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An incentive-compatible experiment on probabilistic insurance and implications for an insurer‘s solvency level

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Abstract

This paper is the first to conduct an incentive-compatible experiment using real monetary payoffs to test the hypothesis of probabilistic insurance which states that willingness to pay for insurance decreases sharply in the presence of even small default probabilities as compared to a risk-free insurance contract. In our experiment, 181 participants state their willingness to pay for insurance contracts with different levels of default risk. We find that the willingness to pay sharply decreases with increasing default risk. Our results hence strongly support the hypothesis of probabilistic insurance. Furthermore, we study the impact of customer reaction to default risk on an insurer's optimal solvency level using our experimentally obtained data on insurance demand. We show that an insurer should choose to be default-free rather than having even a very small default probability. This risk strategy is also optimal when assuming substantial transaction costs for risk management activities undertaken to achieve the maximum solvency level.

Keywords: Behavioral Insurance, Probabilistic Insurance, Risk Management of Insurance Companies

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1 Introduction

After the financial crisis of 2008, financial services customers became highly concerned about the safety of financial products. The default risk inherent in such contracts has become a driving factor of purchase decisions; a situation highlighted by the emergence of financial strength ratings for financial services providers.[1] In fact, there is ample empirical evidence that awareness of default risk has an influence on consumers' insurance purchase behavior. Experimental research by Wakker et al. (1997), Albrecht and Maurer (2000), and Zimmer et al. (2009) shows that people dislike insurance contracts with default risk and that insurance demand is very sensitive to the insurer's level of default risk. These studies demonstrate that people will purchase an insurance contract that has the possibility of defaulting only if the insurance premium is substantially reduced compared to a default-free contract. Moreover, Zimmer et al. (2009) find that there are a considerable number of consumers who will refuse to buy insurance at any level of default risk.

The very pronounced sensitivity of individuals' willingness to pay that has been elicited in experiments cannot be plausibly explained by expected utility theory. Instead, Wakker et al. (1997) propose prospect theory, put forward by Kahneman and Tversky (1979), to explain this drop in willingness to pay caused by only small increments in the default probability. They coined the term "probabilistic insurance" for insurance contracts that have a non-zero probability of default. While existing experimental evidence and survey data support their theory, a rigorous incentive-compatible test of probabilistic insurance is still missing in the literature. We employ

[1] See AMB Credit Reports – Consumer (www.ambest.com/sales/AMBCreditReportsConsumer/default.asp).

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the experimental design by Bolle (1990) allowing us to use unusually high financial stakes in the experiment to ensure a truthful revelation of preferences on part of the participants. To reveal policyholders' true willingness to pay for insurance with default risk, we conducted a laboratory experiment using real money. Participants in that experiment stated their maximum willingness to pay for four different insurance contracts that only differed with respect to their default probability (0%, 1%, 2% and 3%, respectively).

We find that in the presence of default risk, individuals either refuse to purchase insurance altogether or they demand a considerable reduction in the insurance price compared to a default-free situation. For example, while in the case of the default-free insurance contract, 71% of the participants were willing to pay at least the actuarially fair premium, in the case of the insurance contract with a default risk of 3%, 50% of the participants were not willing to pay the actuarially fair premium. The median willingness to pay decreases from 54€ for a default-free contract to 29€ for a contract with 3 % default probability (this compares to actuarially fair premiums of 40€ and 38.80€, respectively). This stark reduction in willingness to pay in the presence of only small default probabilities underscores how sensitively individuals react to only small increases in default risk when purchasing insurance. Our results hence strongly support the hypothesis of probabilistic insurance.

Our second research question is motivated by empirical evidence suggesting that the relationship between default risk and consumers' willingness to pay has important implications for financial services firms. Epermanis and Harrington (2006) observe a significant reduction of insurance demand in the year of and the year following a rating downgrade for the U.S. property-liability insurance market. Eling and Schmit (2008) find a similar relationship for the German insurance market, although to a somewhat lesser degree. Sommer (1996) and Cummins and Danzon (1997) show that a firm's financial distress is accompanied by a decrease in insurance premium income and vice versa. It has thus become crucial for financial services firms to take into consideration consumers' reaction to default risk when pricing products and managing risk. There exist several theoretical approaches to optimal risk management that incorporate the risk sensitivity of policyholders (see Doherty and Tinic, 1981; Rees et al., 1999; Gründl and Schmeiser, 2002; Zanjani, 2002; Gründl et al., 2006; Froot, 2007). However, all these approaches encounter the same problem, namely a lack of information on actual willingness to pay for insurance contracts when there is a default risk. We seek to fill this gap by developing a normative model of optimal risk management that accounts for empirically validated policyholders' reaction to the insurer's safety level and derive the shareholder value maximizing solvency level of an insurance company when consumers are fully aware of the insurance contracts' default risk.

Our shareholder value model is based on Zanjani's (2002) model. To obtain empirically validated insurance demand curves, we use the data from our experiments. We find that the optimal safety level is a corner solution. Shareholder value will be maximized by choosing a default probability of zero, a result mainly driven by the overproportional increase in demand when the insurer chooses to be default-free rather than having even a very small default probability.[2] Insurer safety is therefore not only an effective means of attracting clients; it also contributes substantially to shareholder value.

[2] We are fully aware that in the "real" world, complete certainty as to the insurer's solvency level cannot be achieved due to the prohibitively high costs of the risk management that would be necessary to eliminate every possibility of risk. However, an insurance company with a default probability very close to zero will be viewed by consumers as essentially default-free (see, e.g., Wakker et al., 1997).

We have three reasons for believing that a controlled laboratory experiment is the best way to empirically study individuals' willingness to pay for insurance with default risk. First, consumers only have a vague idea of their insurer's default risk. In a laboratory setting, the necessary information can be provided. Second, it is difficult or even impossible to control for consumer knowledge and manipulate the level of default risk in other types of empirical studies. Third, the experimental approach enables us to measure willingness to pay for insurance with default risk isolated from confounding variables, such as insurer reputation or size.

