continuous one-year horizon by increasing the frequency of observations. In doing so, we depart from the classical ruin theory developed by Lundberg (1903) and Cramér (1930), which focuses on finding analytical solutions for the probability of ruin. We use Monte Carlo simulations and adopt a market value approach to assets and liabilities, where the assets' process corresponds to a geometric Brownian motion and liabilities' to a jump diffusion process (see, e.g., Doherty and Garven, 1986; Cummins, 1988; Gatzert and Schmeiser, 2008).

[2]For instance, Bühlmann (1996) states that, ceteris paribus, the probability of ruin in continuous time is never lower than the probability of ruin in discrete time.

The overarching goal of insurance regulation, as outlined in Solvency II and SST is to protect the policyholder's claims from default risk of the insurer. Another goal is to ensure the stability of the financial system. In practice, this translates into keeping the probability of ruin (and/or the expected policyholder deficit (EPD)) of an insurance company below a certain threshold. Therefore, the present paper aims to open a discussion about whether considering a discrete one-year horizon probability of ruin is adequate, seeing that the underlying processes driving the assets and liabilities of insurance companies are time continuous. In particular, we know from the classical theory of risk that by looking at the discrete time probability of ruin over a one-year period, the true probability of ruin of an insurer will be underestimated. The purpose of this paper is to provide an indication of how large the underestimation is in practical applications. Since the probability of ruin does not offer full information about the solvency of an insurance company (cf. Butsic, 1994), we also complement our analysis by using the EPD as a risk measure and provide a numerical example of how using a probability of ruin in continuous time implies higher capital requirements for insurance companies. The analysis also looks at the way in which the risk measures observed at daily vs. annual observation frequencies differ when varying the asset/liability ratio of an insurance company, the characteristics of the asset portfolio and the jump process, as well as the correlation between assets and liabilities.

The magnitude of the difference between solvency measures observed at daily vs. annual intervals is of interest because it can change our perspective on the solvency of an insurance company. Our analysis aims to sensitize for the underlying problem related to adopting a one-year discretization interval and can support risk managers and insurance regulators to better estimate the true one-year ruin probability of an insurance company. Based on this, more adequate levels of risk-based capital can be derived, by employing the real one-year ruin probability in the calculation of VaR.

This paper is organized as follows: Section 2 presents background theory underlying this paper. In section 3 we provide an overview of the model and the risk measures used, with the numerical analysis following in section 4. In section 5 one-year capital requirements for the discrete and continuous case probability of ruin are computed. Section 6 concludes.

2 Background

The risk theory literature has shown that both the planning horizon of an insurance company and the frequency with which the solvency of an insurance company is observed have an impact on the probability of ruin. Following Bühlmann (1996), we denote with R the set of states in which ruin of an insurance company occurs, where the first subscript denotes the planning horizon of the insurance company and the second subscript denotes the discretization interval. Hence, four cases for ruin probability can be derived (Bühlmann, 1996):

- A discrete case for a finite planning horizon with the ruin case $R_{T,h}$
- A continuous case for a finite planning horizon with the ruin case $R_{T,0}$
- A discrete case for an infinite planning horizon with the ruin case $R_{\infty,h}$
- A continuous case for an infinite planning horizon with the ruin case $R_{\infty,0}$

where T stands for a finite planning horizon, ∞ stands for the infinite planning horizon, h stands for the discretization of the observations and 0 shows the continuous time case. The following relationships hold (Bühlmann, 1996):

$$R_{T,h} \subset R_{\infty,h} \subset R_{\infty,0}$$
$$R_{T,h} \subset R_{T,0} \subset R_{\infty,0}$$

On the basis of these cases and the relationships between the different subsets, we can order the probabilities of ruin as follows (Bühlmann, 1996):

$$\mathrm{P}[R_{T,h}] \leqslant \mathrm{P}[R_{\infty,h}] \leqslant \mathrm{P}[R_{\infty,0}]$$
$$\mathrm{P}[R_{T,h}] \leqslant \mathrm{P}[R_{T,0}] \leqslant \mathrm{P}[R_{\infty,0}]$$

To see how this theoretical approach relates to the real-world scenario of an insurance company, we analyze the following example in which ruin occurs for an insurance company if its risk-based capital becomes negative.

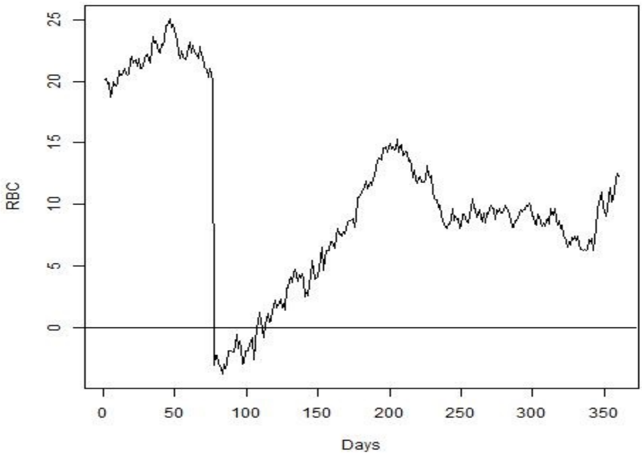

Figure 1: Example of a One-year Development of the Risk-based Capital.

Consider a situation in which the risk-based capital (i.e., the equity capital in market values) of an insurer develops as in Figure 1 over a one-year period (Figure 1 is a realization of the underlying stochastic process). In this case, the risk-based capital becomes negative at t=77 days and stays negative until t=106. Hence, the insurance company becomes over-indebted during this time interval. However, by checking the probability of ruin only at the end of the year (t=360), we would conclude that the insurance company is able to continue its operations. The only way in which we can spot insolvency early on is by checking the solvency more frequently.

3 Model Framework

3.1 Modeling Assets and Liabilities

We start by considering a one-year planning horizon $t \in [0,1]$ for the insurance company. The model framework closely follows Cummins (1988) and Gatzert and Schmeiser (2008), who use the option pricing model developed by Merton (1976) as a starting point. Consistent with this stream of literature, we assume that the asset process follows a geometric Brownian motion, whereas the liabilities follow a jump diffusion process. We define the asset process under the real-world probability measure $\mathbb{P}$ as follows:

$$dA_t = \mu_A A_t dt + \sigma_A A_t dW_{A,t}^{\mathbb{P}} \tag{35}$$

The liabilities are described by the following process:

$$\frac{dL_t}{L_-} = \mu_L L_t dt + \sigma_L L_t dW_{L,t}^{\mathbb{P}} + dJ_t \tag{36}$$

Thereby, μ and σ denote the drift and volatility of the Brownian motions and $L_- = lim_{u \to t} L_u$. μ_A and σ_A of the asset process correspond to different asset portfolios which we develop in the Appendix based on market data. The diffusion parts of the two stochastic processes have the following correlation:

$$dW_A dW_L = \rho dt \tag{37}$$

The independent jump process J can be expressed as

$$J_t = \sum_{j=1}^{N_t} (Y_j - 1) \tag{38}$$

where N_t is a Poisson process with intensity λ and $(Y_j - 1)$ is the size of the jump. The development of the asset and liability processes in time are given by (see, e.g., Bjork, 2009):

$$A_t = A_0 \exp((\mu_A - \frac{1}{2}\sigma_A^2)t + \sigma_A W_{A,t}^{\mathbb{P}}) \tag{39}$$

$$L_t = L_0 \exp((\mu_L - \frac{1}{2}\sigma_L^2)t + \sigma_L W_{L,t}^{\mathbb{P}}) \prod_{j=1}^{N_t} Y_j \tag{40}$$

In this model setup, jumps are idiosyncratic shocks which concern only the liabilities, thus representing a risk which is nonsystematic and diversifiable (see Merton, 1976). In accordance with prior literature (see, e.g., Merton, 1976; Cummins, 1988), we assume an i.i.d. process for Y_j, which follows a lognormal distribution ln(Y_j)$\sim$N(a,b^2). Consistent with existing literature on risk management, the paths of assets and liabilities are generated under real-world probabilities $\mathbb{P}$ (see, e.g., Gatzert and Kling, 2007; Grosen and Jørgensen, 2000).

In accordance with the definition used in the regulatory framework (see, e.g., IAIS (1999)) for a broad overview of international standards, Luder (2005) for an application in the SST framework, and the more recent EIOPA (2014) for Solvency II guidelines), the risk-based capital of an insurance company (RBC) is defined as the difference between the market value of assets and the market value of liabilities:

$$RBC_t = A_t - L_t \tag{41}$$

3.2 Risk Measures

Our model considers a one-year planning horizon and measures the likelihood that the insurer will become over-indebted (i.e., assets lower than liabilities) over the following year. An insurance company is ruined if its assets are not sufficient to cover its liabilities (i.e. the risk-based capital becomes negative). We distinguish between the discrete and continuous cases. The discrete probability of ruin measures the likelihood that the insurance company will face ruin at the end of the next year. Therefore, we can write the discrete case probability of ruin (in accordance with the notation of Bühlmann (1996)) as:

$$\psi_{1,h} = \mathbb{P}(RBC_1 < 0) \tag{42}$$

Because in the case of annual observation of the probability of ruin the distance between discretization steps is equal to one, we only look at the value of the RBC at the end of the first year. As laid out in section 2, the probability of ruin for a one-year planning horizon for the continuous case can be written as:

$$\psi_{1,0} = \mathbb{P}(RBC_t < 0) \;\; for \;\; a \;\; certain \;\; t \in [0,1] \tag{43}$$

where t is a multiple of the discretization step h. As the number of observations throughout the year increases, the distance between subsequent observations decreases to h=1/360 for the daily cases, which we presume to be sufficiently close to zero and therefore consider it in our analysis to be an approximation for the continuous process and denote it by $\psi_{1,0}$.

One of the shortcomings of the ruin probability as a risk measure is that it does not account for the severity of ruin (see, e.g., Butsic, 1994). An alternative risk measure which is commonly referred to in the literature (see Butsic, 1994; Barth, 2000) is the EPD, which measures the extent of loss in case of insolvency and is defined as follows:

$$EPD = E[max(L_t - A_t, 0)] = E[max(-RBC_t, 0)] \tag{44}$$

As a complement to our study regarding the probability of ruin, we analyze how the EPD varies when the discretization step changes. The approach of analyzing the solvency of a company daily allows us to observe the losses incurred by the policyholders and either discontinue the activity of the insurance company or raise additional capital (or use other risk management tools). However, if the solvency is not checked frequently enough, the insurance company can continue its operations and losses can be aggravated further, with the policyholder bearing (on average) higher insolvency costs.

4 Simulation Analysis

We present numerical analyses obtained from Monte Carlo simulations. These are used because closed-form solutions can only be applied to determine the one-period result in discrete time (hence, h=1), whereas simulations allow us to look at intermediate points within the time intervals (0 $\leq h \leq$ 1) for the risk measures in focus. Closed-form solutions for the probability of ruin and EPD for the case in which h=1 are available from the authors upon request. The methodology is as follows: First, we generate 500,000 times the paths of the asset and liability processes using Monte Carlo simulations and compute the RBC[3]. Then we choose our discretization value and check whether the value of the RBC is negative at points corresponding to multiples of the discretization steps. For example, for discretization h=1, we check the solvency of the insurance company at the end of year one. For a discretization of h=1/360, we check the solvency at the end of day 1, day 2, day 3,..., day 360. If at any of these points the RBC has a negative value, the path counts as a ruin. At the end of the process, we count the number of paths in which ruin has occurred and divide the number by the total number of simulations. In order to compute the EPD, we check whether the RBC is negative at points in time which are multiples of the time discretization steps. We only take into consideration and register the value of the deficit at the first point in time where the RBC becomes negative for a certain discretization value for each of the paths. If no negative values are encountered for the RBC, the value of the deficit for that particular path is zero. We proceed to compute the average value of the deficit across the different simulations for the particular discretization.

After the initial base case scenario for the one-year ruin probability, a sensitivity analysis is presented for various parameters. In particular, we are interested in the effects of the asset-to-liability (A/L) ratio, different asset allocations based on market values, the characteristics of the jump process (in particular the intensity of the jump), as well as the correlation between assets

[3]For details on the Monte Carlo simulation approach for financial applications, see e.g. Glasserman (2004).

and liabilities on the probability of ruin at different frequency intervals.[4] Our initial assumption is that a daily discretization is a proxy for the continuous time probability of ruin, whereas the annual discretization is the proxy for the discrete time probability of ruin. Results for intermediate discretizations (semi-annual, quarterly, monthly, weekly) are reported as well. Afterwards, we compute the EPD for a one-year horizon for the same cases as in the sensitivity analysis. Robustness checks by the authors also use 1,000,000 and 5,000,000 simulations, yielding similar results.

4.1 Base Case

The initial values of the liabilities L_0=100 and assets A_0=160 were set to obtain a ruin probability acceptable from a regulator's point of view. The drift and volatility of the assets were set to correspond to a reference portfolio of assets of a property-liability insurer. The asset classes included in the portfolio and their respective weights were chosen in accordance with Braun et al. (2015) and the derivation of the portfolio can be found in the Appendix. Drift and volatility of the assets are set to μ_A=4.5% and σ_A=4.2%. For the liabilities, the drift and volatility are given by μ_L=1.75% and σ_L=5%. As for the jump process, the expected value of the jump size is E(Y)=1.15, and the standard deviation is given by σ_Y=10% (see, e.g., Gatzert and Schmeiser, 2008). Because ln(Y_j)$\sim$N(a,b^2), we get a=0.136 and b=0.087. The intensity of the jump process is λ=0.2, implying a jump every five years. There is a correlation ρ=0.2 between assets and liabilities.

Table 13 presents the ruin probabilities for the base case scenario. Checking the solvency of an insurance company more often increases the probability of ruin. Therefore, by checking the solvency of the insurance company once a year, we obtain a ruin probability of 0.13% compared to 0.14% on a semi-annual basis, providing an approximately 8% increase in the probability of ruin by doubling the frequency of observations. By checking the solvency quarterly, the observed probability of ruin increases by a further 7% to 0.15%, whereas the monthly

[4] We repeat the numerical analyses for the 20 years' horizon, with similar results. The discrepancy between the probabilities of ruin observed at daily and annual intervals remains, although it decreases in relative value, since the long-term ruin probabilities are larger. Results are available upon requests from the authors.

Discretization	Ruin Probability	Std. Error	Lower Bound 95%CI	Upper Bound 95%CI
Annual	0.13%	0.0001	0.12%	0.14%
Semi-annual	0.14%	0.0001	0.13%	0.15%
Quarterly	0.15%	0.0001	0.14%	0.16%
Monthly	0.16%	0.0001	0.15%	0.17%
Weekly	0.17%	0.0001	0.16%	0.18%
Daily	0.18%	0.0001	0.16%	0.19%

Table 13: Ruin Probabilities for the Base Case Scenario.

probability of ruin stands at 0.16%. Last, the probability of ruin generated by checking the solvency daily is 0.18%. Daily vs. annual observation yields an increase in the probability of ruin of 39%. Since the base case probability of ruin is small, the difference appears to be marginal. The second column of Table 13 presents the standard error of the estimates, which stands at 0.0001, providing for stable estimates of the probability of ruin due to the large number of simulations employed. The robustness of the estimates can also be observed in columns 4 and 5, due to the narrowness of the 95% confidence intervals.

4.2 The Impact of the Asset-Liability Ratio

A/L ratio	1.2	1.4	1.6	1.8	2
Annual	5.12%	0.73%	0.13%	0.02%	4.00E-05
Semi-annual	5.69%	0.79%	0.14%	0.03%	4.00E-05
Quarterly	6.12%	0.86%	0.15%	0.03%	4.60E-05
Monthly	6.61%	0.94%	0.16%	0.03%	5.40E-05
Weekly	6.92%	0.99%	0.17%	0.03%	5.80E-05
Daily	7.18%	1.05%	0.18%	0.03%	6.40E-05

Table 14: The Impact of the A/L Ratio on the One-year Ruin Probability.

Table 14 presents the sensitivity of the ruin probabilities to the variation in the A/L ratio. Increasing the amount of assets for a given amount of liabilities reduces the probability that an insurance company will face ruin since the available equity increases. Therefore, in the annual case, the probability of ruin is reduced from 5.12% in the base case with an A/L ratio of 1.2 to 0.004% for an A/L ratio of 2. For daily observations, the probability of ruin decreases from 7.18% to 0.0064%. The differences in ruin probabilities between the annual case and the daily case are larger for those cases in which the A/L ratio is low, as the ruin probabilities are also larger when the company is more leveraged. For example, for an A/L ratio of 1.2, the difference in ruin probability between annual and daily cases is 2.06%, whereas for an A/L ratio of 2, the difference is 0.002%.

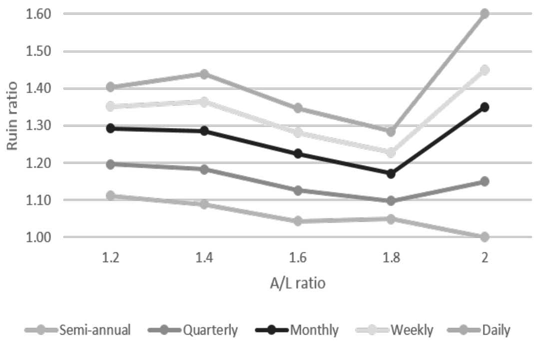

Figure 2: Continuous vs. Discrete Ruin Probabilities Based on Table 14.
This figure shows the ratio between the one-year probability of ruin at the semi-annual, quarterly, monthly, weekly and daily frequency and the annual probability of ruin for different A/L ratios.