Our paper consists of two parts, each of which is concerned with one of our two research questions. While the first part (Sections 2 to 4) describes our incentive compatible test of probabilistic insurance, the second part (Section 5) analyzes the optimal solvency level of a shareholder value-maximizing insurance company in the presence of policyholders whose willingness to pay for insurance depends on the company's default risk. In Section 6, we disuss our findings, and draw conclusions in Section 7.

2 Behavioral Theory and Hypothesis

In economic analysis, expected utility theory has been long established as the standard model of individuals' decision behavior. For the case of insurance, it states that a risk-averse individual is willing to purchase insurance at a premium above the expected value of indemnity payments in order to reduce their risk exposure (Mossin, 1968, Smith, 1968, Schlesinger 1981, 2000). Expected utility theory implies that if there is a small default probability of the insurance contract, this will only marginally reduce an individual's willingness to pay for such a contract. Doherty and Schlesinger (1990) show that while the presence of default risk in an insurance contract does alter the demand for insurance in an expected utility framework, it does not necessarily reduce the demand. However, experimental studies have found that if there is a nonzero probability of contract nonperformance, individuals' willingness to pay decreases sharply (Wakker et al., 1997, Albrecht und Maurer, 2000, Zimmer et al., 2009). As Wakker et al. (1997) note, one would have to assume a degree of risk aversion that is far beyond the usual parameters found in experimental studies on risk aversion in order to explain this behavior within the framework of expected utility theory. The reason for such a behavior, which would be dubbed irrational under the paradigm of expected utility theory, seems to lie in individuals' perception of risk. A coherent theory on what drives individuals' decisions under risk and what role the perception of risk plays in this process was first presented by Kahneman and Tversky (1979) and is known as *prospect theory*. According to this theory, individuals assign subjective probability weights to outcomes, which differ from the objective probabilities. Events with a small objective probability are assigned a too large weight, whereas events with a high objective probability are assigned a too small weight. Wakker et al. (1997) apply this insight to the purchase of probabilistic insurance, i.e. an insurance contract that bears a non-negative default risk. In this context, prospect theory predicts that individuals will weigh the small probability of contract nonperformance very highly, i.e., assign a weight that is larger than the objective probability, and hence substantially reduce their willingness to pay for such a contract.

Wakker et al. (1997, p. 12) state that under the hypothesis of expected utility, the willingness to pay for probabilistic insurance should be close to the actuarially adjusted fair premium that accounts for the potential nonperformance of the contract. More formally, this can be expressed as follows:

$$WTP_{dp=x\%} \approx (1 - x\%)\pi_{dp=0\%}, \qquad (1)$$

where $WTP_{dp=x\%}$ denotes the willingness to pay for an insurance contract with a default probability of $x\%$, and $\pi_{dp=0\%}$ denotes the insurance premium for a default risk-free contract. This result holds across various specifications of the utility functions as well as risk aversion parameters. It follows that for an individual maximizing expected utility, the ratio of willingness to pay and the actuarially adjusted premium should be close to one, regardless of the level of default risk. The theory of probabilistic insurance, however, suggests that the willingness to pay for an insurance contract with default risk should be less than the actuarially fair premium for an insurance contract, adjusted for the probability of nonperformance. For our analysis of individuals' willingness to pay for contracts with different levels of default risk, we therefore hypothesize the following:

Hypothesis: The ratio of willingness to pay and the actuarially adjusted premium decreases with increasing default risk.

3 Experiment

The goal of the laboratory experiment is to elicit individuals' willingness to pay[3] for several theft insurance contracts, each having a different level of default risk. The results of this experiment allow us to test the theory of probabilistic insurance by Wakker et al. (1997). To ensure that

[3] See Hanemann (1991), p. 635, for the definition of "willingness to pay".

subjects were involved and interested in the experimental tasks (i.e., to elicit *true* or *real* indications of willingness to pay), all the decisions they made had real-money consequences.[4]

Experimental Design[5]

Our experiment adapts basic features of Schade et al.'s (2012) design. Similar to the exact probabilities treatment in that study, our participants were asked to imagine that they had inherited a coin collection worth 800 Euro.[6] Each participant was given a picture of the collection, which later would serve as a receipt. Subjects were informed that only *one* person out of all those participating in the experiment would be given a *real* coin collection[7] and that this person would receive the value of the collection (800 Euro) in cash. All other participants would receive a forgery. The person owning the real coin collection—and thus the 800 Euro—would be chosen at random at the end of the experiment. Each participant was also told that the real collection was threatened by a 5% risk of theft. To help them better understand this concept, participants were told that a 5% chance of theft is comparable to the chance of drawing ball 1 out of 20 numbered balls in a bingo cage.[8]

Subjects were next offered full insurance to protect against a possible loss of the 800 Euro. It was pointed out that *only* the owner of the real coin collection would actually pay for the insurance contract; all other insurance purchase decisions would be considered hypothetical.

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[4] For a discussion of hypothetical vs. real payoff experiments, see, e.g., Holt and Laury (2002, 2005).

[5] For the complete experimental instructions, see Appendix A.

[6] This is an artificial situation where it is unlikely that our respondents would have any reference to real-life risks and insurance prices.

[7] This "randomized reward scheme" was first proposed and demonstrated to work by Bolle (1990). The Schade et al. (2011) study was its first implementation in a realistic insurance scenario.

[8] See Slovic et al. (1977) for an early application of an urn game in the insurance context.

To elicit maximum willingness to pay, we employed Schade and Kunreuther's (2001) secret price mechanism (see also Schade et al., 2012; Wang et al., 2007), which is a modification of the standard Becker-DeGroot-Marschak mechanism.[9] This modification is necessary to deal with the situation of multiple probabilities for which the original BDM mechanism is known to cause problems (Safra et al., 1990). Subjects were asked to state their maximum willingness to pay for the respective insurance contract. They were not given any information about the selling price but were instead informed that the seller had already set a price (the "secret price"), which is written on an index card within a sealed envelope. The envelope was shown to the participants. Subjects were further told that if their buying price was equal to or higher than the secret selling price, they would be able to purchase the theft insurance for the secret price. However, if their maximum willingness to pay was lower than the secret price, they would be refused insurance protection. We made it clear that it would be in the participants' best interest to state their true maximum willingness to pay and advised them to do so from different perspectives. If they stated a price lower than their maximum willingness to pay, they might not be able to purchase insurance even though they would have been willing to buy protection at a higher price than the amount stated. If they stated a price higher than their maximum willingness to pay, they might have to pay this higher price (assuming they were the owner of the real coin collection) even though they would not have been willing to do so.

[9] Becker et al. (1964). Note that the argument for incentive compatibility of the secret price mechanism is, however, the same as made and mathematically proven by Vickrey (1961). Basically, it is essential that the probability density of the subjective distribution of the secret price is non-zero in all relevant parts.

Participants were then asked to indicate, on a computer screen, their maximum willingness to pay for each of four alternative contracts.[10] All contracts were displayed on the computer screen at the same time, and the order of the contracts was the same for everyone. Participants were informed that each contract had a different level of default risk (0%, 1%, 2%, or 3% default probability[11]) but that in all other aspects, the insurance contracts were identical. Each contract had a secret price. Subjects were further told that one of the contracts would be chosen at random and that the stated price for this chosen contract would determine whether or not the person would purchase that particular insurance contract. Thus, participants should have been aware that each insurance purchase decision could be the relevant one, and thus constitute their only chance to buy theft insurance. Participants had no choice in the matter of which contract would be the relevant one for them.[12] Figure 1 shows one example of the theft insurance contracts offered.

[10] The computer-assisted part of the experiment was programmed and conducted with z-Tree software (Fischbacher, 2007).

[11] To specify the insurer's default situation, we decided to use numeric default probabilities instead of, e.g., insurer financial strength rating or issuer credit rating definitions provided by rating agencies. In a prestudy we found that individuals overestimate default probabilities for verbal insurer rating definitions. For example, for an insurer rating definition by Standard and Poor's of BBB (i.e., good financial security characteristics), which corresponds to an actual annual default probability of 0.3%, individuals estimate the insurer's default probability to be 8% on average (median = 1%, standard deviation = 13%).

[12] Using the random lottery incentive system, we ensure that all participants have an incentive to reveal their true maximum willingness to pay for each insurance contract. Because of money constraints for recruiting subjects, we could not use a between-subjects design. To obtain the same amount of data, we would have had to invite four times as many participants. For the validity of the random lottery incentive system, see, e.g., Cubitt et al. (1998).

Figure 1
Theft insurance contract

Risk Exposure	
Risk of theft	Loss of a coin collection valued at 800 Euro with a 5% probability of theft; 95% probability of no theft
Insurance contract 4:	
Insurance:	1-year theft insurance
Scope of indemnity	Loss due to theft of coin collection
Sum insured:	800 Euro
Default risk	**3%,** i.e., the insurer pays its valid claims in 97 out of 100 cases, and in 3 out of 100 cases the insurer does not pay!

Note: The figure shows an example of the theft insurance contracts offered. The reported contract has a 3% default probability.

After all experimental sessions to elicit individuals' willingness to pay had been conducted, we scheduled a further session in order to determine both the participant to whom the payoff from the experiment would be made in real terms, as well as the amount of this real-money payoff.[13] We invited all participants from the experiment to participate. In a first step, a random draw determined who would be eligible for obtaining the value of the coin collection from the experiment. The decision that the individual had made during the experiment was used to determine whether or not he or she would purchase theft insurance. The owner of the real coin collection drew one ball from a bingo cage with 20 balls to determine whether theft occurred. If theft occurred and the participant did not have an insurance contract, he lost the coin collection. If theft occurred and the participant had purchased insurance, the owner of the coin collection did a further random draw from a bingo cage to determine whether or not the insurance company would pay the claim.

[13] The experimental sessions were held in November and December 2007. The additional session to determine the participant who would get the real-money payoff was held in January 2008.

Sample. We conducted 16 experimental sessions, with a total of 181 subjects. Participants were invited to take part through subject pools of the faculty of business and economics and the faculty of psychology of a major public university in Germany. The invitation explained that the experiment would last for about 75 minutes and that the amount that could be earned from participating would depend on decisions made and chance. However, all participants were guaranteed 4 Euros remuneration. The number of subjects varied across the sessions, ranging from 4 to 14. All subjects were seated in separate computer booths during the sessions. Table 1 provides some summary statistics about the sample.

Table 1
Summary statistics about the subject pool in the experiment.

	n	%
Gender		
Female	*79*	*44%*
Male	*102*	*56%*
Highest educational degree		
No high-school degree	*23*	*13%*
High-school degree	*124*	*68%*
University degree	*34*	*19%*
Other	*1*	*0%*
Occupation		
Student	*117*	*65%*
Employee	*28*	*15%*
Other	*36*	*20%*
Field of study		
Economics/ Business Administration	*145*	*80%*
Other	*36*	*20%*

Note: The table provides some summary statistics on the participants in the experiment (N=181).

4 Results from the experiment: Willingness to pay and demand curves

Descriptive Analysis

Tables 2 and 3 set out our findings. Seven percent of the participants were unwilling to pay anything for insurance, regardless of the insurer's default situation. Of those who did want insurance protection, 3% refused to accept any default risk, 2% were willing to pay only for an insurance contract with 1% default risk, and 10% rejected the contract having 3% default risk, but accepted all other levels of default risk. Six percent could not be categorized due to inconsistent behavior. For example, one person was willing to accept all levels of default risk, but refused to buy a default-free contract. The biggest fraction of individuals (71%) was willing to purchase insurance at every level of default risk. The results further show that individuals who—in principle—accept default risk demand a considerable reduction in insurance premiums compared to their willingness to pay for a default-free contract. For example, individuals require a premium reduction of 9% (comparison of median values) when facing a 1% default probability.[14] For a contract with 3% default probability, over 50% of the participants stated a price less than the expected claims payment (i.e., 38.80 €), whereas in the default-free case, only 29% were unwilling to purchase insurance for the price of the expected claims payment of 40 Euro.[15]

[14] We report median values (or other percentiles) because we observed right-skewed and fat-tailed distributions of willingness to pay.