Figure 2 shows how the ratio between the more frequent observations of the probability of ruin and the annual observation of probability of ruin develops as a function of the A/L ratio. For example, the line entitled semi-annual presents the evolution of the ratio between semi-annual and annual ruin probabilities at the various A/L ratios. The ratio of the ruin probabilities between annual and daily observations is 1.40 for A/L ratio=1.2, 1.44 for A/L ratio=1.4, 1.35 for A/L ratio=1.6, 1.28 for A/L ratio=1.6, and 1.6 for an A/L=2. These figures indicate that the percentage underestimation of the ruin probability for the annual case with respect to the daily case persists as the A/L ratio increases. However, there seems to be a mixed effect of the increase in the A/L ratio on the difference in probability of ruin between annual and daily cases. Even if a 28% increase in ruin probabilities from 0.0246% to 0.0316% (for A/L ratio=1.8) can be considered almost negligible, a 40% increase in the ruin probability in the case of A/L ratio=1.2 translates into an increase from 5.12% to 7.18%. The inverse relationship between the ratios of continuous vs. discrete ruin probability and the A/L ratio observed between A/L ratios of 1.4 to 1.8 is reversed when the A/L ratio= 2. This is due to the fact that the ruin probabilities for A/L ratio=2 are very small (see Table 14) and hence the difference between the annual and daily observation appears to be large in relative value. Hence, it is important to consider these numbers in both absolute and relative terms to fully understand the effect that the discretization process has on the probability of ruin.

A/L ratio	1.2	1.4	1.6	1.8	2
Annual	0.5496	0.0821	0.0162	0.0035	0.00047
Semi-annual	0.5189	0.0782	0.0152	0.0033	0.00047
Quarterly	0.4981	0.0756	0.0147	0.0031	0.00047
Monthly	0.4731	0.0723	0.0142	0.0029	0.00046
Weekly	0.4508	0.0679	0.0134	0.0027	0.00044
Daily	0.4466	0.0669	0.0132	0.0027	0.00044

Table 15: The Impact of the A/L Ratio on the EPD over a One-year Period.

Table 15 shows that the observed value of the EPD can be reduced by increasing the number of times we check the solvency of an insurance company throughout a year. When we increase the number of observations throughout a year, we can detect a negative RBC earlier in the process. Since the EPD only registers the first negative value of the RBC, if the liabilities further increase throughout the year relative to assets, an earlier detection of the negative RBC translates into a lower EPD. However, if assets were to increase relative to liabilities as time progresses, it could also happen that checking the value of the RBC less frequently leads to a lower value of the EPD. Similar to the ruin probability case, the number of times we check the solvency of the insurance company is more important at lower levels of the A/L ratio, because checking the solvency daily instead of annually can reduce the EPD by 0.1, from 0.54 to 0.44. These results indicate that - both in the case of ruin probability and the EPD - time discretization matters most for those companies that have a lower A/L ratio.

4.3 The Impact of Asset Portfolio

The characteristics of the asset portfolio are expected to have an impact on the probability of ruin of an insurance company because they affect the development of the capital available to the insurance company. This subsection looks at the way in which the mean and standard deviation of the asset portfolio affect the probability of ruin at different time discretizations.

Table 16 presents the ruin probabilities at different frequencies for the different combinations of asset returns and volatilities. The portfolios are ordered according to their risk-return characteristics and, with the exception of the second portfolio which has been derived with weights corresponding to a typical portfolio of a property-liability insurer (see Appendix), they represent efficient portfolios derived according to Markowitz (1952). The first portfolio, with a return of μ_A= 2.20% and a standard deviation σ_A= 0.46%, represents the minimum variance portfolio, corresponding to a portfolio consisting entirely of money market securities. We only look at μ-σ efficient portfolios in the absence of other sources of risk (such as taking into account the liabilities of the insurer). μ-σ efficient portfolios in an ALM context where assets and liabilities are correlated have been studied in the work of Brito (1977), Mayers and Smith (1981) and Turner (1981). The ruin probability for the annual case is very close to that of the base case at 0.15%, further increasing to 0.19% for daily observations, translating into a 30% growth in the probability of ruin. For the second values of the asset portfolio, we draw on a representative portfolio of a property-liability insurer. The probability of ruin in this case also develops in accordance with theory, increasing from 0.13% to 0.18% from an annual to a daily basis. In the third column, we focus on a portfolio with μ_A=4.79% and σ_A=5%, whereas in columns 4 and 5 we consider the asset portfolios with μ_A= 6.55% and σ_A= 10% and the maximum return portfolio with μ_A= 7.74% and σ_A= 10.02%, corresponding to an undiversified portfolio composed exclusively of hedge funds. Overall, we observe a mixed effect of increasing the risk-return profile on the probability of ruin. For the first three portfolios, increasing the risk-return profile translates into a decreasing ruin probability. From the third to the fourth portfolio, the increase in return is offset by an increase in volatility, which translates into a higher probability of ruin. On the other hand, from the fourth to the fifth portfolio, the maximum return portfolio, the return increases significantly, whereas the volatility is increased only slightly, thus reducing the probability of ruin. The discrepancies between probabilities of ruin observed at annual and daily frequencies are substantial for all portfolios, but seem even more pronounced for those portfolios that have a higher volatility of the assets.

Asset Portfolio	μ_A= 2.20% σ_A= 0.46%	μ_A= 4.5% σ_A= 4.2%	μ_A= 4.79% σ_A= 5.00%	μ_A= 6.55% σ_A= 10%	μ_A= 7.74% σ_A= 10.02%
Annual	0.15%	0.13%	0.12%	0.18%	0.16%
Semi-annual	0.15%	0.14%	0.12%	0.20%	0.17%
Quarterly	0.16%	0.15%	0.13%	0.22%	0.19%
Monthly	0.17%	0.16%	0.14%	0.25%	0.22%
Weekly	0.18%	0.17%	0.15%	0.27%	0.24%
Daily	0.19%	0.18%	0.17%	0.30%	0.26%

Table 16: The Impact of the Asset Portfolio on the One-year Ruin Probability.

Therefore, in the case of the last portfolio, the probability of ruin increases by 66.3% in the case of annual vs. daily observations.

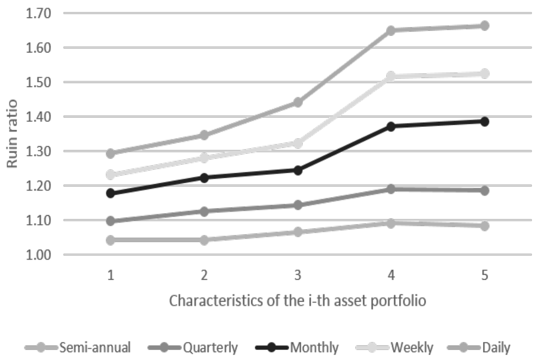

Figure 3: Continuous vs. Discrete Ruin Probabilities Based on Table 16.
This figure shows the ratio between the one-year probability of ruin at the semi-annual, quarterly, monthly, weekly, and daily frequency and the annual probability of ruin for different asset portfolio characteristics.

The ratios among the semi-annual, quarterly, monthly, weekly and daily vs. annual observations are presented in Figure 3. We can observe that the ratios increase as the risk-return profile of the portfolio is increased, suggesting that when the asset return is high enough, the economic capital of an insurance company can become positive again over the long term and hence, by checking for the solvency of the insurance company only once, one can miss bankruptcies that occur throughout the year. Overall, daily discretization provides a probability of ruin that is between 30% and 66% higher than the probability of ruin in the annual case.

The asset allocation also has a mixed effect on the EPD, since it decreases for the first three portfolios, then increases for μ_A= 6.55%, σ_A= 10% and then decreases again for the last portfolio, as represented in Table 17. This is exactly the effect we have seen on the ruin probability and is due to the fact that we have a large jump in volatility between portfolios 3 and 4, whereas portfolio 5 generates a much higher return for almost the same level of volatility as portfolio

Asset Portfolio	μ_A= 2.20% σ_A= 0.46%	μ_A= 4.5% σ_A= 4.2%	μ_A= 4.79% σ_A= 5.00%	μ_A= 6.55% σ_A= 10%	μ_A= 7.74% σ_A= 10.02%
Annual	0.0171	0.0162	0.0133	0.0196	0.0182
Semi-annual	0.0166	0.0152	0.0131	0.0196	0.0179
Quarterly	0.0153	0.0147	0.0128	0.0191	0.0170
Monthly	0.0143	0.0142	0.0126	0.0175	0.0155
Weekly	0.0136	0.0134	0.0117	0.0160	0.0145
Daily	0.0135	0.0132	0.0118	0.0151	0.0135

Table 17: The Impact of the Asset Portfolio on the EPD over a One-year Period.

4.[5] The EPD is most effectively reduced when the risk-return profile of the asset portfolio is high, from 0.0182 to 0.0135 in the case of the last portfolio, as opposed to 0.0171 vs. 0.0135 in the case of the first portfolio.

4.4 The Impact of Jumps

We next analyze how the jumps in liabilities affect the probability of ruin. First, we consider a case with a jump intensity of λ=0.2, corresponding to a jump (on average) every five years, 0.33, corresponding to a jump every three years, 0.5, the equivalent of a jump occurring every second year and, last, λ=1, the equivalent of one yearly jump.

Jump intensity	λ=0.2	λ=0.33	λ=0.5	λ=1
Annual	0.13%	0.35%	0.86%	3.88%
Semi-annual	0.14%	0.37%	0.89%	3.99%
Quarterly	0.15%	0.39%	0.94%	4.16%
Monthly	0.16%	0.42%	1.01%	4.38%
Weekly	0.17%	0.44%	1.04%	4.48%
Daily	0.18%	0.46%	1.09%	4.66%

Table 18: The Impact of the Jumps' Intensity on the One-year Ruin Probability.

An increase in the intensity of the jumps of the liability process translates into higher volatility of the liabilities, therefore negatively affecting the economic capital available to an insurance company. In the absence of a jump in the liabilities process (λ=0), there would be no ruin for the insurance company under the A/L ratio assumed. As we decrease the time interval between jumps (increase λ), the ruin probability increases. As the intensity of the jump interval goes to infinity, the probability of ruin in discrete time converges towards the probability of ruin in continuous time. Starting with λ=0.5, corresponding to a jump in liabilities every two years, the probability of ruin is never below 0.5% - the regulatory threshold under Solvency II.

[5]Recall that portfolios 3 and 4 were constructed so as to maximize return for a given level of volatility.

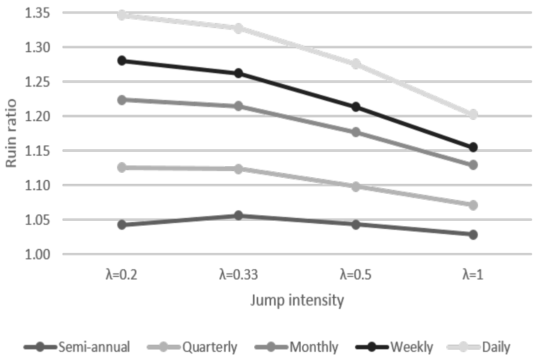

Figure 4: Continuous vs. Discrete Ruin Probabilities Based on Table 18.
This figure shows the ratio between the one-year probability of ruin at the semi-annual, quarterly, monthly, weekly, and daily frequency and the annual probability of ruin for different jump intensities of the liability process.

In Figure 4, we outline the development of the ratios between the probabilities of ruin at different time horizons and the intensity of the jumps. One counterintuitive result derived in the figure is that the intensity of the jump has a higher impact on the probability of ruin at lower jump intervals. Therefore, the ratio decreases from values above 1.35 for the ratio between daily observation of the probability of ruin and annual observation to values as low as 1.2.

Jump intensity	λ=0.2	λ=0.33	λ=0.5	λ=1
Annual	0.0162	0.0496	0.1395	0.8533
Semi-annual	0.0152	0.0472	0.1294	0.7402
Quarterly	0.0147	0.0447	0.1194	0.6428
Monthly	0.0142	0.0426	0.1100	0.5559
Weekly	0.0134	0.0394	0.1008	0.4999
Daily	0.0132	0.0392	0.0989	0.4885

Table 19: The Impact of the Jumps' Intensity on the EPD over a One-year Period.

As the intensity of the jump process increases, the difference between the observed value of the EPD at annual vs. daily intervals is greater. When more jumps in the liability process occur during a particular year, the observed value of the EPD at the end of the year is higher - a daily discretization allows for early detection of ruin and lower EPD values. If solvency is only checked at the end of the one-year period, further jumps in liabilities can occur throughout the year, which increases the observed value of the EPD. The same remarks hold for the size of the jump: as we increase the size of the jump, the discrepancy between the risk measures observed on a daily vs. annual basis increases proportionally.

4.5 The Impact of Correlation

We next analyze the impact of correlation (measured by Pearson's correlation coefficient) on the discrepancy between ruin probabilities observed at different frequencies. Previous literature shows that the choice of dependence measure between assets and liabilities has a significant impact on the risk measures of an insurance company (see, e.g., Eling and Toplek, 2009; Schmeiser et al., 2012). However, since the regulatory framework currently in place in Europe only considers linear dependence between assets and liabilities, we restrict our sensitivity analysis to linear dependence, as measured by correlation. The results indicate that the most desirable outcome is a high positive correlation between assets and liabilities. However, the impact of correlation on the shortfall probability seems to be rather low, as an increase in correlation from -1 to 1 only reduces the probability of ruin from 0.19% to 0.09% in the annual case and from 0.28% to 0.10% in the daily case, as presented in Table 20.

Figure 5 summarizes the development of the ruin probability ratios for different observation intervals as a function of correlation. We present the entire rage of correlation from ρ_{AL}=-1 to ρ_{AL}=1, in steps of 0.1. We can observe that correlation more negatively affects the probability of ruin for low values and the discrepancy between annual and daily observations is larger for negative correlations. We can observe a general trend of decreasing ruin probability when increasing the correlation, with the exception of ρ_{AL}=0. The ratios between daily observations and annual observations of the probability of ruin start at

Correlation	ρ_{AL}=-1	ρ_{AL}=-0.6	ρ_{AL}=-0.2	ρ_{AL}=0	ρ_{AL}=0.2	ρ_{AL}=0.6	ρ_{AL}=1
Annual	0.19%	0.17%	0.15%	0.13%	0.13%	0.10%	0.09%
Semi-annual	0.20%	0.18%	0.16%	0.14%	0.14%	0.11%	0.09%
Quarterly	0.22%	0.19%	0.17%	0.15%	0.15%	0.11%	0.09%
Monthly	0.24%	0.21%	0.19%	0.16%	0.16%	0.12%	0.10%
Weekly	0.26%	0.23%	0.20%	0.17%	0.17%	0.13%	0.10%
Daily	0.28%	0.24%	0.22%	0.18%	0.18%	0.14%	0.10%

Table 20: The Impact of Correlation on the One-year Ruin Probability.

1.5 for ρ=-1 and steadily decreases to 1.1 for the case of ρ=1. In general, also the ratios between discrete and continuous ruin probability decreases as the correlation increases, although there are some points (such as ρ_{AL}=-0.4) where the ratios seem to increase. However, we attribute these small variations to minimal simulation errors, which can impact the exact values of the ratios.

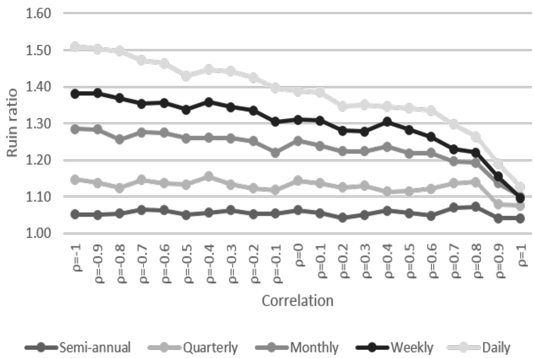

Figure 5: Continuous vs. Discrete Ruin Probabilities Based on Table 20

This figure shows the ratio between the one-year probability of ruin at the semi-annual, quarterly, monthly, weekly, and daily frequency and the annual probability of ruin for different correlations of the diffusion parts of the stochastic processes.

The EPD is reduced the most in the case of a negative correlation of -1, from a value of 0.0231 for annual observation of the probability of ruin to 0.0162 for daily observation. As the correlation between assets and liabilities increases, the discrepancy between the EPD checked daily vs. annually also decreases. As in the case of ruin probability, an exception is encountered at ρ_{AL}=0, which we attribute to the random nature of the relationship between assets and liabilities when correlation is fixed at 0.

5 Capital Requirements

The historical reason behind the study of ruin was to determine the amount of capital necessary to ensure the solvency of an insurance company over a certain horizon (see, e.g., Trufin et al., 2011, p. 175). In this section, we provide

	ρ_{AL}=-1	ρ_{AL}=-0.6	ρ_{AL}=-0.2	ρ_{AL}=0	ρ_{AL}=0.2	ρ_{AL}=0.6	ρ_{AL}=1
Annual	0.0231	0.0197	0.0195	0.0160	0.0162	0.0130	0.0110
Semi-annual	0.0215	0.0188	0.0177	0.0155	0.0152	0.0126	0.0107
Quarterly	0.0203	0.0176	0.0163	0.0150	0.0147	0.0126	0.0106
Monthly	0.0189	0.0164	0.0157	0.0140	0.0142	0.0126	0.0103
Weekly	0.0170	0.0151	0.0000	0.0133	0.0134	0.0123	0.0102
Daily	0.0162	0.0146	0.0000	0.0129	0.0132	0.0123	0.0104

Table 21: The Impact of Correlation on the EPD Over a One-year Period.

a numerical example in which we illustrate how the capital requirements for an insurance company over a one-year horizon change when we consider the one-year probability of ruin in continuous time vs. the one-year probability in discrete time. Our starting point is the capital requirements formula of the Solvency II Directive[6], which is calibrated to correspond to a 99.5% confidence level value at risk (VaR) over a one-year period. In this regulatory framework, both the risk-based capital (RBC) and the solvency capital (SC) of an insurance company are computed. The solvency capital is the amount of capital necessary at the beginning of the period to incur a probability of ruin of α over the next period. Insurance companies are required to hold an amount of capital at t=0 greater than the solvency capital at the end of the period (see, e.g, Gatzert and Schmeiser, 2008; Schmeiser et al., 2012).

$$RBC_0 \geqslant SC_t$$

The solvency capital depends on the underlying stochastic process and the risk measure. To derive the solvency capital, we have to determine the change in the RBC within the one-year period:

$$\Delta RBC = RBC_t e^{-r_f t} - RBC_0$$

where the solvency capital is computed as the α quantile of the change in capital within one year:

$$SC_t = \text{VaR}_\alpha(\Delta RBC)$$

The definition of the VaR is therefore given by: VaR=-$F^{-1}(\alpha)$=inf$\{$x: $\alpha \leq$ F(x)$\}$. In the Solvency II calibration, α corresponds to 0.5%. In our model, we adjust the confidence level to the probabilities of ruin in continuous vs. discrete time. We calibrate our parameters to obtain a discrete time one-year ruin probability close to the threshold set by the regulator. Therefore, we follow the calibration in Gatzert and Schmeiser (2008), with A_0=200, L_0=100, μ_A=0.08, μ_L=0.015 σ_A=0.1, σ_L=0.2, ρ_A=0.2, λ=0.5, a=0.136, b=0.0868, and r_f=2%.

[6] The US NAIC Standards also relies on VaR for setting capital requirements, whereas the Swiss Solvency Test relies on TVaR.

In this case, the one-year ruin probability in the discrete case corresponds to a value of 0.54%, whereas in continuous time it corresponds to 0.94%, leading to an underestimation of the ruin probability by 75%. The corresponding one-year capital requirements are equivalent to 78.8 in discrete and 89.9 in continuous time, meaning that to have an actual one-year ruin probability of 0.5%, an insurance company must provide a substantial amount of additional capital.

6 Conclusion

In this paper, we look at how the probability of ruin and the EPD in continuous time differ from discrete time in order to determine whether these discrepancies are small - case in which they can be neglected in real-world applications - or substantial. Using simulation analysis, we provide evidence that assessing risk measures on a daily (as an approximation of a continuous time setup) or annual basis (as an approximation of a discrete time setup) produces substantial numerical and economic differences. Our results indicate, for instance, that by looking at the probability of ruin on an annual basis (as is done under Solvency II), we consistently underestimate the probability of ruin by values up to 75% (as seen in Section 5) of its annual value.

In order to get a complete picture of the magnitude of the underestimation, both the absolute and the relative difference between the ruin probability observed on an annual vs. daily basis must be considered. Numerical analysis indicates that a smaller annual probability of ruin leads to a larger underestimation as a percentage of the annual ruin probability. If the initial ruin probability in the annual case is small, as in the case of the regulatory framework, we can expect the ruin probability to be almost 75% higher than the annual value when observed on a daily basis. As the annual ruin probabilities become larger, the relative value of the difference decreases, but the difference in ruin probabilities becomes larger in absolute value, as was the case for an A/L ratio=1.2.

On the other hand, the observed values of the EPD can be reduced substantially by choosing a daily discretization step. When we check the value of the RBC more frequently throughout the year, we can detect a negative RBC earlier in the process and thus prevent a further negative development of the

RBC, which would translate into higher losses (EPD) for the policyholder. The results are thus of particular interest to policyholders, since a transition from a discrete to a continuous discretization translates into a reduction of the EPD. In general, the results for the EPD are even more pronounced than for the ruin probability. Since policyholders bare the losses in the case of limited liability insurance companies, the discretization interval seems to be of particular interest for them and therefore for the regulators whose end purpose is to protect the policyholders. The sensitivity analysis is a further important contribution of the paper, since in practice parameter values may differ substantially from those used in the model, which can have major consequences on the value of risk measures (see, e.g., Schmeiser et al., 2012; Wagner, 2014).

Our paper also adds to the literature on model misspecification risk. Schmeiser et al. (2012) find that producing interim reports helps reduce the model misspecification risk for insurance companies. Moreover, the authors show that risk measures react more sensitively than capital requirements when it comes to model misspecification. In our paper, we provide further evidence that increasing the number of interim reports impacts the solvency measures, since by checking the solvency of a property-casualty insurance company once a year, we consistently underestimate the real one-year probability of ruin. Even if current regulation does not explicitly require insurance companies to check their solvency more than once a year, insurers need to hold enough capital to have a certain ruin probability (e.g., 0.5% for Solvency II) over a one year period. The results found from deriving both the ruin probability and the EPD indicate that the choice of discretization interval has an impact on the risk assessment using these measures. We complement our analysis with the capital requirements and conclude that a more frequent discretization translates into higher capital requirements for the insurance company. This is of particular interest to regulators, rating agencies and the management of insurance companies. However, one must recognize that the practical shortcomings (e.g., transaction costs) associated with more frequent monitoring of the risk measures might outweigh the benefits of a more exact numerical result. Therefore, our recommendation for risk managers is to complement the capital requirements in solvency regulation with sensitivity analyses of the risk measures presented with respect to time discretization. On the one hand, it seems to us that there is value in knowing about the substantial discrepancy between the focused time discrete ruin probability and EPD compared to the continuous version. On the other hand, and if there are no substantial transaction costs associated with more frequent monitoring of solvency figures, a more frequent update would be helpful to increase the accuracy of the calculations and reduce the EPD. However, the authors of this paper recognize that a daily update of the solvency figures - while desirable - might not be realistic for insurers in practice, due to the complexity of the model and the time-consuming calculations associated with such a process.

Appendix

We assume the portfolio of a property-casualty insurance company to have the following composition: 15% shares, 51% government bonds, 8% corporate bonds, 8% real estate, 3% hedge funds and 15% money market instruments. This is the structure of a typical asset portfolio of an insurance company active in the German market, as derived by Braun et al. (2015). The return on the portfolio of assets, r_A therefore represents the weighted average returns on the individual asset classes, $r_A = \sum_{i=1}^{n} r_i w_i$, where r_i represents the return on the individual asset classes, n is the number of asset classes included in the portfolio and w_i represents the weight of the individual asset classes in the portfolio. We assume that the returns on the individual asset classes are normally distributed with $r_i \sim N(\mu_i, \sigma_i)$ and therefore expect $r_A \sim N(\mu_A, \sigma_A)$. We can write the first and second moments of the portfolio of assets in matrix form as follows:

$$\mu_A = \mathrm{E}[r_A] = \mathbf{w}^\top \mathrm{M} \tag{45}$$

$$\sigma_A^2 = \mathbf{w}^\top \sum \mathbf{w} \tag{46}$$

where **w** represents the vector of weights and M is the vector of mean returns of the individual asset classes, whereas $\sum$ is the variance-covariance matrix of returns. The descriptive statistics of the individual asset classes are presented in the Table 6.

The portfolio constructed using the aforementioned asset classes and the respective weights - as seen in the portfolios of German P& L insurers - has a return μ_A=4.5% and a standard deviation σ_A=4.2%, using market data for the corresponding indices for the period 01.01.1994-31.12.2014. The reference portfolio used for the base case is therefore constructed to correspond to a typical P&L insurer active in the German market, whereas the other portfolios are efficient. For the sensitivity analysis, we depart from the typical weights as encountered in the portfolio composition of a German P &L insurer and construct optimized portfolios using Markowitz (1952). For the analysis we therefore select in addition to the base portfolio (μ_A=4.5%, σ_A=4.2%) the minimum risk portfolio (μ_A=2.20%, σ_A=0.48%), maximum return portfolio

Asset Class	Index	μ_i	σ_i	w_i
Stocks	S&P 500	3.43%	15.25%	0.15
Sovereign Bonds	S&P Eurozone Sovereign Bond	5.02%	3.26%	0.51
Corporate Bonds	Barclays US Corporate High Yield	7.74%	10.02%	0.08
Real Estate	MSCI Europe Real Estate	3.93%	18.58%	0.08
Hedge Funds	Hedge Funds Weighted Return	5.83%	6.39%	0.03
Money Market	FIBOR 1month	2.20%	0.46%	0.15

Table 22: Descriptive Statistics of the Asset Classes (01.01.1994-31.12.2014)

This table illustrates the mean (μ_i) and the standard deviation (σ_i) of the asset classes included in the portfolio of a property-casualty insurance company. All figures are reported on an annual basis. The weights of the asset classes in the portfolio (w_i) are those derived in Braun et al. (2015) for the portfolio of a property-casualty insurance company.

	Stocks	Sovereign Bonds	Corporate Bonds	Real Estate	Hedge Funds	Money Market
Stocks	1	-0.2041	0.6428	0.6210	0.7609	-0.2692
Sovereign Bonds		1	-0.0827	0.0190	-0.1789	-0.0008
Corporate Bonds			1	0.5642	0.6916	-0.2433
Real Estate				1	0.5147	-0.2370
Hedge Funds					1	-0.1608
Money Market						1

Table 23: Correlation Matrix for the Selected Asset Classes.
Historical daily returns of all indices were extracted for the period from January 1994 through December 2014.

(μ_A=7.74%, σ_A=10.02%), as well as two portfolios yielding the maximum return for set levels of volatility of 5% (μ_A=4.79%, σ_A=5%) and 10% (μ_A=6.55%, σ_A=10%).

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Part III
Do Consumers Want Investment Guarantees?

Abstract

Drawing on data from a survey among financial decision makers in Germany, we elicit customer preferences for investment guarantees through a choice-based conjoint analysis. In contrast with previous studies which focus on eliciting willingness-to-pay for investment guarantees directly via questionnaires, our methodology is more appropriate for revealing preferences for products whose purchase involve complex cognitive decisions and an infrequent purchase pattern. We start by deriving part-worth utility profiles of customers for different product attributes and continue with simulating shares of preferences in a real market scenario. We then split the sample with the help of eight sociodemographic and psychographic moderators. Thereby, different customer segments are derived for which insurance companies can optimize product designs in order to maximize customers' utility.[1]

[1]Luca D., Schmeiser H. and Schreiber F. (2018). Do Consumers Want Investment Guarantees?. *I.VW-HSG Working Papers on Risk Management and Insurance*

1 Introduction

Investment guarantees are widespread features in many financial products (Lachance and Mitchell, 2003; Mitchell and Smetters, 2003; Antolín et al., 2011; Gale et al., 2016). Well-known examples, among others, include mutual funds (Gatzert and Schmeiser, 2009) and defined contribution schemes such as German Riester pensions (Lachance and Mitchell, 2003) or IRA accounts (Gale et al., 2016). Similarly, they are also found in many participating (Cummins et al., 2007) and unit-linked life insurance contracts (Finkelstein et al., 2003). While the specific guarantee type and level differ by country and product, their common characteristic is the provision of a minimum rate of return on an investment.[2] In recent years, however, minimum interest rate guarantees came under significant pressure (Holsboer, 2000; Kablau and Wedow, 2012; Hartley et al., 2016) due to the global low interest rate environment. Moreover, in the European Union member states, this situation has been exacerbated by the consecutive introduction of Solvency II which further challenges the solvency and profitability of the companies providing such guarantees.

From the perspective of consumers, guarantees are vital for ensuring a minimum level of old-age provision, but their associated costs might negatively impair an individual's available pension capital (Finkelstein et al., 2003; Gale et al., 2016). Nevertheless, in case of the European unit-linked market, the latest figures of EIOPA (2017) underline that consumer demand is still growing. Interestingly, the large popularity of products with an investment guarantee can neither be explained by expected utility theory (Døskeland and Nordahl, 2008), prospect theory (Dierkes et al., 2010; Dichtl and Drobetz, 2011), nor - in many cases - by multi cumulative prospect theory (Ruß and Schelling, 2017; Braun et al., 2017).

Apart from those theory-based approaches, however, a thorough investigation of consumer preferences for investment guarantees in financial products has not been conducted to date. Our research is intended to fill this gap by providing a behavioral perspective through discrete choice experiments. More

[2] A cross-country comparison of investment guarantees can be found in Miltersen and Persson (2003), Cummins et al. (2007), and Gale et al. (2016).

specifically, we draw on choice-based conjoint analysis (CBC), a powerful preference elicitation method grounded in random utility theory (RUT). The latent class (LC) model underlying this approach allows us to estimate segment-level part-worth utility profiles from choice data that has been collected through an online questionnaire among 1,017 German financial decision makers. Based on the obtained results, we inspect which investment guarantee features are associated with a positive marginal utility and therefore most important for the different consumer groups. In the next step, we then construct a realistic market environment with three fully-fledged investment guarantees and determine demand as well as market expansion effects. Finally, we test whether individual group membership can be explained by central socioeconomic and psychographic characteristics.

2 Survey Data and Methodology

2.1 Choice-based Conjoint Analysis

Investment guarantees are typically valuated by means of option pricing theory (Boyle and Schwartz, 1977; Hansen and Miltersen, 2002; Finkelstein et al., 2003; Sinha and Renteria, 2005; Cummins et al., 2007; Eling and Holder, 2013). Gatzert et al. (2011), in contrast, aim to provide a behavioral perspective by asking consumers to directly state their WTP for this type of product feature. Such direct stated preference approaches, however, are associated with a number of drawbacks (Voelckner, 2006; Miller et al., 2011) and thus, less suitable for insurance policies. One promising alternative is choice-based conjoint (CBC) analysis, a powerful indirect stated preference elicitation approach (Johnson, 1974; Gustafsson et al., 2007). Its major advantage is that it comes closest to a real-life purchase situation since respondents are required to trade-off different product alternatives against each other within repeated choice tasks (Huber, 1997). Particularly for infrequently purchased and rather abstract products such as insurance policies, CBC is considered superior to other methodologies for eliciting consumer WTP (Orme, 2002; Breidert et al., 2006).[3] So far, most

[3]Technical details on random utility theory (RUT), which forms the theoretical basis of CBC, can be found in McFadden (1974) and Train (2009), respectively.

conjoint studies in insurance focus on health insurance (Chakraborty et al., 1994; Telser and Zweifel, 2002; Kerssens and Groenewegen, 2005; van den Berg et al., 2008), value-added services in insurance (von Watzdorf and Skorna, 2010), and crop insurance (Sherrick et al., 2003). The recent study of Braun et al. (2016) employs CBC to determine consumer preferences and WTP for term life insurance contracts, while Dominique-Ferreira (2017) demonstrates that price is the most important product attribute in non-life insurance purchases.

2.2 CBC Product Attributes and Levels

Generally, there are no defined guidelines for determining appropriate product attributes and their corresponding levels in CBC analysis. We included the five attributes that are needed to derive the guarantee price by means of OPT: (1) guarantee period, (2) investment premium, (3) guarantee level, (4) underlying fund, and (5) price of the guarantee. As suggested in the extant literature (Orme, 2002), we took into account criteria regarding the number, independence, and mutual exclusivity of attributes and levels during our selection process. Similarly, in order to avoid the so-called range and number-of-levels effects (Verlegh et al., 2002), all attributes have between three to five levels. Table 24 shows all attributes and their corresponding levels.

In line with the long-term contract terms of investment products, the guarantee period is either 10, 20, 30, or 40 years. The customer can further choose between three different investment premiums, i.e. EUR 10,000, EUR 30,000, or EUR 50,000 to be paid upfront at contract inception.[4] Regarding the guarantee level, we allow for a range between 0 percent and 0.9 percent. The former represents a money-back guarantee, while the latter is the current maximum technical interest rate for participating life insurance contracts in Germany. Additionally, two intermediate guarantee levels of 0.3 percent and 0.6 percent are offered.The profiles that determine the riskiness of the underlying were chosen to correspond to current investment funds observable on the market and categorized as low, medium, or high-risk fund. In order to obtain these, we have relied on marketing materials of investment funds available on the market.The annualized average

[4]This part strictly refers to the savings component of the contract and only holds under the assumption that no early surrender such as death or early payout occurs.

No.	Attribute	Levels	Further remarks
1	Guarantee period	10 / 20 / 30 / 40 years	
2	Investment premium	EUR 10,000	*to be paid upfront*
		EUR 30,000	
		EUR 50,000	
3	Guarantee level	0 percent p.a.	*money-back guarantee*
		0.3 percent p.a.	
		0.6 percent p.a.	
		0.9 percent p.a.	*maximum guarantee level for Cliquet-style participating life insurance in Germany*
4	Underlying fund	Low-risk fund	*100 percent domestic and foreign bonds*
		Medium-risk fund	*45 percent bonds, 55 percent equities*
		High-risk fund	*100 percent equities*
5	Guarantee price	40 percent	*in percent of the OPT price*
		70 percent	
		100 percent	
		130 percent	
		160 percent	

Table 24: CBC Product Attributes and Levels

returns and standard deviations were computed as average results of the latest five-years available. More specifically, the annualized average returns (μ) and return standard deviations (σ) equal μ=1.44 percent and σ=2.42 percent for the low-risk fund, μ=4.47 percent and σ=5.41 percent for the medium-risk fund, as well as μ=7.67 percent and σ=12.18 percent for the high-risk fund. Finally, the attribute guarantee price exhibits five different levels quoted in percent of the OPT price.[5] The OPT price was computed with the Black-Scholes formula, and is the price that the investor needs to pay in addition to the upfront premium in order to obtain a guaranteed return at the end of the investment period.[6] The low range prices are represented by discounts of 60 percent and 30 percent from the reservation price. Similarly, the higher price levels correspond to markups of 30 percent and 60 percent to the guarantee price. In a real market environment, the 100 percent OPT price represents the minimum level that a provider must charge in order to provide the guarantee, without taking into account further loadings due to transaction costs or model and parameter risk. Offering a price range from 40 percent to 160 percent, however, allows us to capture WTP figures below the reservation price as well (Miller et al., 2011).

2.3 Sample Selection and Survey Design

Our sample comprises 1,017 German consumers who identified themselves as responsible financial decision makers in their households (Hofstetter et al., 2013).[7] Participants were aged between 20 and 54 years old and representative of the German population with respect to gender and domicile state. The web-based questionnaire was distributed by a market research firm in order to maximize response rates and minimize the amount of missing data. For their participation, respondents received a financial reimbursement.

The questionnaire underwent a series of pretests before its three-week field phase. In order to ensure that all respondents had an understanding of how an investment guarantee works, the survey started with an explanation of its

[5] Note that the reference price of a guarantee (100 percent) depends on its exact product composition, i.e. the selected levels of attributes (1) to (4).

[6] More detailed information on the OPT framework for pricing investment guarantees can be found, among others, in Lachance and Mitchell (2003) or Gatzert et al. (2011).

[7] Financial decision makers are either fully responsible for making financial decisions or are at least involved in doing so.

general mechanics in the context of unit-linked life insurance. We then introduced the five product attributes and their corresponding levels (Table 24). The introductory part was completed by a mini simulator, in which respondents could familiarize themselves with the guarantee concept. More specifically, the simulator allowed to combine the most preferred attribute levels and highlighted the impact on the OPT price.