[15] The latter result is in line with a study by Loubergé and Outreville (2001, p. 231). They report that around 70% of their 192 subjects were willing to buy an actuarially fair insurance contract for a loss occurring with a probability equal to or smaller than 5%.

Table 2
Consumers' reactions to insurance with default risk

Participants who …	*Frequency (percent)*
do not want to buy insurance (or willingness to pay = 0)	*13 (7.2)*
demand insurance protection in general	*168 (92.8)*
of those	
only accept a default-free insurance contract	*6 (3.6)*
do not accept insurance contracts with 2% and 3% default risk	*4 (2.4)*
do not accept insurance contracts with 3% default risk	*18 (10.7)*
accept all levels of default risk	*129 (76.8)*
show inconsistent behavior	*11 (6.5)*

Note: The first two rows show the portion of consumers unwilling or willing to purchase insurance ($N = 181$). Rows 4–7 report the fraction of individuals who generally demand insurance protection but only accept certain default levels.

Table 3
Consumer willingness to pay

			Insurance contracts with a default probability of			
			0%	*1%*	*2%*	*3%*
Willingness to pay		*Mean*	*92 €*	*69 €*	*57 €*	*46 €*
		SD	*99 €*	*81 €*	*71 €*	*71 €*
	Percentiles	*25%*	*30 €*	*20 €*	*15 €*	*5 €*
		50%	*54 €*	*49 €*	*40 €*	*29 €*
		75%	*100 €*	*80 €*	*72 €*	*50 €*
		90%	*222 €*	*150 €*	*125 €*	*100 €*

Note: The table reports the descriptive statistics of willingness to pay for all insurance contracts and those individuals who are generally willing to purchase insurance protection ($N = 168$).

Regression Analysis

To provide a more formal test of probabilistic insurance, we conduct a regression analysis of individuals' willingness to pay. For every individual, we observe the willingness to pay for four contracts with different levels of default risk, resulting in a total of 724 observations. Of the 181 participants in the experiment, 13 have stated that they were not willing to pay anything for insurance. We exclude those individuals from our regression. The remaining data set still contains several observations with zero willingness to pay. We account for this censoring in the distribution of willingness to pay by employing a Tobit regression model with random effects and a cut-off value of zero at the lower end of the distribution.

Our dependent variable is the ratio of an individual's willingness to pay for an insurance contract with a given default risk and the fair premium for the corresponding contract. Because of this standardization, we can compare the willingness to pay across different levels of default risk for a given individual. Furthermore, since probabilistic insurance predicts this ratio to be declining in the default probability, it allows for a straightforward test whether the hypothesis of expected utility can be rejected with our experimental data.

As we want to analyze the effect of default risk on the (relative) willingness to pay for insurance, we include dummies for each of the three insurance contracts that are exposed to default risk. The contract with zero default probability hence serves as a reference category. The results of the regression of willingness to pay on variables indicating the level of default risk of the different contracts are reported in column (1) in Table 4. The parameter estimates for the dummies for contracts with default risk are all negative and statistically significant at the 0.1% level. Participants' willingness to pay for probabilistic insurance relative to the actuarially fair premium hence decreases with increasing default risk. This result strongly supports the hypothesis of probabilistic insurance.

We further include control variables for the respondents' socio-economic characteristics. In particular, we include a dummy for female respondents, the respondents' highest educational degree, a dummy for students enrolled in an economics or business administration program, the respondents' self-assessed general willingness to take risks as well as their optimism and their self-assessed competence in insurance-related questions. The results from that regression are reported in regression (2) in Table 4. The parameters for the variables indicating the different contracts are again negative and statistically significant.

The variables representing personal characteristics, however, do not have any significant influence on the outcome variable. On average, the overproportionally negative effect of an increase in the default risk on willingness to pay is independent of observable characteristics of the participants.

In a third regression we exclude those 15 individuals whose willingness to pay was increasing in default risk. Under the assumption of risk-averse or risk-neutral individuals, an increase in stated willingness to pay when default risk is increasing, these responses are irrational. This could mean that either participants did not understand the experimental task or they were not stating their real willingness to pay. The results from this regression are reported in column (3) of Table 4. The parameter estimates do not significantly differ from those in the first regressions.

Table 4
Tobit regression with random effects of individuals' willingness to pay for probabilistic insurance, divided by the actuarially fair premium.

	(1)	(2)	(3)
Contract			
3% dp	*-1.2785****	*-1.2784****	*-1.5147****
	(-10.45)	*(-10.45)*	*(-14.27)*
2% dp	*-0.8802****	*-0.8803****	*-1.0975****
	(-7.31)	*(-7.31)*	*(-10.50)*
1% dp	*-0.5921****	*-0.5922****	*-0.7027****
	(-4.93)	*(-4.93)*	*(-6.76)*
Female		*-0.3773*	*-0.3842*
		(-1.17)	*(-1.12)*
Degree		*-0.1310*	*-0.1726*
		(-0.89)	*(-1.08)*
Economics		*-0.2764*	*-0.3351*
		(-0.72)	*(-0.81)*
Willingness to take risks		*0.0975*	*0.0713*
		(0.80)	*(0.54)*
Competence		*-0.0425*	*-0.0319*
		(-0.41)	*(-0.29)*
Optimism		*-0.1900*	*-0.1645*
		(-1.60)	*(-1.22)*
Constant	*2.2629****	*3.6120****	*3.9406****
	(13.56)	*(3.99)*	*(4.18)*
Observations	*672*	*672*	*612*