During the subsequent discrete choice experiment, respondents had to complete a total of 12 choice tasks, each of which comprised three fully-fledged investment guarantees and a no-choice option, i.e. the possibility for not selecting any guarantee.[8] Out of these, nine were random choice tasks and three were so-called holdout tasks.[9] In the nine random choice tasks, the attribute order was held constant and the three guarantee profiles were generated by the balanced overlap method. This randomized experimental design ensured orthogonality, level balance, as well as minimal overlap between levels (Sawtooth Software, 2013). In the three holdout choice tasks at positions four, eight and twelve, all respondents were confronted with identical product profiles. Their purpose was to test the consistency of responses across the survey and further provided us with face validity for the in-sample conjoint analysis. More specifically, we first computed the part-worth utility profiles from the responses to the random choice tasks. Afterwards, those profiles are used to predict the choices to the holdout tasks within a conjoint market simulator (Orme, 2014).[10] Finally, the third part of the survey contained further questions regarding central socioeconomic information as well as general behavioral characteristics such as investment risk attitudes of the respondents.

2.4 Estimation of Aggregate-level Part-worth Utility Profiles

We estimated aggregate-level part-worth utility profiles from the observed choices by means of latent class analysis (LC) implemented in Sawtooth Light-

[8] Please note that we did not show the guaranteed amount at contract maturity since it might induce unintended framing or anchoring effects (Tversky and Kahneman, 1981).

[9] Throughout all choice tasks, respondents could at any time access information regarding the product attributes and levels.

[10] The number of holdout tasks was chosen in accordance with the results of Chrzan (2015). The first two holdout tasks were generated by the balanced overlap method, while in the third task minimal overlap was employed.

house Studio V8 (Sawtooth Software, 2004,0). Let i denote the number of respondents, j the different conjoint profiles with k attributes each, n the individual choice task, and M_n the three alternatives shown in choice task n. Moreover, X_{jk} denotes the k-th dummy variable for the j-th conjoint profile, s the number of market segments, and β_{ks} the part-worth utility for the k-th attribute of market segment s (Desarbo et al., 1995). Following Desarbo et al. (1995), we assume that s latent market segments with identical part-worth profiles exist. Their relative sizes are denoted via the S segment parameters α_s with $0 \leq \alpha_s \leq 1$ and $\sum_{r=1}^{S} \alpha_r$, i.e. all respondents are allocated to a market segment. The choice probability of individual i can now be expressed as the choice probability of these S segments (Kamakura and Russell, 1989). Thus, for segment s, we obtain:

$$\mathrm{Prob}_s(j \in M_n) = \frac{\exp\left(\beta_{0js} + \sum_{k=1}^{K} X_{jk}\beta_{ks}\right)}{\sum_{a \in M_n} \exp\left(\beta_{0as} + \sum_{k=1}^{K} X_{ak}\beta_{ks}\right)}, \tag{47}$$

with β_{0js} being the intrinsic part-worth utility of product profile j to segment s and β_{ks} the impact coefficient for attribute k in segment s (Desarbo et al., 1995).[11] While the CBC parameters are known, the segment compositions are latent and unknown. Therefore, the latter need to be estimated from the observed CBC data. More specifically, the unconditional choice probability that conjoint profile j is chosen among M_n is given by (Desarbo et al., 1995):

$$\mathrm{Prob}(j \in M_n) = \sum_{s=1}^{S} \alpha_s \mathrm{Prob}_s(j \in M_n). \tag{48}$$

In Equation (48), α_s denotes the size of segment s and might be interpreted as the a priori probability of a respondent being part of segment s. With a total of

[11] We imposed a monotonicity utility constraint for estimating the part-worth profiles of the attribute guarantee price, which ensured that higher prices have larger negative utility values. As pointed out by Sawtooth Software (2004), such constraints are helpful to obtain more meaningful and interpretable within-segment preferences.

I respondents in our sample, the likelihood (LL) of the observed CBC data is determined as (Desarbo et al., 1995):

$$\mathrm{LL} = \prod_{i=1}^{I} \sum_{s=1}^{S} \alpha_s \prod_{n=1}^{N} \prod_{j \in M_n} \left[\frac{\exp\left(\beta_{0js} + \sum_{k=1}^{K} X_{jk}\beta_{ks}\right)}{\sum_{a \in M_n} \exp\left(\beta_{0as} + \sum_{k=1}^{K} X_{ak}\beta_{ks}\right)} \right]^{Y_{ijn}}, \tag{49}$$

The dummy variable Y_{ijn} captures the choice of individual i in choice task n, i.e. $Y_{ijn} = 1$ if respondent i decides in favor of j in n among all alternatives M_n, or $Y_{ijn} = 0$ otherwise. The LC estimation now strives to maximize Equation (49) of the observed CBC data subject to $\mathbf{B} = (\beta_{0js}, \beta_{ks})$, the S proportions $\mathbf{A} = (\alpha_s)$, and the constraint $\sum_{r=1}^{S} \alpha_r = 1$ (Wedel and Desarbo, 1994).

Finally, by using Bayes rule, the posterior probability of respondent i's segment membership ($\tilde{R}_{is}$) is computed by (Desarbo et al., 1995):

$$\tilde{R}_{is} = \frac{\tilde{\alpha}_s \prod_{n=1}^{N} \prod_{j \in M_n} \left[\tilde{P}_s(j)\right]^{Y_{ijn}}}{\sum_{s=1}^{S} \tilde{\alpha}_s \prod_{n=1}^{N} \prod_{j \in M_n} \left[\tilde{P}_s(j)\right]^{Y_{ijn}}}, \tag{50}$$

with $\tilde{P}_s(j)$ being the estimated choice probability of profile j conditional on segment s (Equation 47). The approach shown by Equation (50) allows for fractional membership of respondents. More specifically, depending on their individual preference structures, respondents can be part of multiple segments at the same time. However, since we are interested in discrete market segments, each individual i is assigned to the segment whose value of $\tilde{R}_{is}$ is highest (Desarbo et al., 1995; Sawtooth Software, 2004). Compared to other two-stage approaches, such as estimating individual-level part-worth utilities by Hierarchical Bayes (HB) and running a cluster analysis afterwards, the LC procedure is associated with several benefits. For instance, the discrete assumption of heterogeneity allows for a more accurate modeling of individuals than HB, if segments are quite compact and different with respect to their preference profiles (Sawtooth Software, 2004).

Generally, the number of market segments is unknown a priori. We therefore estimated the model for a varying number of segments and determine the final solution based on selected goodness-of-fit statistics. First, we draw on the consistent Akaike information criterion (CAIC) proposed by Bozdogan (1987), which is determined as:

$$\mathrm{CAIC} = -2 \log \mathrm{LL}(ps + s - 1) \cdot (ln\ N + 1), \tag{51}$$

where p is the number of independent parameters estimated per segment, s the number of segments, and N the total number of choice tasks. A smaller value of CAIC is preferable. Second, we report the so-called percent certainty (Hauser, 1978) that indicates how much better the respective solution is than the one-group (null) solution:

$$\mathrm{PC} = \frac{\log \mathrm{LL}_y - \log \mathrm{LL}_0}{\log \mathrm{LL}_0}, \tag{52}$$

with LL_y being the likelihood of the final iteration of solution y and LL_0 the likelihood before the first iteration (Sawtooth Software (2004)). Finally, we also calculate the Chi Square and relative Chi Square. For solution y, the former is obtained as:

$$\mathrm{Chi\ Square}_y = 2\,(\log \mathrm{LL}_y - \log \mathrm{LL}_0). \tag{53}$$

The relative Chi Square, on the other hand, is calculated by dividing the solution from Equation (53) by the number of parameters estimated, i.e. $ps + s - 1$ (Sawtooth Software, 2004). However, all these measures need to be interpreted with caution. More specifically, both PC and $\mathrm{Chi\ Square}$ increase as more segments are included. The CAIC, on the other hand, is useful for comparing alternative solutions with a different number of groups, but not for assessing a solution's absolute level of fit (Sawtooth Software, 2004).

2.5 Relative Attribute Importance and Shares of Preference

For estimating parameter values in CBC analysis, effects coding of the product attributes has proven itself as standard procedure since the early 1990s (Sawtooth Software, 2017). To avoid linear dependency, this procedure omits the last level of every attribute and estimates it as the negative sum of the remaining levels (Sawtooth Software, 2004). Thus, the sum of part-worth utilities within each attribute is zero. As pointed out by Orme (2010), the resulting CBC part-worth utilities are interval data. This, in turn, implies that adding any arbitrary constant to the part-worth utilities for all levels would not affect the predicted choice probabilities. Moreover, interval data does neither allow for inter-attribute comparisons nor the forming of ratios.

Nevertheless, in order to turn the part-worth utilities into economic interpretable information and facilitate inter-attribute comparison, some metrics can be derived. The relative attribute importance (RAI) denotes the difference each attribute makes to the total utility of a product in percentage terms (Orme, 2010). It is defined as:

$$\mathrm{RAI}_{ks} = \frac{\max\limits_{l}(\beta_{kls}) - \min\limits_{l}(\beta_{kls})}{\sum_{k=1}^{K}\left(\max\limits_{l}(\beta_{kls}) - \min\limits_{l}(\beta_{kls})\right)}, \tag{54}$$

where $\mathrm{k} \in \{1, 2, 3, 4, 5\}$ denotes our product attributes with the following levels $\mathrm{l} \in \{1, 2, ..., \mathrm{L_k}\}$ (Table 24). In contrast to part-worth utilities, the RAI_{ks} follow a ratio scale and add up to 100 percent. Therefore, they allow for making inter-attribute comparisons: a higher attribute range translates into a higher potential to positively or negatively affect a segment's choice probability for a product.[12]

Finally, we construct a hypothetical market environment and run several different scenarios to transform our part-worth utility profiles into so-called shares of preference (SOP). The SOP are most intuitive for interpreting the results of CBC analysis since they are scaled from zero to one hundred, follow a ratio scale, and indicate whether respondents decide in favor of a product or not (Orme, 2010).[13] Moreover, they are well suited for analyzing product switching and market expansion effects (Orme, 2010). In this hypothetical

[12] Generally, as is apparent from Equation (54), the RAI_{ks} are based on the extreme level values of an attribute. Consequently, due to statistical noise, attributes with little to no importance might be biased upwards (Orme, 2010).

[13] With ratio data, a SOP of 50 percent is indeed twice as much as a SOP of 25 percent. Compared to real-world market shares, however, SOP do not take into account external effects from advertising, sales force marketing, etc. so that these two concepts should not be confounded.

market setting, we draw on the randomized first choice method (RFC) to predict segment-level demand for investment guarantees. Compared to the standard first choice method (maximum utility rule), which is most common in simulation analyses, RFC allows for adding error terms both at the attribute and product level. Mathematically, the utility U_j for product j is therefore determined as (Huber et al., 1999):

$$U_j = X_j\left(\beta + \mathrm{Err}_{attr}\right) + \mathrm{Err}_j \tag{55}$$

with X_j being the row of design matrix for product j and β the vector of part-worth profiles. Furthermore, Err_{attr} denotes the part-worth error term identical for all products, while Err_j is the unique product error term (Gumbel-distributed).[14] Generally, in hypothetical market setting MS, product j is chosen, if its randomized utility U_j is greatest in MS. The corresponding probability $Pr_{j|MS}$ therefore equals (Huber et al., 1999):

$$\mathrm{Pr}_{j|MS} = \mathrm{Pr}\left(U_j \geq U_m \quad \forall m \sum MS\right). \tag{56}$$

Equation (56) is estimated by drawing the product utility from Equation (55) and enumerating the probabilities (Huber et al., 1999). In order to stabilize the SOP, this procedure is simulated several times.[15] The main advantage of RFC compared to other choice methods is that it satisfies three critical properties in choice modeling, i.e. differential impact, differential substitution, and differential enhancement (Huber et al., 1999). More specifically, differential impact relates to the fact that attribute level changes are most promising if the product is near the purchase threshold, i.e. primarily affects those segments that are likely to change their behavior. Differential substitution, on the other hand, reflects the property that a new product should take market shares disproportionately from similar compared to dissimilar products. It is therefore critical to minimize undesired cannibalization effects. Finally, differential enhancement requires that small value differences have a higher impact on highly similar alternatives and almost none impact on dissimilar product offerings. The underlying idea

[14]Note that the product error term Err_j corresponds to the error level in the logit model (Huber et al., 1999), while the part-worth error term Err_{attr} reflects taste variation in product choices (Hausman and Wise, 1978; Revelt and Train, 1998).

[15]As suggested by Orme (2005), we ran a total of 200,000 sample iterations.

is that consumers find it easier to compare similar than dissimilar alternatives (Huber et al., 1999).

3 Empirical Results

3.1 Latent Class Segments

From the survey participants, we removed those with answer times below five minutes and those that gave repeatedly identical answers to all Likert statements on specific consumer attitudes such as investment behavior, individual risk-taking behavior, etc. Moreover, since we were only interested in financial decision makers, all respondents with low involvement in the financial literacy questions, i.e. who consistently chose "I don't know", have been excluded from our analysis as well. After the elimination was complete, our final sample comprised 1,017 consumers. Respondents needed an average of 31.9 minutes to complete the survey, which includes their familiarization with all mechanics of an investment guarantee through the explanations, minimal working examples, and the mini simulator. Regarding the CBC experiment, the average time was 47.8 seconds per choice task.

Table 25 shows all goodness-of-fit statistics for the two- to five-group solutions of the LC analysis.[16] For each solution, we ran several replications with varying starting seeds in order to avoid problems associated with local maxima. To select the optimal number of segments, we look for inflection points at which the statistics do no longer change significantly rather than their absolute values (Sawtooth Software, 2004). Moreover, we also take into account the replicability of the solution, as well as its managerial interpretability (Desarbo et al., 1995). In light of these criteria, the four-group solution turns out to be the optimal choice.[17] More specifically, the percent certainty (PC) and Chi Square (CS) both increase with the number of segments (Sawtooth Software, 2004), but not significantly from four toward five groups. Similarly, the consistent Akaike information criterion (CAIC) and relative Chi Square ($\mathrm{CS_{rel}}$) are not significantly

[16] The reported values are taken from the replication with the highest Chi Square.

[17] The log-likelihood (LL) of the four-group solution is –14,560 compared to –20,576 for the null solution.

lower for the five-segment solution, but much higher for three groups. Finally, with an associated average maximum membership probability of 94.1 percent, the four-group solution further indicates that it fits our data well.

Solution	CAIC	PC	CS	CS_{rel}
2 groups	30,983.07	25.52	10,500.21	338.72
3 groups	30,353.97	27.46	11,300.27	240.43
4 groups	29,793.2	29.24	12,031.99	190.98
5 groups	29,455.85	30.47	12,540.29	158.7

Table 25: Goodness-of-fit Statistics for the LC Analysis

This table shows the consistent Akaike information criterion (CAIC), the percent certainty (PC), the Chi Square (CS), and the relative Chi Square (CS_{rel}) for the two- to five group solutions of the LC analysis.

3.2 Latent Class Part-worth Utilities

In the selected four-group solution, segments 1 and 2 account for approximately 23 percent of our sample, while group 3 is smallest with a share of 18.2 percent (Table 26). The remaining 363 respondents (35.7 percent), in turn, are allocated to the fourth segment. Table 26 further shows the estimated segment utility for the none option, i.e. the utility respondents derive from not choosing a product at all.[18] The negative none utility value of –595.5 of segment 1 indicates that those respondents are interested in almost any form of investment guarantee. Groups 2 to 4, on the other hand, exhibit positive none utilities, which suggest that only carefully composed products are likely to be chosen. However, the high none utility value of 1,173.3 observed in segment 2 underlines that an investment guarantee is not preferred at all.

Figure 6(a) shows the average segment-level utility profiles for the guarantee period. It is evident that all groups clearly prefer shorter over longer terms with 10 years being their first choice. For segments 1, 2, and 4, maturities of more than 30 years are associated with negative utility values. A similar result is observed for the investment premium (Figure 6b). More specifically, utility is decreasing in the premium level for all groups. However, as is apparent,

[18]Note that respondents choose a product if its total utility exceeds the none utility.

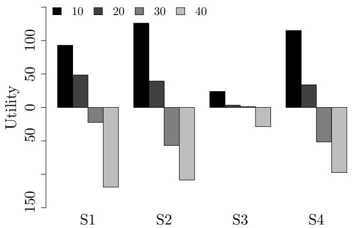
	S1	S2	S3	S4
Members (persons)	236	233	185	363
Share (percent)	23.2	22.9	18.2	35.7
None utility	–595.5	1,173.3	375.3	257.6

Table 26: Segment Characteristics

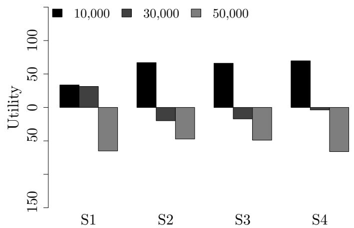
This table shows the characteristics of the groups in terms of number and share of members. The utility of the none option is displayed as well.

segment 1 is almost indifferent between an investment of EUR 10,000 and EUR 30,000. All other segments, in contrast, would not be willing to invest more than EUR 10,000. Both the guarantee level and underlying fund shown in Figures 6(c) and 6(d) lead to a more heterogeneous preference distribution. While respondents in segments 1, 2 and 4 prefer guarantee levels of 0.6 percent and 0.9 percent, the latter result in a negative utility value for segment 3. Compared to the other groups, those respondents prefer lower to higher guarantee levels, which presents a coherent picture with Figure 6(d). That is, segment 3 favors a low-risk underlying fund, which also holds true for the fourth group. Segments 1 and 2, on the other hand, are more interested in medium-risk and high-risk funds, respectively. The price-utility curves displayed in Figure 6(e) demonstrate that all groups prefer lower over higher prices. Particularly the second group has a flat price-utility profile, which demonstrates that the price does not matter for them. As already indicated by their high none utility value (Table 26), those respondents are unlikely to buy any guarantee, regardless of the price.