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Note: The table reports the results of a Tobit regression with random effects and a cut-off value of zero. The dependent variable in all three regressions is the respondents' willingness to pay for each of the four insurance contracts divided by the actuarially fair premium. The first two regressions use all the observations for participants who stated a nonzero willingness to pay for at least one contract (N=168). The third regression excludes those participants whose willingness to pay was increasing in the contract's default risk (N=153).
The variables *contract1* to *contract3* are dummy variables indicating the insurance contract. The contract with no default risk serves as the reference category. The variable *Session size* is a variable that counts the number of participants that attended the experimental session of the respective individual. The variable *female* is a binary variable indicating female respondents. The variable *Degree* represents the highest educational degree a respondent has attained. It is a category variable that ranges from 1 to 9, where higher values indicate a higher educational degree. The variable *Economics* is a dummy variable indicating students enrolled in an economics or business administration program. The variable *Willingness to take risks* is the respondent's self-assessed proneness to take risks, the variable *Competence* is the respondent's self-assessed competence in insurance-related

questions, and the variable *Optimism* is the respondent's self-assessed degree of optimism. The self-assessments of *Willingness to take risks, Competence* and *Optimism* were done on a Likert-scale from 1 to 7, where higher values indicate a higher degree of the respective attribute.

5 Optimal safety level of an insurer

We analyze the optimal safety level of an insurance company using a single-period model of shareholder value maximization. This is a modified version of the model proposed by Zanjani (2002).[16] We keep the model as simple as possible in order to focus on the effects stemming from insurance demand. We explain our model in some detail so as to clarify our system of notation as well as our underlying assumptions.

At the beginning of the period, shareholders invest equity capital E_0 which is constant over the entire period, and Q policyholders pay insurance premiums $Q \cdot \pi$ which are invested within the company and serve as safety capital. Insurance demand depends on the insurance price as well as the default risk and is obtained from our experimental data, as will be discussed below. For the sake of simplicity and to match the experimental design discussed above, we assume independent and identically binomially distributed risks in a single line of business. Policyholder claims L will be settled at the end of the period. Shareholders favor a company policy that maximizes the net present value of their equity capital investment,[17] i.e., they favor a (net) shareholder value (SHV) maximization. Assuming that the loss distribution is uncorrelated with

[16] For related approaches, see, e.g., Doherty and Garven (1986), Cummins and Sommer (1996), Cummins and Danzon (1997), Rees et al. (1999), and Gründl and Schmeiser (2002).

[17] For a discussion of the rationality of the objective function "maximize shareholder value," see Wilhelm (1989).

financial asset prices, and further that the insurance company invests at the risk-free rate, we can write the shareholder value of the insurance company as follows:

$$SHV = Q\pi - \frac{1}{1+r_f} E(L) + DPO(L;Y), \tag{2}$$

where r_f denotes the risk-free rate of return, Y denotes the terminal asset value of the insurer ($= (Q\pi + E_0)(1 + r)$) and $DPO(L;Y)$ denotes the value of the default put option in the presence of shareholders' limited liability. i.e., the value of the payments policyholders will not receive in the case of insolvency.[18]

Shareholder value thus arises from premium income, reflecting policyholder willingness to pay depending on the insurer's risk situation, minus the arbitrage-free value of the claims payment.[19]

Note that if there is information asymmetry between shareholders and policyholders, the insurer could increase risk after the contracts were signed,[20] e.g., by extracting equity capital from the firm. This would increase the default put option value and, by the same amount, shareholder value. In our model, policyholders cannot be cheated like this because of, for example, regulatory intervention. Instead, we assume—and this is in line with our experimental design—that policyholders receive the safety level originally promised. The insurer's decision variables are thus its safety level and the insurance premium π.

[18] Butsic (1994).

[19] This model is in line with Doherty's two-factor valuation model (Doherty, 1991, p. 234), or the similar approach by Froot and Stein (1998), in that the shareholder value, in principle, contains the valuation of systematic risk components as well as of idiosyncratic firm risk. The firm-specific risk situation influences firm value for its shareholders, in our case via the policyholder demand function. Lower demand for insurance due to higher firm risk can reduce shareholder value. This value reduction can be subsumed under "bankruptcy costs" (Stulz, 1996, p. 13). Therefore, it becomes rational for the insurer to engage in corporate risk management. For the importance of corporate risk management, see also Nocco and Stulz (2006).

[20] Smith and Stulz (1985, p. 398).

Since equity capital cannot be adjusted (in the short run), given a certain default-dependent premium income, additional risk management measures like purchasing reinsurance or financial derivatives may be necessary to achieve the desired (and promised) level of default risk. In our model, we calculate the value of those necessary risk management measures as the difference between the actual shareholder value and the shareholder value under the promised level of default risk, i.e.

$$RM_{x\%} = SHV_{actual\_dp} - SHV_{promised\_x\%},$$

where $x \in \{0; 1; 2; 3\}$.[21] Whenever the actual shareholder value is less than the shareholder value under the promised default probability, it means that the insurer's default probability is higher and risk management measure need to be taken. In the reverse case, the insurance company is safer than it needs to be and it can for example free up equity capital. We assume that these transactions come at a proportional cost *c*, so that the shareholder value after all necessary transactions equals

$$SHV_{ensured\_x\%} = SHV_{promised\_x\%} - c \cdot RM_{x\%}.$$

Data

We use data from the experiment described above in determining the optimal safety level of an insurance company. Our "sample" insurance company has the following characteristics. The insurer operates in the market for property-liability insurance with a market size of 181

[21] Appendix B provides a more detailed description of how we determine the value of the necessary risk management measures.

policyholders.[22] The price-demand functions for insurance contracts with different levels of default risk are derived from our experimentally obtained data.[23] The best model fit is obtained from the nonlinear model $q_{dp} = e^{b\pi + c}$, where q_{dp} characterizes the percentage of the sample willing to purchase theft insurance at the price of π. The parameters b ($b < 0$) and c represent the coefficient estimates that are presented in Table 5.