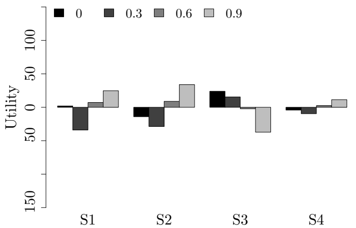
Based on the preference profiles shown in Figure 6, we classify the respondents of segment 1 as *guarantee accepting yield seekers* since they prefer a high guarantee level in combination with a medium-risk underlying fund. The *guarantee skeptics yield seekers* (segment 2) also favor high guarantee levels, but are more interested in high-risk funds with the potential of generating higher returns. Respondents belonging to segment 3, on the other hand, are denoted as *risk averse assets preservers*. They are characterized by a defensive attitude, which is expressed through their strong preference for low-risk funds and money-back guarantees. Finally, *risk averse yield optimizers* are most interested in low-risk funds and the highest guarantee level of 0.9 percent.



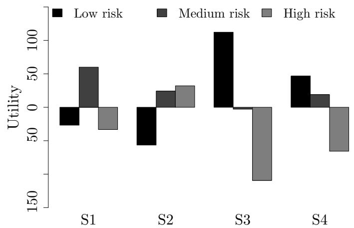
(a) Guarantee period (in years)



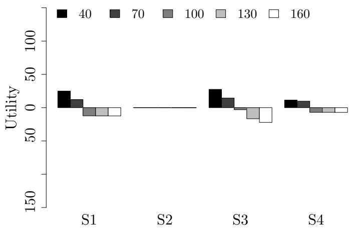
(b) Investment premium (in EUR)



(c) Guarantee level (in percent)



(d) Underlying fund



(e) Guarantee price (in percent of the OPT price)

Figure 6: Latent Class Part-worth Utility Profiles

This figure shows the cluster-level part-worth utility profiles for the attributes across the 1,017 respondents in our sample.

3.3 Relative Attribute Importances

The absolute utility values in Figure 6 give a first indication which attributes contribute the largest amount of utility to an investment guarantee. This information allows us to determine the relative importance (RAI) of each attribute for the four consumer segments. The corresponding percentages are shown in Figure 7. At first glance, one can see that the guarantee period is the most important attribute for segments 1, 2, and 4 with an average RAI between 42 percent and 47 percent. Consequently, changes in the guarantee period trigger the largest utility changes for these respondents. We further observe that the investment premium with an RAI between 20 percent and 27 percent is the second key factor for them, followed by the underlying fund (18 percent to 22 percent). Segment 3, on the other hand, exhibits a different attribute ranking than the other groups with the underlying fund being the most important attribute (RAI of 44 percent). The guarantee period with an RAI of 11 percent is almost irrelevant for them. In contrast, they are more likely to care about the investment premium as indicated by the RAI of 23 percent.

Another striking result is that none of the four segments considers the guarantee price as an important attribute. More specifically, the corresponding RAI range from almost zero to ten percent, which underlines that the price is no potential lever when constructing a guarantee product. This observation confirms the suspicion that consumers find it difficult to assign a monetary value to complex financial products such as an investment guarantee. Although the offered prices might be considerably lower than the corresponding OPT prices, consumers do not obtain large changes in utility. Instead, they rather concentrate on the more tangible attributes such as the guarantee period or investment premium. A similar pattern, even though not as strongly pronounced, is observed for the guarantee level. With a RAI varying between 4 percent and 13 percent and low-ranking positions particularly in segments 1 to 4, this attribute plays only a minor role in the choice processes of consumers. At first glance, this seems to be a counter-intuitive result. One possible explanation might be that guarantee levels have been significantly reduced for the past few years, i.e. from 3.25 percent at the beginning of the 2000's to 0.9 percent in 2017 (Federal Ministry of Justice and Consumer Protection (BMJV), 2016). Hence, as demonstrated by our results, consumers rather tend to choose products based on underlying funds with attractive risk-return profiles.

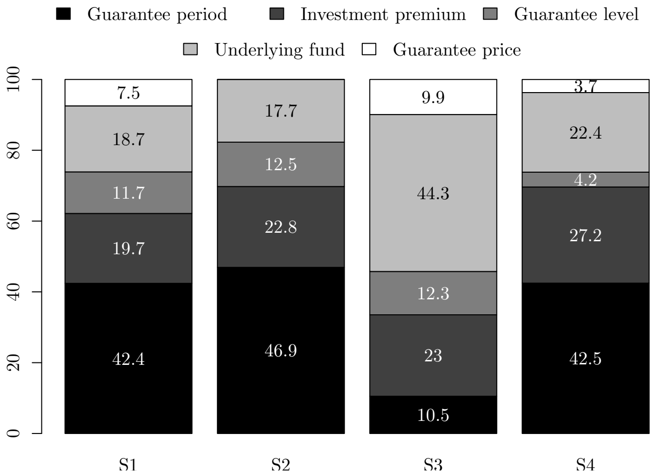


Figure 7: Cluster-Level Average Attribute Importance
This figure summarizes the relative importance of attributes across the different clusters in our sample.

3.4 Shares of Preference

In this section, we introduce three generic investment guarantees that represent a realistic snapshot of the German marketplace and run comprehensive simulation analyses to examine the choice behavior of our four latent class segments. An overview of the product details is given in Table 27. Investment guarantee A (IG A) runs for ten years and requires an upfront investment premium of EUR 10,000. Moreover, it has a money-back guarantee (zero percent), a low-risk underlying, and a OPT price of EUR 34. While both the guarantee period (10 years) and investment premium (EUR 10,000) of investment guarantee B are identical, the guarantee level is 0.9 percent, i.e. the legal limit in Germany. Given that the underlying fund exhibits a medium risk, the OPT price (100 percent) amounts to EUR 632. Finally, investment guarantee C has a 20-year guarantee period, a guarantee level of 0.6 percent, and an investment premium of EUR 30,000. The underlying fund comprises 100 percent equities and is therefore considered to be in the high-risk category. Thus, the fair OPT price is highest among all products and equals EUR 5,117.

Investment guarantee A	
Guarantee period	10 years
Investment premium	EUR 10,000
Guarantee level	0 percent
Underlying fund	Low risk
Reservation price (OPT)	EUR 34

Investment guarantee B	
Guarantee period	10 years
Investment premium	EUR 10,000
Guarantee level	0.9 percent
Underlying fund	Medium risk
Reservation price (OPT)	EUR 632

Investment guarantee C	
Guarantee period	20 years
Investment premium	EUR 30,000
Guarantee level	0.6 percent
Underlying fund	High risk
Reservation price (OPT)	EUR 5,117

Table 27: Generic Investment Guarantees

This table highlights the specifications (attribute levels) of the three generic investment guarantees that form the basis for all remaining analyses.

Table 28 contains the SOP (in percentage points) for each aforementioned guarantee and the four consumer segments. The scenario in the left panel shows results from a single-product analysis, in which consumers could choose either to buy each single product or not. As already indicated by their low none utility value (–595.5) and attribute-level utilities, consumers in segment 1 are highly interested in investment guarantees. More specifically, the SOP range from 77.64 percent (IG B at price level five) to 90.87 percent (IG C at price level one) and remain almost stable across all five price levels. Thus, one can conclude that those consumers are relatively insensitive to changes in the guarantee price. A different picture is obtained for segment two, which exhibits no preference for investment guarantees as underlined by the low SOP between 1.19 percent and 2.28 percent. Even substantial price discounts of up to 60 percent of the OPT price do not result in notable SOP. Segment three, on the other hand, shows little interest in product IG A, but none in products IG B and IG C. This can be explained by the guarantee level of 0.9 percent of IG B (Figure 6(c)) and the high-risk underlying fund of IG C (Figure 6(d)). Compared to segments one and two, the wider SOP range for product IG A indicates that this segment has a higher price sensitivity. Finally, between 43.09 percent and 48.05 percent as well as 38.91 percent and 45.44 percent of segment four choose products IG A and IG C, respectively. The third alternative IG B, in contrast, only attracts 18.12 percent, if offered at the lowest price.

The right panel contains results from a portfolio analysis, in which all products have been offered simultaneously, i.e. consumers could choose either to buy any of the three product or none at all. Compared to the single-product analysis, we observe that segment one still favors product IG C. However, both IG A and IG B generate significant SOP as well, while less than four percent of those consumers decide not to buy any offering. Therefore, we conclude that this segment is highly competitive. Again, segment two is characterized by a significant share of non-buyers (more than 95 percent) and not interested in any form of an investment guarantee. In segment three, alternative IG A achieves a SOP of up to approximately 15 percent, while more than 83 percent stay out of the market. Approximately two thirds of segment four, on the other hand, decide in favor of a product with IG A being the most preferred alternative.

3.5 Socioeconomic Characteristics

In our final analysis, we examine whether individual group membership can be explained by central socioeconomic characteristics (Table 35). Overall, we can observe that the sample is almost evenly split between male (48 percent) and female (52 percent), similar to the general profile of the German population, with slight differences between the clusters. The majority of the sample is older than 45 (34 percent) or aged 35-44 (27 percent). Over a third of the sample has

		Single-product analysis			Portfolio analysis			
	Price level	IG A	IG B	IG C	IG A	IG B	IG C	None
Segment 1 ($n = 236$)	1	80.03	82.00	90.87	30.26	28.32	37.99	3.43
	2	79.78	80.00	90.24	30.20	28.25	37.93	3.62
	3	79.34	78.29	89.45	30.09	28.24	37.84	3.83
	4	79.32	78.09	89.33	30.08	28.25	37.81	3.86
	5	79.04	77.64	89.09	30.06	28.21	37.78	3.96
Segment 2 ($n = 233$)	1	1.51	1.28	2.28	1.30	1.41	2.22	95.07
	2	1.35	1.26	2.16	1.18	1.40	2.13	95.29
	3	1.32	1.27	2.11	1.10	1.38	2.09	95.43
	4	1.23	1.28	2.07	1.05	1.37	2.05	95.53
	5	1.19	1.24	2.02	1.03	1.35	2.03	95.58
Segment 3 ($n = 185$)	1	15.26	0.01	2.03	15.37	0.01	0.65	83.97
	2	11.52	0.01	1.45	11.76	0.01	0.56	87.67
	3	9.97	0.01	1.23	10.25	0.01	0.51	89.23
	4	8.92	0.01	1.12	9.25	0.01	0.50	90.24
	5	8.83	0.00	1.08	9.07	0.00	0.50	90.42
Segment 4 ($n = 363$)	1	48.05	18.12	45.44	34.21	9.32	23.18	33.30
	2	45.73	17.19	41.87	32.58	9.18	22.69	35.56
	3	44.31	16.71	40.20	31.51	9.09	22.39	37.01
	4	43.56	16.62	39.50	30.98	9.10	22.18	37.74
	5	43.09	16.37	38.91	30.67	9.01	22.15	38.16
Full sample ($n = 1,017$)	1	38.88	25.90	38.20	22.30	10.24	17.79	49.67
	2	37.30	25.07	36.68	21.00	10.16	17.53	51.31
	3	36.42	24.54	35.84	20.28	10.12	17.41	52.18
	4	35.93	24.39	35.48	19.87	10.09	17.36	52.67
	5	35.70	24.19	35.25	19.77	10.08	17.26	52.89

Table 28: Shares of Preference (SOP) for Generic Investment Guarantees

This table shows the SOP (in percentage points) for each investment guarantee and the five price levels. The left panel contains results from a single-product analysis, in which consumers could choose between each guarantee and the none option. In the right panel, results from a portfolio analysis are shown, in which all products were simultaneously offered. In addition to the four consumer segments, results for the full sample ($n = 1,017$) are highlighted as well.

a monthly income of EUR 1,500 - EUR 3,000 (35 percent). The majority of the respondents also have a mid level education (such as apprenticeship, vocational trainings) (61 percent) and 29 percent have attained higher education such as university degree. The distribution of total assets is highly spread across the sample, whereas a third of the sample (31 percent) state they own no assets or that the total accumulated wealth lies below EUR 50,000 (cumulative percentage 76 percent). The level of financial literacy is almost evenly split between low (48 percent) and high (52 percent), whereas a slightly higher percentage (54 percent) have a tendency to prefer lower risk investments. The majority of the sample (45 percent) does not own a financial product with a guarantee, but has an interest in such a product.

After dividing the sample into cluster of preferences, we inspect whether there are any differences between the segments with regards to demographic and psychographic characteristics. In order to test this, we perform one-tail ANOVA and Tukey-Kramer analyses in order to inspect differences in p-values between segment pairs. The results of the analyses are reported in Table 30. Overall, we can see that the differences between segment pairs with regards to these variables are relatively small. In particular, we can conclude that by just looking at the sociodemographic and psychographic characteristics it remains difficult to identify which segments the respondents belong to. Significant differences between segments 1 and 2 can be found with regards to the monthly income under EUR 1,500 and between EUR 3,000 and EUR 5,000, no assets, assets between EUR 10,000 and EUR 50,000 and assets larger than EUR 1 million. Significant differences are also encountered with respect to the investment risk attitude and all three levels of ownership of a financial product with guarantee. Similarly, there are significant differences between clusters 1 and 3 with regards to gender, no assets, investment risk attitude and the ownership of a financial product. Fewer significant differences are encountered between segment 1 and segment 4, where respondents differ in their investment risk attitude, financial literacy level and the ownership of a financial contract with guarantee. There are no significant differences between segments 2 and 3 with regards to sociodemographic or psychographic characteristics. Segments 2 and 4 differ in terms of monthly income below EUR 1,500 and between EUR 3,000 and EUR 5,000, in terms of higher education, assets (no assets, assets between EUR 10,000 and

Variable	Level	Full	S1	S2	S3	S4
Gender	Female	51.8	47.5	54.1	61.1	48.5
	Male	48.2	52.5	45.9	38.9	51.5
Age	< 25	5.0	5.9	3.9	2.7	6.3
	25-34	23.8	25.4	22.3	22.2	24.5
	35-44	27.3	30.1	24.9	27.0	27.3
	45-54	43.9	38.6	48.9	48.1	41.9
Monthly income	$\leq$ EUR 1,500	30.5	25.4	42.9	34.6	23.7
	EUR 1,500 - EUR 3,000	35.3	34.3	31.3	36.2	38.0
	EUR 3,000 - EUR 5,000	27.8	33.1	20.2	23.2	31.7
	$\geq$ EUR 5,000	5.9	5.9	5.6	5.5	6.3
	No answer	0.5	1.3	0.0	0.5	0.3
Education	Low	7.1	5.9	8.2	6.0	7.7
	Medium	60.7	61.0	64.4	64.3	56.2
	High	29.4	30.5	24.0	25.4	34.2
	No answer	2.8	2.5	3.4	4.3	1.9
Total assets	No assets	30.5	23.8	43.8	37.8	22.9
	$\leq$ EUR 2,500	9.6	11.9	8.6	9.2	9.1
	$\leq$ EUR 10,000	15.6	11.9	16.7	14.1	18.2
	$\leq$ EUR 50,000	19.0	22.0	11.6	17.8	22.3
	$\leq$ EUR 100,000	8.5	11.9	6.4	5.9	8.8
	$\leq$ EUR 250,000	8.6	11.4	3.4	7.6	10.5
	$\leq$ EUR 500,000	5.5	5.5	5.2	4.9	6.1
	$\leq$ EUR 1 MM	1.1	0.8	0.4	1.1	1.6
	$\geq$ EUR 1 Mio.	1.6	0.8	3.9	1.6	0.5
Financial literacy	Low	52.0	57.2	55.8	51.9	46.3
	High	48.0	42.8	44.2	48.1	53.7
Investment risk attitude	Low	53.9	64.4	45.5	50.3	54.3
	High	46.1	35.6	54.5	49.7	45.7
Ownership of a financial product with guarantee	Yes, I own such a product.	19.6	37.7	9.0	7.6	20.7
	No, but I have an interest to purchase such a product.	45.2	45.8	34.3	33.0	58.1
	No, and I have no interest to purchase such a product.	35.2	16.5	56.7	59.4	21.2

Table 29: Full and Cluster-Level Socioeconomic Characteristics of the Sample

This table presents the total and cluster-level demographic characteristics.

EUR 50,000, assets between EUR 100,000 and EUR 250,000 and above EUR 1 Million), as well as ownership of an investment product. Lastly, segments 3 and 4 differ in terms of gender, monthly income below EUR 1,500, no assets and ownership of an investment product with guarantee. The fact that the differences in sociodemographic and psychographic characteristics between the segments are so small leads us to conclude that by only looking at these characteristics, it is difficult to determine what kind of guarantee each of the consumers prefer. Therefore, the benefit segmentation based on choice-based conjoint analysis seems to be more appropriate.

4 Conclusion

We conduct a choice-based conjoint analysis for investment guarantees through an online survey on a sample of 1,017 financial decision makers from Germany. We estimate part-worth utility profiles of segments of customers with similar preferences through a latent class analysis. Consequently, we inspect whether there exist any significant differences between these segments with regards to several sociodemographic characteristics. We perform extensive simulations in order to derive shares of preference for three generic investment guarantees in a hypothetical market environment. Several conclusions can be drawn from this study. Firstly, there is great heterogeneity between consumers with regards to their likelihood of purchasing investment guarantees. A large portion of consumers are not going to purchase investment guarantees at all (segment 2), irrespective of how the guarantees are designed, due to their high utility of the none option. On the other hand, there is also a high proportion of consumers (segment 1) that are interested in any form of guarantee. The majority of the consumers (segments 3 and 4), will only choose carefully designed guarantees that maximize their utility. Secondly, there is heterogeneity with regards to the attributes and levels preferred by the segments. While all the segments prefer shorter guarantee periods and lower investment premiums, the guarantee level and the risk of the underlying differ among segments. By providing shorter guarantee periods and lower investment premiums, insurers can maximize the utility of consumers, since these attributes are also the ones that bare the highest relative importance. The guarantee and the price levels play a limited role in the

Variable	Level	S1-S2	S1-S3	S1-S4	S2-S3	S2-S4	S3-S4
Gender	Female	0.4753	0.0279**	0.9947	0.4822	0.5392	0.0268**
	Male	0.4753	0.0279**	0.9947	0.4822	0.5392	0.0268**
Age	< 25	0.7336	0.4335	0.9962	0.9493	0.5310	0.2536
	25-34	0.8596	0.8641	0.9942	1.0000	0.9274	0.9284
	35-44	0.5887	0.8979	0.8751	0.9623	0.9206	0.9999
	45-54	0.1068	0.2030	0.8545	0.9983	0.3263	0.5040
Monthly income	$\leq$ EUR 1,500	0.0001***	0.1690	0.9685	0.2463	0.0000***	0.0401**
	EUR 1,500 - EUR 3,000	0.9057	0.9778	0.7920	0.7274	0.3425	0.9756
	EUR 3,000 - EUR 5,000	0.0098***	0.1132	0.9830	0.8972	0.0116**	0.1553
	$\geq$ EUR 5,000	0.9985	0.9959	0.9970	0.9998	0.9810	0.9722
	No answer	0.2007	0.7115	0.3227	0.8613	0.9658	0.9751
Education	Low	0.7849	1.0000	0.8405	0.8187	0.9970	0.8715
	Medium	0.8786	0.9009	0.6393	1.0000	0.1901	0.2539
	High	0.4125	0.6627	0.7718	0.9900	0.0403**	0.1436
	No answer	0.9383	0.6959	0.9713	0.9484	0.7039	0.3832
Total assets	No assets	0.0000***	0.0084***	0.9958	0.5425	0.0000***	0.0015***
	$\leq$ EUR 2,500	0.6254	0.7930	0.6755	0.9968	0.9967	1.0000
	$\leq$ EUR 10,000	0.0047	0.0093	0.0016	0.0088	0.0096	0.5895
	$\leq$ EUR 50,000	0.0020***	0.6931	0.9998	0.3647	0.0061***	0.5829
	$\leq$ EUR 100,000	0.1492	0.1327	0.5554	0.9979	0.7382	0.6629
	$\leq$ EUR 250,000	0.0103**	0.4896	0.9755	0.4335	0.0143**	0.6568
	$\leq$ EUR 500,000	0.9983	0.9918	0.9916	0.9993	0.9647	0.9383
	$\leq$ EUR 1 Mio.	0.9720	0.9957	0.7886	0.9192	0.4945	0.9285
	$\geq$ EUR 1 Mio.	0.0426**	0.9205	0.9918	0.2573	0.0082***	0.7745

Table 30: Differences in p-values

This table presents the differences in p-values for the cluster-level demographic characteristics.