Table 5
Aggregate demand curves

	Model	Parameter	Estimate	Std. error	T-ratio	R^2
Price-demand curves	$q_{0\%}$	b	-0.011	3.13E–04	-33.99	0.997
		c	-0.081	5.41E–03	-15.59	
	$q_{1\%}$	b	-0.014	3.8E–04	-38.53	0.996
		c	-0.086	1.20E–02	-7.15	
	$q_{2\%}$	b	-0.017	4.05E–04	-42.76	0.996
		c	-0.095	1.11E–02	-8.60	
	$q_{3\%}$	b	-0.021	6.56E–04	-31.24	0.993
		c	-0.206	1.61E–02	-12.82	

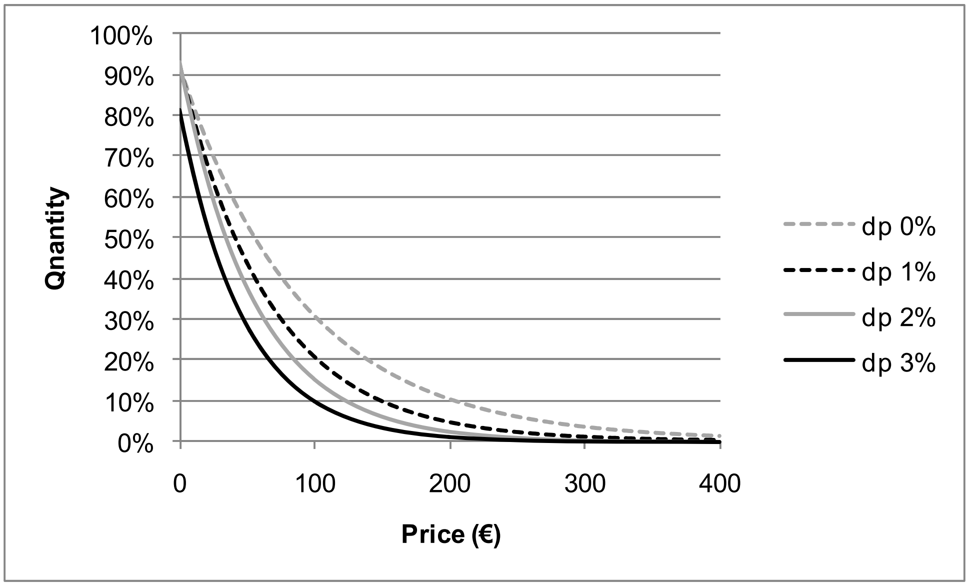
Note: The table reports the regression results of the estimated price-demand models for each default probability. The dependent variable is the percentage of the respective sample willing to purchase theft insurance contracts. The sample size for estimating the price-demand curves is 181 subjects for each contract type.

[22] Note that for the sake of simplicity, market size is determined by the number of participants in our experiment. To have adjusted demand to any market size would not have changed the basic results.

[23] Appendix C provides more details on the estimation of the demand curves.

Figure 2 shows the estimated price-demand curves for each default probability. The figure clearly illustrates that the lower the default probability of an insurance contract, the higher the demand for it.

Figure 2
Price-demand curves



Note: The figure shows the estimated price-demand curves for each default probability (dp). Demand is expressed as the percentage of the market size.

Results

Tables 6.1–6.3 report the results of our analyses on the insurer's optimal safety level for three different amounts of initial equity capital E_0, a risk-free interest rate of $r_f = 10\%$, and a cost rate for risk management of c = 20%. The results show that shareholder value is inversely related to the level of default risk: the higher the insurer's default probability, the lower the shareholder value. Thus, it is optimal for our "sample" insurer to choose a default probability of 0%, regardless of the transaction cost of risk management,[24] because there will be an overproportional increase in premium income when reducing the probability of default by 1%.[25] By choosing a safety level of 0% instead of 1%, premium income increases from 3,960 Euro (3,996 Euro respectively in case of no initial equity capital) to 5,240 Euro, i.e., by 32% (31% respectively). This leads to an increase in shareholder value of 42% as compared to the shareholder value at the higher default risk of 1%. Moreover, for safety levels of 0% or 1%, shareholders need only little or even no additional risk management due to the optimal price of insurance for each chosen default probability. For a default-free insurance contract, around 25% of the policyholders will be willing to pay more than 2.5 times the expected loss. For a default risk of 1%, 25% of the policyholders will still be willing to accept insurance contracts at a price twice as high as the expected claims payment. Thus, the premium obtained for each insurance contract sold, together with the equity capital endowment, serves as sufficient safety capital.[26] Independent of the initial equity endowment, choosing a high default probability of 3% always requires a substantial amount of costly additional risk management.

The parameters for the demand curves were derived from our experiment. Since they are the main driver for our result that a default probability of zero is optimal for an insurer, we performed a robustness check to test the sensitivity of our results to changes in these parameters. To that end, we constructed demand curves with parameters that were either two standard

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[24] A more realistic modeling of the transaction costs would imply to positively relate them to the level of default risk. However, this would further extend the optimality lead of the 0% default probability situation.

[25] There are different risk management measures that an insurer can undertake in order to achieve the promised default level, as for example reinsurance, alternative risk transfer, or raising equity capital.

[26] *Note*: Since the aggregate losses are binomially distributed, the arbitrage-free value of any calculated risk management measure, $RM_{dp\%}$, is the minimum value of risk management measures needed to meet the promised default probability.

deviations below or above the actual estimate (see Table 5 for the parameters). Our results did not change significantly in either of these specifications.

Table 6.1
Insurer's optimal safety level

Contractually agreed default probability (safety level)	Q	Optimal π in €	$Q\pi$	$SHV_{actual\_dp\%}$ in €	Actual dp	$SHV_{promised\_dp\%}$ in €	$RM_{dp\%}$ in €	$SHV_{ensured\_dp\%}$ in €
0%	40	131	5240	3785.69	0.07%	3785.45	0.24	**3785.41**
1%	36	110	3960	2652.54	0.83%	2658.58	-6.04	2658.58
2%	31	99	3069	1948.16	1.79%	1958.18	-10.02	1958.18
3%	25	85	2125	1235.23	3.41%	1222.14	13.09	1219.52

Note: The table provides the insurer's optimal safety level with constant equity $E_0 = 400€$, a cost rate $c = 20\%$, a risk-free interest rate $r_f = 10\%$, and a market size of 181 potential policyholders. Q represents the number of policyholders willing to purchase the specific insurance contract at price π. dp is the default probability of the respective insurance contract. $SHV_{actual\_dp\%}$, $SHV_{promised\_dp\%}$, and $SHV_{ensured\_dp\%}$ represent situation-specific insurer shareholder values (see Figure 4 for a more detailed explanation of these variables). $RM_{dp\%}$ is the arbitrage-free value of risk management.