Variable	Level	S1-S2	S1-S3	S1-S4	S2-S3	S2-S4	S3-S4
Gender	Female	0.4753	0.0279**	0.9947	0.4822	0.5392	0.0268**
Financial literacy	Low	0.9900	0.6987	0.0441**	0.8567	0.1049	0.5976
	High	0.9900	0.6987	0.0441**	0.8567	0.1049	0.5976
Investment risk attitude	Low	0.0002***	0.0194**	0.0688*	0.7609	0.1499	0.8077
	High	0.0002***	0.0194**	0.0688*	0.7609	0.1499	0.8077
Ownership of a financial product with guarantee	Yes, I own such a product.	0.0000***	0.0000***	0.0000***	0.9805	0.0016***	0.0008***
	No, but I have an interest to purchase such a product.	0.0545*	0.0381**	0.0131**	0.992	0.0000***	0.0000***
	No, and I have no interest to purchase such a product.	0.0000***	0.0000***	0.5776	0.9156	0.0000***	0.0000***

Table 30: Differences in p-values

This table presents the differences in p-values for the cluster-level demographic characteristics.

choice of guarantee. Last but not least, there is little difference in sociodemographic characteristics between clusters.

Insurers and regulators need to understand consumer preferences towards investment guarantees in long-term saving products such as unit-linked or participating life insurance in order to provide them with products which fit their needs. Otherwise, they run the risk of offering expensive features which customers are not ready to pay for and which provide them with negative utility. In particular, investment guarantees have been previously documented to be costly, with potential negative outcomes on an investor's retirement account. Therefore, it is important to find out which attributes of the guarantee provide customers with positive marginal utility. This information is also helpful for guarantee providers, such as insurers and banks, to offer right guarantee forms and levels to particular customer groups and to extend their product portfolio.

If the utility derived by customers from a particular guarantee type is lower than the utility of the customers not choosing any guarantee type, providers should rethink whether investment guarantees make economic sense and what the best way to organize their provision is. It might be that on an individual level, given the utility provided by the guarantee, it does not make sense from an economic point of view for insurers to offer such features for voluntary long-term savings products. However, the situation might be very different in the case of mandatory pension schemes. In these cases, even if utility is reduced for some consumer groups by the current investment guarantee setting, regulators might take into considerations other general economic and social aspects, such as reducing the risk of poverty among the elderly and avoiding a socialization of potential costs in this respect within the society.

5 Appendix

Holdout Tasks

In order to get a first indication of the validity of our results, we have included holdout tasks in our conjoint analysis. These allow us to measure the ability to predict choices from the part-worth utilities derived from the random choices (cf. Johnson, 1987). The holdout choices included in the conjoint analysis are presented in Table 31 (holdout task 1), Table 32 (holdout task 2) and Table 33 (holdout task 3).

Table 34 presents the shares of preference obtained from simulation based on the part-worth utilities obtained from the random tasks (left panel) and those obtained from the holdout tasks. Overall, we can observe that we can predict the shares of preference for the guarantees presented in the holdout tasks fairly accurately, an indication that our analysis has performed well.

Investment guarantee A	
Guarantee period	30 years
Investment premium	EUR 30,000
Guarantee level	0 percent
Underlying fund	Medium risk
Price level (OPT percent)	100
Price	EUR 624

Investment guarantee B	
Guarantee period	30 years
Investment premium	EUR 10,000
Guarantee level	0.9 percent
Underlying fund	Medium risk
Price level (OPT percent)	100
Price	EUR 1,026

Investment guarantee C	
Guarantee period	30 years
Investment premium	EUR 50,000
Guarantee level	0.3 percent
Underlying fund	Medium risk
Price level (OPT percent)	100
Price	EUR 1,881

Table 31: Holdout Task 1

This table highlights the specifications (attribute levels) of the three generic investment guarantees that were presented in holdout task 1.

Investment guarantee A	
Guarantee period	20 years
Investment premium	EUR 10,000
Guarantee level	0 percent
Underlying fund	Low risk
Price level (OPT percent)	130
Price	EUR 17

Investment guarantee B	
Guarantee period	20 years
Investment premium	EUR 10,000
Guarantee level	0.6 percent
Underlying fund	Medium risk
Price level (OPT percent)	130
Price	EUR 774

Investment guarantee C	
Guarantee period	20 years
Investment premium	EUR 10,000
Guarantee level	0.9 percent
Underlying fund	High risk
Price level (OPT percent)	130
Price	EUR 2,643

Table 32: Holdout Task 2

This table highlights the specifications (attribute levels) of the three generic investment guarantees that were presented in holdout task 2.

Investment guarantee A	
Guarantee period	10 years
Investment premium	EUR 50,000
Guarantee level	0 percent
Underlying fund	Medium risk
Price level (OPT percent)	70
Price	EUR 987

Investment guarantee B	
Guarantee period	40 years
Investment premium	EUR 30,000
Guarantee level	0.6 percent
Underlying fund	Low risk
Price level (OPT percent)	160
Price	EUR 535

Investment guarantee C	
Guarantee period	30 years
Investment premium	EUR 10,000
Guarantee level	0.3 percent
Underlying fund	High risk
Price level (OPT percent)	40
Price	EUR 615

Table 33: Holdout Task 3

This table highlights the specifications (attribute levels) of the three generic investment guarantees that were presented in holdout task 3.

		Predicted			Actual		
	Segment	IG A	IG B	IG C	IG A	IG B	IG C
Holdout task 1	1	35.44	43.63	20.92	33.39	51.46	15.15
	2	26.16	54.18	19.66	26.27	61.62	12.11
	3	30.11	52.97	16.92	50.05	48.36	1.59
	4	30.36	50.89	18.75	39.37	49.05	11.58
	Total	30.53	50.34	19.13	36.92	52.36	10.71
Holdout task 2	1	30.65	37.15	32.21	26.26	51.93	21.81
	2	27.21	35.49	37.30	31.46	39.52	29.02
	3	85.77	12.30	1.93	81.19	16.22	2.59
	4	42.46	33.07	24.47	41.41	40.76	17.83
	Total	44.10	30.79	25.10	42.85	38.61	18.54
Holdout task 3	1	47.81	20.62	31.57	50.08	30.11	19.81
	2	48.36	14.92	36.72	54.86	15.24	29.89
	3	26.85	44.82	28.33	17.75	67.31	14.93
	4	46.83	23.48	29.69	45.09	33.41	21.51
	Total	43.78	24.74	31.49	43.51	34.65	21.84

Table 34: Shares of Preference (SOP) for Generic Investment Guarantees

This table shows the SOP (in percentage points) for each investment guarantee presented in the holdout tasks. The left panel contains results for predicted SOP obtained from the part-worth utilities derived from the random tasks. In the right panel, actual SOP are computed from the holdout tasks.

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Part IV
Does Prevention as an Investment Strategy Explain the Intention to Purchase Guarantees for Unit-linked Life Insurance?

Abstract

The present paper examines the relationship between prevention as an investment strategy and the perceptions about unit-linked insurance and the intention to purchase interest rate guarantees for such products. We propose a framework in which the relationship between adopting prevention as an investment strategy and the intention to purchase interest rate guarantees is moderated by the level of financial literacy of the individual and suggest that this interaction is mediated by the perceptions regarding unit-linked insurance. We find support for our conceptual model by testing it on a sample of 1,017 financial decision makers in Germany using a moderated mediation analysis. The paper therefore offers insights into the decision making process of financial consumers in Germany and presents practical implications for designing products for age old provision.[1]

[1]Luca D. (2018). Does Prevention as an Investment Strategy Explain the Intention to Purchase Guarantees for Unit-linked Life Insurance? *I.VW-HSG Working Papers on Risk Management and Insurance*

1 Introduction

Interest rate guarantees have been a ubiquitous feature for endowment life insurance products in Europe for decades. In recent years, the level of interest rate guarantees has been steadily declining, as the costs encountered by life insurers in order to finance the guarantees are considerable. At the same time, a new type of insurance product has been steadily growing in popularity on the international market: the unit-linked life insurance, which allows consumers to combine the cover of biometric risk with an investment component.[2]This investment component allows individuals to accumulate wealth which is paid back to them in case of survival at the end of the insurance contract, or, in case of death to their beneficiaries. Therefore, such insurance contracts also classify as a private pension plan, where individuals can freely choose how their money is invested. Comparable to other long-term saving products such as endowment life insurance, interest rate guarantees are also present in some unit-linked products. Their purpose is to insure asset preservation rather than growth: i.e., the guaranteed amount is paid back to the investor upon expiration of the contract or to the beneficiaries in case of death. In light of this new development, it is worth asking what the drivers behind the intention to purchase guarantees in life insurance from a customer's perspective are.

The demand for guarantees for long-term saving products such as unit-linked insurance has so far only been analyzed under a theoretical framework. In so far, expected utility theory, prospect theory and multi-cumulative prospect theory have all failed to fully explain the demand for guarantees in life insurance products (see, e.g., Døskeland and Nordahl, 2008; Ebert et al., 2012; Braun et al., 2017; Ruß and Schelling, 2017). In this paper, we propose an alternative approach, in which we investigate the impact of the investment strategy, in particular the propensity of focusing on prevention of negative outcomes in an investment strategy, the impact of financial literacy of customers and the

[2]For example, in Germany the premium income from participating life insurance contracts with mandatory interest rate guarantee has declined 5.4% for the year 2015-2016, whereas the premium income from unit-linked insurance has grown 3.1% over the same period (cf. Gesamtverband der Deutschen Versicherungswirtschaft, 2017). At a European level, EIOPA (European Insurance and Occupational Pension Authority) (2013) reports an increase in the share of unit-linked as a percentage of the life insurance market, with total gross written premium for unit-linked of EUR 277 mn in 2015 (cf. EIOPA (European Insurance and Occupational Pension Authority), 2017).

perceptions about unit-linked life insurance on the decision to purchase interest rate guarantees for unit-linked insurance products. In contrast to previous studies which try to explain the demand for such products within financial theory, we design our hypotheses by combining elements from previous research in marketing, economics and psychology.

The present paper brings a contribution both to the existing theory and practice. To the best of our knowledge, this is the first article that examines the relationship between prevention and the decision to purchase interest rate guarantees. In order to establish this relationship, we draw on two main theories from psychology: the regulatory focus theory which states that people are either motivated to achieve desired states or to avoid undesirable outcomes (see, e.g., Higgins, 1998; Brockner and Higgins, 2001). On the other hand, we draw on the theory of reasoned action in which the intention to engage in a certain behavior is influenced by the attitudes regarding that behavior (see, e.g, Ajzen, 1991; Ajzen, 2005). In this sense, we highlight the fact that our concept of prevention, which has been previously tested in the marketing literature, is also closely related to the concept of prudence which has been gaining popularity in the insurance economics literature. Previous studies have shown that prudence is a necessary trait for increased prevention strategies (see, e.g., Jullien et al., 1999; Dionne and Li, 2011), as risk aversion alone is not sufficient to explain investment in prevention (see, e.g., Dionne and Eeckhoudt, 1985; Briys and Schlesinger, 1990). Therefore, our work adds to the literature on financial decision making by analyzing the relationship between investment strategy, perceptions about a specific product and the intention to purchase an additional safety characteristic for said financial product. We highlight that prevention as an investment strategy is not only crucial for the intention to purchase interest rate guarantees, but it is also important in determining the perceptions regarding unit-linked insurance. The influencing role of financial literacy is in accordance with recent literature that stresses the importance of financial literacy in financial decision making (see, e.g., Lusardi and Mitchell, 2007; Lusardi and Mitchell, 2009; Lusardi and Mitchell, 2011a; Lusardi and Mitchell, 2011b). However, the present study is the first - at least to our knowledge - to include financial literacy in a perception-intention to engage in a behavior framework. The mediating role of perceptions regarding unit-linked insurance is also new in the literature, although Huber and Schlager (2018) have previously analyzed the role of perceptions about life insurance on the intention to purchase life insurance. Moreover, to our knowledge, the present study is the first to analyze the decision making process that drives consumers to purchase interest rate guarantees.

In general, knowledge of the decision making process regarding the purchase of interest rate guarantees presents great interest for several stakeholders. In the light of current developments in the life insurance and pension markets, where demographic developments shift more responsibility of pension provision towards individuals, the question of what drives individuals' intention to purchase interest guarantees is of utmost importance, since the costs of guarantees are usually high and can significantly impact an individual's retirement account (see, e.g., Lachance and Mitchell, 2003; Finkelstein et al., 2003; Sinha and Renteria, 2005; Renz and Stotz, 2015; Gale et al., 2016). If customers are willing to purchase guarantees alongside with their contracts in order to have a guaranteed return at the end of the investment period, the costs of the guarantees can be covered by individuals directly. If, in turn, individuals are not willing to purchase guarantees, the high costs of guarantees must either be transferred to the government, in order to ensure the stability of the pension system, or the insurer or pension provider must discontinue the provision of such guarantees if the risk management costs associated with their provision cannot be covered.

The remainder of this paper is organized as follows: in section 2, we introduce the theoretical framework and the relevant literature, deriving the hypotheses. In section 3, we present the empirical results. Finally, we derive theoretical and practical implications in section 4, present limitations and potential future research in section 5 before concluding in section 6.

2 Theoretical Background and Conceptual Model

The antecedents of the decision making process that leads customers to purchase interest rate guarantees has not been investigated so far. Huber and Schlager (2018) explore the antecedents of purchasing life insurance and find out that the presence of an interest rate guarantee moderates the relationship between risk avoidance and risk perception in the intention to purchase life insurance, whereas Hecht and Hanewald (2012) investigate the determinants of the demand for endowment life insurance in Germany. In contrast, we try to determine the antecedents of the decision to purchase interest rate guarantees and our conceptual model has its foundations in the regulatory focus theory, in which people are motivated either to achieve desired results or to avoid undesired results (see, e.g., Higgins, 1998; Brockner and Higgins, 2001), which has direct consequences on financial choices (see, e.g., Hamilton and Biehal, 2005). Consumers who have prevention as an investment strategy are more focused on avoiding losses rather than achieving gains and therefore should positively influence the decision to purchase interest rate guarantees. Moreover, we hypothesize that the perceptions about unit-linked mediate the relationship between prevention and intention to purchase interest rate guarantees, since we believe that the perception about protection, transparency and performance risk of the unit-linked can in part explain the intention to purchase an interest rate guarantee. Moreover, financial literacy is expected to moderate the relationship between investment strategy and the perceptions about unit-linked insurance. This second part of our conceptual framework, in which attitudes about unit-linked influence the intention to purchase interest rate guarantees comes from the theory of reasoned action (see, e.g, Ajzen, 1991; Ajzen, 2005), which states that perceptions and attitudes towards a certain behavior influence the intention to engage in such behavior. In doing so, we do not focus on the actual behavior, since the actual purchase behavior of interest rate guarantees might differ from the intention to engage in such behavior. For example, a customer might have the intention to purchase an interest rate guarantee, but might have insufficient willingness to pay for such a feature (see, e.g., Gatzert et al., 2011; Luca et al., 2017) and therefore there would be a discrepancy between actual behavior and intention. However, regulators might be interested in which customers have an intention to purchase such a feature, since these customers are more likely to need financial protection.

2.1 Prevention as an Investment Strategy and the Intention to Purchase Interest Rate Guarantees

The main premise of regulatory focus theory is that when pursuing a goal, humans are motivated to achieve pleasure and avoid pain (see, e.g, Higgins, 1998; Brockner and Higgins, 2001). In what regards an investment strategy, this would translate into investors being motivated to achieve desired end states and avoid undesired states. In other words, the investment strategy of consumers determines the amount of risk that they are willing to accept in a financial product. Investors with promotion as an investment strategy seek growing their asset base, striving for positive outcomes and seeking to decrease the discrepancy between current and desired end states. On the other hand, consumers with prevention as an investment strategy seek financial safety, avoiding negative outcomes in order to decrease the discrepancy between current and undesirable end states. Financial investors who have prevention as a goal or investment strategy tend to focus on losses rather than gains, therefore exhibiting what behavioral finance calls loss aversion and what represents the cornerstone of prospect theory (see, e.g., Kahneman and Tversky, 1979).