Table 6.2
Insurer's optimal safety level (continued)

Contractually agreed default probability (safety level)	Q	Optimal π in €	$Q\pi$	$SHV_{actual\_dp\%}$ in €	Actual dp	$SHV_{promised\_dp\%}$ in €	$RM_{dp\%}$ in €	$SHV_{ensured\_dp\%}$ in €
0%	40	131	5240	3785.91	0.07%	3785.45	0.45	**3785.36**
1%	36	110	3960	2655.04	0.83%	2658.58	-3.08	2658.58
2%	31	99	3069	1953.53	1.79%	1958.18	-4.65	1958.18
3%	29	78	2262	1249.66	5.48%	1219.71	29.96	1213.72

Note: The table provides the insurer's optimal safety level with constant equity $E_0 = 100€$, a cost rate $c = 20\%$, a risk-free interest rate $r_f = 10\%$, and a market size of 181 potential policyholders.

Table 6.3
Insurer's optimal safety level (continued)

Contractually agreed default probability (safety level)	Q	Optimal π in €	$Q\pi$	$SHV_{actual\_dp\%}$ in €	Actual dp	$SHV_{promised\_dp\%}$ in €	$RM_{dp\%}$ in €	$SHV_{ensured\_dp\%}$ in €
0%	40	131	5240	3785.98	0.07%	3785.45	0.08	**3785.88**
1%	37	108	3996	2655.96	0.95%	2656.15	-0.19	2656.15
2%	31	99	3069	1955.32	1.79%	1955.68	-0.36	1955.68
3%	29	78	2262	1255.14	5.48%	1219.71	35.43	1212.62

Note: The table provides the insurer's optimal safety level with constant equity $E_0 = 0€$, a cost rate $c = 20\%$, a risk-free interest rate $r_f = 10\%$, and a market size of 181 potential policyholders.

6 Discussion

Given that policyholders have full information about the insurer's safety situation, our results suggest that the insurer should choose a default-free safety level rather than even a small probability of default. The overproportional increase in premium income when reducing the default probability outweighs any costs of risk management necessary to achieve a higher solvency level. This result is in line with Rees et al.'s (1999) theoretical results on solvency regulation, which show that shareholder value is maximized by reducing the default risk to zero if expected utility maximizing consumers are fully informed of the insurer's insolvency risk. Our result is of higher empirical validity, however, because we extend the Rees et al. approach in two major ways: we allow consumers to be heterogeneous with respect to their purchase behavior, and the insurer faces an empirically observed price-default-demand curve.

The above results imply that shareholder value is mainly determined by choice of solvency level. The lower the level of insurer default risk, the higher the shareholder value. The negative relationship between the level of default risk and shareholder value is chiefly driven by policyholder reaction to default risk. Our experimental results reveal that individuals are willing to pay substantially more to avoid or reduce default risk. The question now arises as to whether these results can be generalized to other insurance purchase contexts. We believe the answer is "yes." Although individuals' absolute willingness to pay may vary between different settings of insurance purchase decisions, the observed general behavior, i.e., the relative differences in willingness to pay between different solvency levels, should remain valid, for two reasons. First, our results confirm previous results in the literature on policyholder reactions to default risk:[27] Individuals either will not accept default risk or they will ask for a greater than expected reduction in insurance premiums. Moreover, this reaction is sensitive to the level of default probability, i.e., the higher the default probability, the lower the willingness to pay.[28] Second, we are the first to demonstrate the robustness of those results in an incentive-compatible experiment. Previous experimental research on policyholder reactions to default risk is based on hypothetical insurance purchase decisions. The insurance purchase decisions in our experiment had real-money consequences. Subjects could buy an insurance contract to protect themselves against a real possible loss.

The resulting extremely high shareholder values of the insurance company and the respective profitability indices (shareholder value divided by initial equity capital), e.g., 3,785% for risk-free contracts in the case of 100€ initial equity capital, are driven by our assumption of a monopolistic insurance market in which the insurer is free to set insurance prices to maximize shareholder value. The incentive-compatible elicitation of willingness to pay for insurance contracts is comparable to a purchase decision in a monopoly situation. To the best of our knowledge, there is no mechanism for measuring incentive-compatible willingness to pay in a nonhomogeneous goods situation; and even if there was, such a mechanism probably would be complex and difficult to implement in a laboratory experiment because of limited rationality. Based on the chosen elicitation method, therefore, a natural next step was to derive our price-default-demand curves for the monopoly case. However, our results also hold under different

[27] See Wakker et al. (1997), Albrecht and Maurer (2000), and Zimmer et al. (2009).

[28] See particularly Zimmer et al. (2009).

conditions, such as a price regulation regime allowing only a certain level of markup over expected losses. Even when prices are set at a level that just covers expected losses,[29] we observe an optimal solvency level of 0% (see Table 7).

Table 7
Insurer's optimal safety level under price regulation

Contractually agreed default probability (safety level)	Q	π in €	$Q\pi$	$SHV_{actual\_dp\%}$ in €	Actual dp	$SHV_{promised\_dp\%}$ in €	$RM_{dp\%}$ in €	$SHV_{ensured\_dp\%}$ in €
0%	108	40	4320	839.51	29.59%	392.73	446.78	**303.37**
1%	95	39.4	3762	755.25	33.91%	316.18	439.07	272.27
2%	85	39.2	3332	682.28	42.11%	251.86	430.42	208.82
3%	65	38.8	2522	564.26	41.00%	174.59	389.67	135.62

Note: The table provides the insurer's optimal safety level with constant equity $E_0 = 100€$, a cost rate $c = 20\%$, a risk-free interest rate $r_f = 10\%$, and a market size of 181 potential policyholders. The variables are defined in Table 6.1.