In financial theory, loss aversion has been previously investigated as a means to explain optimal design strategies for portfolio insurance, strategies that seek to minimize the downside risk in an investment portfolio. Dichtl and Drobetz (2011) show that in the framework of prospect theory, loss aversion is a prerequisite for investors which prefer financial products with guaranteed returns over other investment strategies, in spite of the reduced returns. Similarly, multi cumulative prospect theory extends this framework to incorporate the subjective (dis)utility that investors gain from interim changes in their portfolio and find that the demand for guarantees can be explained in such a setup (see, e.g., Braun et al., 2017; Ruß and Schelling, 2017).

Leimberg et al. (2012) states that an important part of the background analysis of consumers is determining the amount of financial risk they are willing to accept in a financial plan. In particular, a financial consumer who has prevention as a strategy might be more willing to purchase an interest rate guarantee than someone who has asset growth as a strategy, since guarantees are meant to protect investors against negative developments in the financial markets that could affect their payout at maturity of the contract. Following this reasoning, we expect a positive relationship between prevention as an investment strategy and the intention to purchase interest rate guarantees in life insurance, as follows:

H_1: Prevention as an investment strategy has a positive effect on the intention to purchase interest rate guarantees.

2.2 Mediating Role of Perceptions Regarding Unit-Linked Insurance

The role of perceptions has been previously investigated in the context of financial decision making, in particular in the framework of theory of planned behavior. For example, Ruefenacht et al. (2015) find that the perceptions about long-term savings can impact a financial consumer's involvement in long-term savings, whereas the perceptions about a certain financial product play an important role in the intention to purchase said financial product (see, e.g., Huber and Schlager, 2018). We take this reasoning a step further and hypothesize that the perceptions about unit-linked insurance mediate the effect of prevention on the decision to purchase interest rate guarantees, as follows:

H_{2a}: Perceived protection mediates the relationship between prevention as an investment strategy and the intention to purchase interest rate guarantees.

H_{2b}: Perceived transparency mediates the relationship between prevention as an investment strategy and the intention to purchase interest rate guarantees.

H_{2c}: Perceived performance risk mediates the relationship between prevention as an investment strategy and the intention to purchase interest rate guarantees.

2.3 Moderating Role of Financial Literacy

Financial literacy is a topic which has been growing in importance in the last couple of years (see, e.g., Lusardi and Mitchell, 2011b; Lusardi et al., 2014). Recent research shows that it can impact saving and borrowing behavior (see, e.g., Lusardi and Tufano, 2015), retirement planning (see, e.g., Lusardi, 2004; Lusardi and Mitchell, 2007; Lusardi and Mitchell, 2011a), investment behavior (see, e.g., van Rooij et al., 2011) and the need for consumer protection in financial services (see, e.g., Bühler et al., 2016). In line with this literature, we expect the level of financial literacy to also impact the intention to purchase interest rate guarantees as an additional safety feature for a unit-linked insurance contract. We expect people with a higher level of financial literacy to be more willing to bare the investment risk of the life insurance contracts themselves, therefore being less likely to purchase interest rate guarantees.

H_{3a}: Financial literacy moderates the relationship between prevention as an investment strategy and the perceived protection from unit-linked life insurance, such that higher levels of financial literacy lead to a positive effect on perceived protection and low levels lead to a negative effect on perceived protection.

H_{3b}: Financial literacy moderates the relationship between prevention as an investment strategy and the perceived transparency of unit-linked life insurance, such that higher levels of financial literacy lead to a positive effect on perceived transparency and low levels lead to a negative effect on perceived transparency.

H_{3c}: Financial literacy moderates the relationship between prevention as an investment strategy and the perceived performance risk of unit-linked life insurance, such that higher levels of financial literacy lead to a negative effect on perceived performance risk and low levels lead to a positive effect on perceived performance risk.

We therefore build a research model in which the perceived protection, perceived transparency and perceived performance risk of a unit-linked insurance contract mediate the relationship between prevention as an investment strategy and the intention to purchase interest rate guarantees as an additional safety feature for a unit-linked contract and the financial literacy of the consumer moderates the relationship between prevention and the perceptions about unit-linked insurance. Figure 8 summarizes the conceptual framework. As a consequence of this model, we can further hypothesize that the financial literacy also moderates the relationship between prevention as an investment strategy and the intention to purchase interest rate guarantees. In this moderated mediation, the indirect effect of prevention on the intention to purchase interest rate guarantees via perceptions can be summarized as follows:

H_{4a}: The direction of the mediated relationship between prevention as an investment strategy and the intention to purchase interest rate guarantees via the perceived protection towards unit-linked life insurance varies according to the level of financial literacy: the indirect effect of prevention via perceptions towards unit-linked life insurance is negative for high levels of financial literacy and positive for low levels of financial literacy.

H_{4b}: The direction of the mediated relationship between prevention as an investment strategy and the intention to purchase interest rate guarantees via the perceived transparency towards unit-linked life insurance varies according to the level of financial literacy: the indirect effect of prevention via perceptions towards unit-linked life insurance is negative for high levels of financial literacy and positive for low levels of financial literacy.

H_{4c}: The direction of the mediated relationship between prevention as an investment strategy and the intention to purchase interest rate guarantees via the perceived performance risk towards unit-linked life insurance varies according to the level of financial literacy: the indirect effect of prevention via perceptions towards unit-linked life insurance is negative for high levels of financial literacy and positive for low levels of financial literacy.

2.4 Covariates

Consistent with previous literature (see, e.g., van Rooij et al., 2011; Campbell, 2006) we have taken into consideration socio-demographic variables such as age, gender, number of children, income, education and wealth. We have also considered unit-linked product knowledge and extant knowledge of financial products. Previous studies (see, e.g., Diacon and Ennew, 2001) have shown that the poor product knowledge can influence consumer's perception of financial risk, whereby Nepomuceno et al. (2014) show that product knowledge can reduce perceived risk. We thereby believe that a consumer's knowledge of unit-linked can affect their intention to purchase interest rate guarantees. We also complement the knowledge about unit-linked with extant knowledge regarding financial investments.

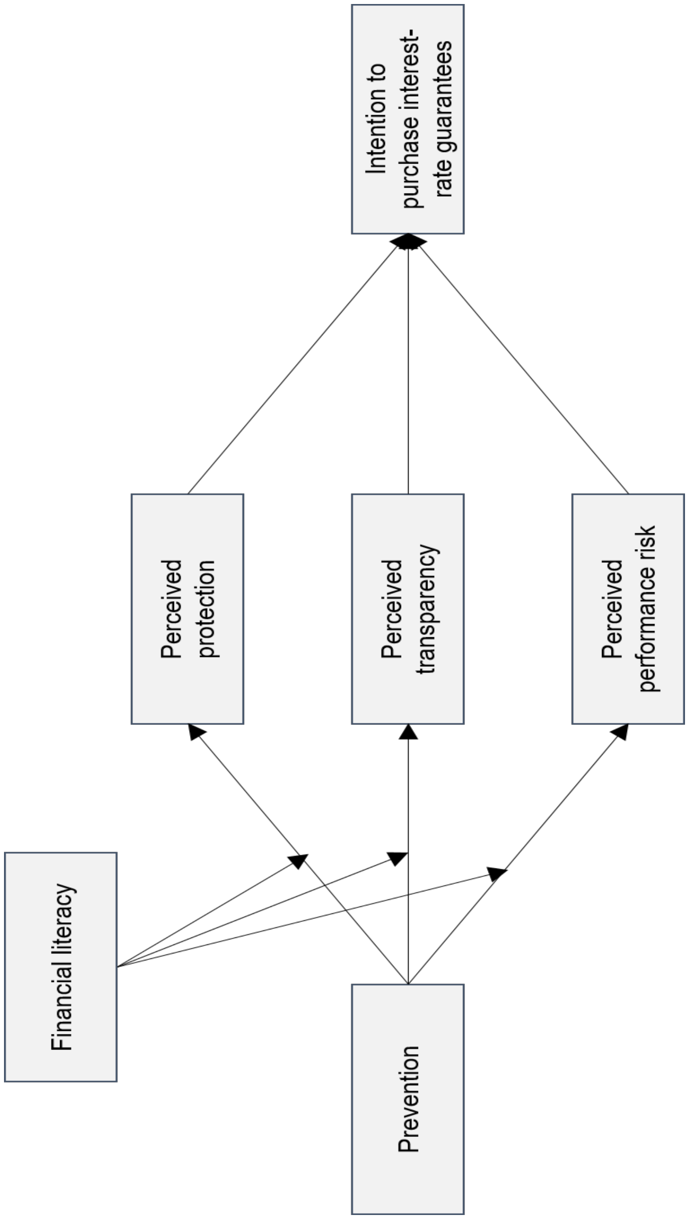

Figure 8: Conceptual Framework

3 Methodology

3.1 Sample and Procedure

We rely on an original dataset of 1,017 financial decision makers in Germany. Before starting the survey, customers were asked whether they were involved in the financial decision making process in their families. We have only surveyed those people which stated that they were either the main financial decision maker in the family or involved in the decision making process to a certain degree. The data was collected through a web-based survey distributed over a period of 3 weeks in Germany and the respondents were recruited through a market research firm. Participation in the study was incentivized by offering participants credit for online purchases. Respondents are representative of the German population in terms of gender and residence. In terms of age, we have imposed a restriction between 20 and 54 years old, since life insurance are long-term contracts that have a minimum term of ten years. A total number of 1,180 people received the questionnaire, out of which we have eliminated 163 respondents (14%) due to low involvement or click-through pattern, thus retaining a total of 1,017 respondents in the sample. The descriptive statistics of the sample are summarized in Table 35.

3.2 Measures

The measurement scales were selected in line with existing literature, while the wording and appearance for some constructs was slightly adapted in order to fit our research question and context. The summary of the scales and their origin can be found in Table 36. For prevention we have excluded some of the items in the original scale which do not exceed the thresholds in the CFA, thus retaining the scale with the 4 items reported. For the financial literacy scale, we use a measure that counts the number of questions the respondent has answered correctly regarding basic numeracy questions (see, e.g., Lusardi and Mitchell, 2007; Lusardi and Tufano, 2015; Lusardi and Mitchell, 2011a; Lusardi and Mitchell, 2011b; van Rooij et al., 2011; Lusardi et al., 2014). Single item measures were used for some of the control variables such as age, gender, income, number of children, education and wealth. Table 37 summarizes the items and the reliability measures (factor loadings (FL)), composite reliability

Variable	Level	Male		Female		Total	
		Count	%	Count	%	Count	%
Age	Born after 1990	31	6%	71	13%	102	10%
	Born between 1980 and 1989	116	24%	162	31%	278	27%
	Born between 1970 and 1979	162	33%	135	26%	297	29%
	Born before 1970	181	37%	159	30%	340	33%
No. children	0	286	58%	264	50%	550	54%
	1	90	18%	116	22%	206	20%
	2	94	19%	110	21%	204	20%
	3	16	3%	25	5%	41	4%
	4	3	1%	8	2%	11	1%
	≥ 5	0	0%	4	1%	4	0%
	More than 5	1	0%	0	0%	1	0%
Monthly household income	$<$ EUR 500	8	2%	13	2%	21	2%
	EUR 500 - EUR 1.000	40	8%	33	6%	73	7%
	EUR 1.000 - EUR 1.500	43	9%	72	14%	115	11%
	EUR 1,500 - EUR 2,000	64	13%	52	10%	116	11%
	EUR 2,000 - EUR 2,500	58	12%	74	14%	132	13%
	EUR 2,500 - EUR 3,000	53	11%	58	11%	111	11%
	EUR 3,000 - EUR 3,500	51	10%	46	9%	97	10%
	EUR 3,500 - EUR 4,000	48	10%	34	6%	82	8%
	EUR 4,000 - EUR 4,500	32	7%	24	5%	56	6%
	EUR 4,500 - EUR 5,000	21	4%	27	5%	48	5%
	EUR 5,000 - EUR 10,000	27	6%	22	4%	49	5%
	$\geq$ EUR 10,000	7	1%	4	1%	11	1%
	No income	2	0%	3	1%	5	0%
	No answer	36	7%	65	12%	101	10%

Table 35: Descriptive Statistics

Variable	Level	Male		Female		Total	
		Count	%	Count	%	Count	%
Education	Still in vocational training	10	2%	14	3%	24	2%
	On the job training/internship	1	0%	8	2%	9	1%
	Pre-vocational training year	1	0%	4	1%	5	0%
	Apprenticeship or similar	126	26%	151	29%	277	27%
	Vocational training completed	116	24%	125	24%	241	24%
	Technical degree	60	12%	39	7%	99	10%
	University of applied sciences degree (Bachelor, Master)	57	12%	39	7%	96	9%
	University degree (Bachelor, Master)	86	18%	103	20%	189	19%
	PhD	3	1%	6	1%	9	1%
	Professor	2	0%	0	0%	2	0%
	Preparatory service	0	0%	3	1%	3	0%
	No vocational degree	19	4%	15	3%	34	3%
	No answer	9	2%	20	4%	29	3%
Wealth	No assets	125	26%	186	35%	311	31%
	$\leq$ EUR 2,500	38	8%	60	11%	98	10%
	EUR 2,500 - EUR 10,000	68	14%	91	17%	159	16%
	EUR 10,000 - EUR 50,000	111	23%	82	16%	193	19%
	EUR 50,000 - EUR 100,000	48	10%	38	7%	86	8%
	EUR 100,000 - EUR 250,000	58	12%	29	6%	87	9%
	EUR 250,000 - EUR 500,000	24	5%	32	6%	56	6%
	EUR 500,000 - EUR 1 Mio.	9	2%	2	0%	11	1%
	$\geq$ EUR 1 Mio.	9	2%	7	1%	16	2%

Table 35: Descriptive Statistics

(CR) and average variance extracted (AVE)). We further report the means, standard deviations and correlations between the items in Table 38.

3.3 Measurement Model

The first step in our analysis was to test the reliability of the measurement model, for which we have performed a confirmatory factor analysis (CFA). Overall, the fit measures indicate a good fit of the model (RMSEA=0.045, CFI=0.980, TLI=0.977). In particular, the incremental fit indices (CFI and TLI) indicate that the default model is significantly different from the independence model, whereas the RMSEA indicates a close model fit. Moreover, all factor loadings (FL) were above the 0.6 threshold suggested by Bagozzi and Yi (2012). As regards the reliability of the individual latent variables, the CR and AVE were used as measures. All values exceed the recommended thresholds of 0.7 for CR and 0.5 for AVE. Our CFA therefore confirms our measurement model, since we have obtained good convergent and discriminant validity measures.

3.4 Hypotheses Testing

The main effect of prevention on the intention to purchase interest-rate guarantees was tested by means of a regression analysis and our results indicate that there is a significant positive direct effect (H_1, β=0.168, p<.001) of prevention on the intention to purchase guarantees. In order to test the mediating role of perceptions, we have employed a mediation analysis (see, e.g., Hayes, 2015; Preacher and Hayes, 2008) with 10,000 simulations in order to bootstrap the values for the confidence intervals and p-values (see, e.g., Edwards and Lambert, 2007). The mediation effects of perceptions were as follows: first, there was a negative effect of prevention on perceived protection (β=-0.238, p<.001), a positive effect of prevention on perceived transparency (β=0.170, p<.001) and a positive effect of prevention on perceived performance risk (β=0.367, p<.001). The effects of perceived protection (β=0.536, p<.001), perceived transparency (β=0.198, p<.001) and perceived performance risk (β=-0.084, p<.01) on the intention to purchase interest rate guarantee were also significant. In contrast, the direct effect of prevention on the intention to purchase interest rate guarantee was insignificant (β=0.059, n.s.) and changed sign, suggesting mediation. In order to test the indirect effects, we have employed the methodology presented

Items and constructs	Measurement	Source
Prevention (Investment strategy)		Appears in Bruner (2009); first developed by Hamilton and Biehal (2005).
I would like to create a combination of investments/ select an investment that would protect against large declines in value.	1="strongly disagree" to 7="strongly agree"	
My primary goal is to preserve my assets.	1="strongly disagree" to 7="strongly agree"	
When considering an investment opportunity, I focus on what I have now.	1="strongly disagree" to 7="strongly agree"	
I want to select investments that would minimize my expected losses.	1="strongly disagree" to 7="strongly agree"	
Perceived protection		Bosmans and Baumgartner (2005)
A unit-linked insurance can protect me against financial difficulties in the future.	1="strongly disagree" to 7="strongly agree"	
With unit-linked life insurance I obtain a sense of financial security.	1="strongly disagree" to 7="strongly agree"	
Unit-linked life insurance is able to protect me against adverse financial situations.	1="strongly disagree" to 7="strongly agree"	
Perceived transparency		Huber and Schlager (2018)
I know exactly what service I get from unit-linked life insurance.	1="strongly disagree" to 7="strongly agree"	
I know exactly what I have to pay for unit-linked life insurance.	1="strongly disagree" to 7="strongly agree"	
I have a clear overview about the product's costs.	1="strongly disagree" to 7="strongly agree"	
I feel well informed about unit-linked life insurance.	1="strongly disagree" to 7="strongly agree"	
Perceived performance risk		Nepomuceno et al. (2014)
If I were to purchase a unit-linked life insurance, I would be concerned that the item will not provide the level of benefits that I would be expecting.	1="strongly disagree" to 7="strongly agree"	
If I were to purchase a unit-linked life insurance, I would be concerned that I would not get my money's worth.	1="strongly disagree" to 7="strongly agree"	
The thought of purchasing a unit-linked insurance causes me to be concerned for how really reliable that product will be.	1="strongly disagree" to 7="strongly agree"	

Table 36: Measurement Model

Items and constructs	Measurement	Source
Intention to purchase an interest rate guarantee		Appears in Bruner (2009) and originates from the work of Burton et al. (1999) and Kozup et al. (2003).
Would you be more likely or less likely to purchase an interest rate guarantee, given the information shown?	1="more likely" to 7="less likely"	
Given the information shown, how probable is it that you would consider the purchase of a guarantee?	1="very probable" to 7="not probable"	
How likely would you be to purchase a guarantee, given the information shown?	1="very unlikely" to 7="very likely"	
Unit-linked product knowledge		Nepomuceno et al. (2014)
The information search I have performed on unit-linked life insurance is:	1="very weak" to 7="very strong"	
I don't have much experience purchasing unit-linked life insurance.	1="strongly disagree" to 7="strongly agree"	
In general, my knowledge of unit-linked life insurance is	1="very weak" to 7="very strong"	
Would you consider yourself uninformed or informed about unit-linked life insurance?	1="very uninformed" to 7="very informed"	
Compared to experts in this area, my knowledge of unit-linked life insurance is:	1="weaker" to 7="stronger"	
Extant knowledge of financial investments		Hofstetter et al. (2013)
Concerning financial investments, I consider myself	1= "not knowledgeable" to 7="knowledgeable"	
Concerning financial investments, I consider myself	1= "not competent" to 7="competent"	
Concerning financial investments, I consider myself	1= "not expert" to 7="expert"	
Concerning financial investments, I consider myself	1= "not trained" to 7="trained"	
Concerning financial investments, I consider myself	1= "not experienced" to 7="experienced"	

Table 36: Measurement Model

Items and constructs	FL	CR	AVE
Prevention (Investment strategy)		0.868	0.627
I would like to create a combination of investments/ select an investment that would protect against large declines in value.	0.62		
My primary goal is to preserve my assets.	0.884		
When considering an investment opportunity, I focus on what I have now.	0.915		
I want to select investments that would minimize my expected losses.	0.71		
Perceived protection		0.923	0.857
A unit-linked insurance can protect me against financial difficulties in the future.	0.869		
With unit-linked life insurance I obtain a sense of financial security.	0.927		
Unit-linked life insurance is able to protect me against adverse financial situations.	0.924		
Perceived transparency		0.954	0.837
I know exactly what service I get from unit-linked life insurance.	0.880		
I know exactly what I have to pay for unit-linked life insurance.	0.903		
I have a clear overview about the product's costs.	0.945		
I feel well informed about unit-linked life insurance.	0.931		
Perceived performance risk		0.929	0.813
If I were to purchase a unit-linked life insurance, I would be concerned that the item will not provide the level of benefits that I would be expecting.	0.862		
If I were to purchase a unit-linked life insurance, I would be concerned that I would not get my money's worth.	0.895		
The thought of purchasing a unit-linked insurance causes me to be concerned for how really reliable that product will be.	0.946		

Table 37: Reliability Model

Intention to purchase an interest rate guarantee		0.975	0.929
Would you be more likely or less likely to purchase an interest rate guarantee, given the information shown?	0.953		
Given the information shown, how probable is it that you would consider the purchase of a guarantee?	0.966		
How likely would you be to purchase a guarantee, given the information shown?	0.973		
Unit-linked product knowledge		0.964	0.844
The information search I have performed on unit-linked life insurance is:	0.822		
I don’t have much experience purchasing unit-linked life insurance.	0.944		
In general, my knowledge of unit-linked life insurance is	0.958		
Would you consider yourself uninformed or informed about unit-linked life insurance?	0.944		
Compared to experts in this area, my knowledge of unit-linked life insurance is:	0.92		
Extant knowledge of financial investments		0.965	0.846
Concerning financial investments, I consider myself 1= “not knowledgeable”, 7=“knowledgeable”	0.933		
Concerning financial investments, I consider myself 1= “not competent”, 7=“competent”	0.921		
Concerning financial investments, I consider myself 1= “not expert”, 7=“expert”	0.929		
Concerning financial investments, I consider myself 1= “not trained”, 7=“trained”	0.889		
Concerning financial investments, I consider myself 1= “not experienced”, 7=“experienced”	0.925		

Table 37: Reliability Model

Variable	Mean	Std. Dev.	1	2	3	4	5	6	7	8
1. Prevention (investment strategy)	5.09	1.26	1.00							
2. Perceived protection	3.97	1.44	0.18	1.00						
3. Perceived transparency	3.70	1.65	0.11	0.60	1.00					
4. Perceived performance risk	4.54	1.59	0.31	-0.02	-0.04	1.00				
5. Financial literacy	2.34	1.23	0.03	0.03	0.03	0.01	1.00			
6. Intention to purchase IRG	3.40	1.68	0.10	0.62	0.47	-0.10	0.01	1.00		
7. UL product knowledge	3.30	1.44	0.00	0.50	0.82	-0.05	0.01	0.44	1.00	
8. Extant knowledge of financial investments	3.62	1.56	0.01	0.43	0.70	0.01	0.12	0.37	0.85	1.00

Table 38: Means, Standard Deviations and Correlations

in Preacher and Hayes (2008) and found significant indirect effects of perceived protection (H_{2a}, β=0.134), perceived transparency (H_{2b}, β=0.031) and perceived protection risk (H_{2b}, β=-0.033), therefore supporting our hypotheses that the perceptions about unit-linked insurance mediate the relationship between prevention as investment strategy and the intention to purchase interest-rate guarantee.

Furthermore, to compute the moderating effect of financial literacy, we have used floodlight analysis (see, e.g., Hayes, 2018, Hayes, 2012) to identify regions where financial literacy would impact the effect of the independent variable on the dependent variable (see, e.g., Johnson and Neyman, 1936; Johnson and Fay, 1950). The Johnson-Neyman points for the various mediators are reported in Table 41. For perceived protection, we have found one Johnson-Neyman point for the interaction effect of prevention and financial literacy on perceived protection, which indicates a significant positive effect of the interaction on perceived protection below the value of 3.75. Similarly, for perceived transparency, we have also found one Johnson-Neyman point for the interaction effect of prevention and financial literacy on perceived transparency, indicating a positive significant effect below the value of 2.90. For perceived performance risk, there are no significant transition points using the Johnson-Neyman technique, indicating that the effect of the interaction between financial literacy and perceived performance risk is insignificant throughout the region. Therefore, we have found first evidence of support for H_{3a} and H_{3b}, but not for H_{3c}. To illustrate our results, we present the conditional indirect effects of prevention on perceived protection, perceived transparency and perceived performance risk in Table 39. This provides us with prima faccia evidence of mediation of an indirect effect, and we therefore follow-up with a formal test of moderated mediation. After estimating the conditional indirect effects, we proceed with an inferential test (see, e.g., Hayes, 2015) of moderated mediation, the results of which are presented in Table 40. The inferential test confirms that the index of moderated mediation for perceived protection and perceived transparency are significantly different from zero, therefore indicating a moderated mediation. In contrast, the indirect effect of perceived performance risk is linearly unrelated to the level of financial literacy. Lastly, we have tested hypotheses 4 (H_{4a}, H_{4b}, H_{4c}) using the bootstrap method (10,000 simulations) in PRO-

CESS. The conditional indirect effect of prevention on the intention to purchase interest-rate guarantee via perceived protection (H_{4a}), perceived transparency (H_{4b}) and perceived performance risk (H_{4c}) moderated by financial literacy was tested at one standard deviation above and below the mean. Our results presented in Table 42 indicate that the indirect effect of perceived protection is positive and significant at low values values of the moderator (financial literacy) (conditional indirect effect=0.1932, SE=0.03. CI=[0.134,0.255]) and becomes insignificant for higher values of financial literacy (3.57) (conditional indirect effect=0.0602, SE=0.03. CI=[-0.0061,0.1287]). Similarly, the conditional effect of prevention on intention to purchase via perceived transparency moderated by financial literacy is positive and significant for low levels of financial literacy (conditional indirect effect=0.0619, SE=0.015. CI=[0.0365,0.0964]), decreases for an intermediate level of financial literacy (2.3422) (conditional indirect effect=0.0274, SE=0.0098. CI=[0.0117,0.0512]) and becomes insignificant for high levels of financial literacy (conditional indirect effect=-0.0071, SE=0.01. CI=[-0.0326,0.0168]). For perceived performance risk, the conditional effects remain significant at all values of financial literacy, but the effect becomes less pronounced, from -0.0384 for a moderator value of 1.1131, to an effect of -0.0261 for a moderator value of 3.5713. Therefore, H_{4a} and H_{4b} were partially supported, while we have found no support for H_{4c}. Table 43 summarizes the results, while in Table 44 we summarize the effects of the covariates on the intention to purchase IRG and we discover that only age has a negative significant impact on the intention to purchase interest-rate guarantee (β=-0.027, p$<$0.001).

4 Implications and Discussion

The present article examined whether and how financial literacy affects the relationship between prevention as an investment strategy and the perceived protection, perceived transparency and perceived performance risk of unit-linked life insurance and the effect of these perceptions on the intention to purchase interest-rate guarantees for life insurance contracts. The results indicate a mediating role of perceived protection, perceived transparency and perceived performance risk in the relationship between prevention as an investment strategy and the intention to purchase interest rate guarantees. Financial literacy is

Mediator	**Index**	**SE(Boot)**	**BootLLCI**	**BootULCI**
Perceived protection	0.1334	0.0244	0.0881	0.1828
Perceived transparency	0.0308	0.0105	0.0134	0.0544
Perceived performance risk	-0.0328	0.0119	-0.0582	-0.0115

Table 39: Conditional Indirect Effect of X on Y

Mediator	Index	SE(Boot)	BootLLCI	BootULCI
Perceived protection	-0.0541	0.0179	-0.0894	-0.0197
Perceived transparency	-0.0281	0.0078	-0.0464	-0.0151
Perceived performance risk	0.005	0.0039	-0.0007	0.0154

Table 40: Index of Moderated Mediation

Moderator	Value	% below	% above
Perceived protection	3.75	79.15	20.85
Perceived transparency	2.90	52.02	47.98
Perceived performance risk	No statistical significance transition points		

Table 41: Johnson-Neyman Significance Regions

Mediator	Financial literacy	Effect	Boot SE	BootLLCI	BootULCI
Perceived protection	1.1131	0.1932	0.0310	0.1337	0.2550
Perceived protection	2.3422	0.1267	0.0241	0.0814	0.1768
Perceived protection	3.5713	0.0602	0.0342	-0.0061	0.1287
Perceived transparency	1.1131	0.0619	0.0150	0.0365	0.0964
Perceived transparency	2.3422	0.0274	0.0098	0.0117	0.0512
Perceived transparency	3.5713	-0.0071	0.0123	-0.0326	0.0168
Perceived performance risk	1.1131	-0.0384	0.0142	-0.0705	-0.0138
Perceived performance risk	2.3422	-0.0322	0.0117	-0.0578	-0.0115
Perceived performance risk	3.5713	-0.0261	0.0108	-0.0521	-0.0088

Table 42: Conditional Indirect Effects

Variables	Perceived protection		Perceived transparency		Perceived risk		Intention to purchase IRG	
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Constant	2.755***	2.321***	2.834***	2.000***	2.670***	1.328**	2.537***	1.624***
Prevention	-0.238***	0.467***	0.170***	0.521***	0.367***	0.481***	0.168***	0.059
Financial literacy		0.495***		0.713***		0.314*		
Prevention x financial literacy		-0.096***		-0.148***		-0.058*		
Perceived protection								0.536***
Perceived transparency								0.198***
Perceived risk								-0.084**
R^2	0.043	0.064	0.017	0.063	0.084	0.095	0.016	0.395

Table 43: Summary of Results

Significance:***p<.001;**p<.05;*p<.01

Control Variable	β	**p-value**
Age	-0.027	0.000
Gender	0.069	0.429
Number of children	0.050	0.241
Income	-0.004	0.755
Education	0.005	0.775
Wealth	0.033	0.142
UL product knowledge	0.121	0.029
Extant knowledge of financial investments	0.003	0.948

Table 44: Control Variables

shown to moderate the relationship between prevention and the perceived protection, perceived transparency and perceived performance risk and indirectly moderates the relationship between prevention and the intention to purchase interest rate guarantees through perceived protection and perceived transparency.

These findings bring several contributions to the current understanding of how prevention as an investment strategy affects the intention to purchase interest-rate guarantees for life insurance. To the best of our knowledge, the present paper is the first to investigate the direct relationship between prevention as an investment strategy and the intention to purchase interest rate guarantees. Previous research in the Multi-Cumulative Prospect Theory (MCPT) has shown that the demand for investment guarantees for long-term saving products such as life insurance can only be explained if one takes into account the fact that investors care about the interim changes in their portfolio (see, e.g., Ruß and Schelling, 2017; Braun et al., 2017) and in particular about the negative developments in their portfolio. Departing from this idea from MCPT, we have settled on an existing construct that has been previously used in the marketing literature before, namely prevention as an investment strategy, to investigate whether the fact that investors care about interim changes in their portfolio can explain the demand for interest rate guarantees. In particular, we draw from existing theories about what motivates individuals in achieving their goals and how perceptions about a particular financial product can influence the decision to purchase said financial product.

First, we have established a direct positive effect of prevention on the intention to purchase interest rate guarantees. However, after taking into account the mediating role of perceptions about life insurance, the direct effect disappears. Therefore, we have advanced the mediating role of perceptions about life insurance on the relationship between prevention and the decision to purchase interest-rate guarantees, and we have found evidence that financial literacy influences this relationship through the perceptions about life insurance. So far, financial literacy has been shown to influence the behavior of individuals with respect to their savings and retirement decisions (see, e.g., Lusardi and Mitchell, 2007), as well as the amount of debt taken (see, e.g., Lusardi and Tufano, 2015). This present paper provides evidence that financial literacy can moderate the relationship between prevention as an investment strategy and the perceptions about a financial product. Moreover, the paper shows that the indirect effect of prevention as investment strategy on the intention to purchase a guarantee through the perceptions of unit-linked insurance depends on the level of financial literacy. This adds to the literature on financial literacy, demonstrating that the level of financial literacy can influence perceptions about a specific product and therefore influence the intention to purchase an additional safety feature for such a product. This is especially important since life insurance with a savings component is usually used for old age provision and previous research has shown that the presence of a guarantee can significantly impact the capital available for retirement, due to the high costs associated with the provision of guarantees (see, e.g., Lachance and Mitchell, 2003; Sinha and Renteria, 2005; Finkelstein et al., 2003; Renz and Stotz, 2015).

In addition to the theoretical implications of the paper, we would also like to address some practical implications. First, due to the mediating role of perceptions about life insurance on the relationship between prevention as an investment strategy and the intention to purchase interest rate guarantees, insurers should develop a strategy of enhancing the customers' perceptions about life insurance rather than trying to sell the customers products with guarantees. Not only would this be more beneficial for customers, who would benefit from more upside potential in their retirement accounts, but this would also reduce the insurer's costs associated with the provision of guarantees. One possibility for insurers to enhance these perceptions (increased perceived protection, increased perceived transparency and decreased perceived performance risk) would be through adequate marketing strategies.

Moreover, given the moderating role of financial literacy on the relationship between investment strategy and intention to purchase interest rate guarantees via perceptions about life insurance, the intention to purchase interest rate guarantee can be influenced by changing the level of financial literacy of consumers. By addressing financial literacy directly through educational programs that specifically target the issues of life insurance transparency, performance risk and the actual risk covered by such a product, customers can be made aware of the real costs and benefits of such an interest rate guarantee and conversely their intention to purchase such an additional feature can be influenced. Thus, it is crucial not only for insurers, but also for regulators to adequately address this issue.

5 Limitations and Future Research

One of the shortcomings of our model framework is that it predicts purchase intention, which does not automatically translate into actual purchase behavior. Previous research has demonstrated that when confronted with additional measures of actual behavior, there is low correlation between actual behavior and purchase intention (see, e.g., Foxall, 2003). For example, a customer who has a purchase intention might refrain from buying a product if their willingness to pay is below the price at which the insurer would be willing to offer such a feature for the life insurance product. Therefore, additional research is needed in order to see whether customers who have a purchase intention have sufficient willingness to pay in order to cover the cost of such products. Moreover, in the present study, we have questioned customers whether they would be willing to purchase an interest rate guarantee. In a real-world scenario, it is more difficult to disentangle the willingness to purchase interest rate guarantees from the willingness to purchase long-term saving products or life insurance. Additionally, the paper suffers from the usual shortcomings of the use of surveys as a data collection methodology, such as endogeneity and hypothetical bias. While we believe that the present study represents an initial step into establishing the role between prevention as an investment strategy and the intention to purchase an interest rate guarantee via perceptions about life insurance and the level of financial literacy, an incentive-aligned experiment might provide more accurate results.

6 Conclusions

The question of how prevention influences the perceptions about life insurance and how this in turn affects the customers' willingness to purchase interest rate guarantees for life insurance contracts (or, guarantees for long term saving products in general) is of paramount importance for insurers, regulators and consumers alike. Guarantees are expensive features which can have a great impact on an individual's retirement account and it is crucial to understand the factors which determine their demand. It is important for insurance companies and regulators to understand the drivers behind consumers' intention to purchase interest rate guarantees. In general, the tendency of regulators has been to ensure safety for all participants in the financial markets and therefore regulatory measures such as mandatory interest rate guarantees, for example in participating life insurance, were taken. However, recent research shows that the one-fits-all approach to regulation is outdated, since different customers have different needs when it comes to protection through financial regulation (see, e.g., Bühler et al., 2016; Milanova and Schreiber, 2017).

In this paper, we investigate the determinants of the intention to purchase interest rate guarantees, which can give us further information about what drives customers to purchase such features in order to be protected against financial adversity. In the current financial environment, it is important to understand to what extent people are willing to purchase such product features that ensure them against bearing financial risk. In particular, such features represent an additional cost layer for insurance companies, which need to employ costly risk management measures in order to be able to offer guaranteed returns. Therefore, it is interesting to see under which conditions consumers actually have the intention to purchase such products. So far, several economic theories have tried to explain the demand for guarantees in life insurance products. In particular, expected utility theory has used the concept of risk aversion, while prospect theory has used loss aversion in order to explain preferences for guarantees, but none of these theories offer a satisfactory explanation for the demand for interest rate guarantees. In this paper, we build on one of the theoretical assumptions underlying the multi-cumulative prospect theory, namely that investors also care about interim changes in their portfolio value and therefore they prefer prevention as an investment strategy, in which they try to minimize the fluctuations in their portfolio. Therefore, the paper tries to investigate whether the desire for stable financial returns explains the demand for interest rate guarantees, when also accounting for other factors such as the attitudes towards life insurance and the level of financial literacy.

The literature on guarantees for life insurance products has so far focused mainly on valuation of guarantees under various different frameworks. The present paper is the first one to our knowledge to survey potential customers on their intention to purchase interest rate guarantees and to analyze the antecedents of the decision making process. In the context of a low interest rate environment, where insurers face difficulties in financing such products and consumers face the risk of poverty during retirement, it seems sensible to us to investigate whether consumers actually want such products and which are the antecedents of such a decision making process.

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