7 Conclusion

In this paper, we test the hypothesis of probabilistic insurance by eliciting individuals' willingness to pay for theft insurance contracts with default risk in an experimental setting. We are the first to show that the effects of probabilistic insurance are not limited to hypothetical (questionnaire) experiments, but that they instead generalize to an economic, incentive-compatible experiment. While most participants in our experiment were generally willing to buy insurance, their willingness to pay for insurance protection decreased significantly when there was a nonzero probability of contract nonperformance. The median willingness to pay decreases from well above the actuarially fair premium in case of a default-free insurance contract to an

[29] Note that such "fair" premiums also contain an implicit markup stemming from discounting.

amount significantly below the fair premium in case of a 3% default probability. This drop in willingness to pay underscores how important insurance is to individuals as a means to completely eliminate risk. This finding is particularly remarkable because it is independent of participants' observable personal characteristics such as gender and risk aversion. We therefore provide not only strong evidence in favor of the hypothesis of probabilistic insurance, but also demonstrate that it applies to individuals from different socio-economic groups.

Based on this result, this paper additionally provides new evidence on the relationship between an insurer's default situation, the price of insurance, and shareholder value. Based on our experimental results, we derive price-demand curves for several default probabilities. These demand curves are implemented in a shareholder value maximization approach to determine the insurer's optimal level of default risk. Our results suggest that the insurer should choose a default probability of zero. This corner solution is even optimal for the insurer when assuming substantial costs of risk management undertaken to achieve the maximum solvency level.

Our results can be utilized for regulatory purposes. Providing consumers with information about insurers' default situation appears to have great potential for effectively protecting policyholder interests via market discipline. Although the insurance industry usually is not in favor of being regulated, our results suggest that disclosure requirements need not actually be very onerous for insurers. Insurers can maximize shareholder value by engaging in a risk policy that ensures solvency. Thus, controlling their solvency level will become critical to the success of insurance companies if they are required to disclose their solvency situations as intended, for example, by the U.S. RBC approach and the European Solvency II project.[30]

Furthermore, our experimentally-based results provide empirical evidence that corporate risk management is a rational course of conduct for the financial services sector. Although the limited liability of shareholders of publicly held insurance companies is conducive to the adoption of risk-prone policies, i.e., the exact opposite of engaging in risk management, customers' strongly negative reaction to default risk self-enforces an almost riskless firm policy. An outside observer might believe that it is the company itself that is risk-averse, instead of such an attitude being the consequence of customer pressure. This may explain why so many theoretical contributions[31] aiming at deriving an optimal firm policy assume a risk-averse insurer or financial services firm instead of taking a more straightforward limited liability shareholder value approach as we have done here.

[30] See Vaughan (2009) and Holzmüller (2009). See also Harrington (2005) for a discussion of the relevance of market discipline for the financial stability of insurance companies.

[31] See, e.g., Grossman and Zhou (1996) and Kaluszka and Okolewski (2008).

Appendix A: Experimental instructions

Note: The complete experiment consisted of two parts. This paper is based on the first part, but some of the instructions refer to both parts. All instructions referring to coin collection B are irrelevant to this paper and should be disregarded. The instructions are translated from German.

Experimental instructions:

Please imagine yourself in the following situation:

- You inherited two coin collections, coin collection A and coin collection B, worth 800 Euro each. You will receive a photo of each collection during the experimental session.

- Unfortunately, only one person out of the entire group of subjects participating in our experiment (180–200 persons) will actually receive a real coin collection A and one person will receive a real coin collection B. All other participants will be given a forgery. We would have liked to give all of you a real coin collection, worth 800 Euro, but the budget for our experiment is not large enough.

- The persons owning a real coin collection will be chosen at random at the end of the experimental study in January 2008. Participants who own a real coin collection will actually receive the value of the coin collection, worth 800 Euro, in cash! It is possible that one person will end up with both real coin collections, in which case that person will receive 1,600 Euro in cash. Thus, when making your decisions, keep in mind that you could be the actual owner of coin collection A and/or coin collection B.

- Further, imagine that you keep coin collection A in your own apartment and coin collection B with your parents' apartment.

- Both coin collections are threatened by the risk of theft. The probability that a theft of your coin collection A or your coin collection B will occur is 5% for each collection. The risk of theft can be illustrated with a bingo cage. A 5% chance that a theft occurs is comparable to the chance of drawing ball #1 out of 20 numbered balls in a bingo cage.

- You can now buy theft insurance for each of the coin collections you have inherited. Each coin collection will be separately insured against a possible theft.

- At this point, we want to clarify that only the owner of the real coin collection will actually pay for the insurance contract.

- Furthermore, during your research into theft insurance contracts, you read an article stating that insurance contracts can be exposed to the risk of default, i.e., there is a small probability that the policyholder will not be reimbursed by the insurer in case of a loss.

Part 1—Coin collection A[32]

In the first part of the experiment you have the opportunity to purchase a theft insurance contract against a possible loss of your coin collection A.

The selling procedure for the theft insurance contract is as follows:

- You do not know the price of the theft insurance contract. Before the experiment, the experimenter selected a secret selling price for the theft insurance contract, which he wrote down and sealed in an envelope and then put the envelope on the front desk.

- You are required to state a buying price equal to your maximum willingness to pay for the theft insurance contract. This is the maximum amount of money you are willing to pay for the insurance contract.

- After the experiment, the experimenter will open the envelope containing the secret selling price. If your buying price is equal to or higher than the secret selling price, you can purchase the theft insurance policy at the secret selling price. If your buying price is lower than the secret price, you will not be allowed to buy the theft insurance contract.

- Note that the experimenter changes the secret selling price for every experimental session. So even if someone from a previously conducted experiment has told you the price revealed at their experiment, your secret selling price will be different.

- If you are able to purchase an insurance contract and if you are the person owning the real coin collection, then you will be required to pay the selling price, not the price you actually stated.

- In this situation, your best course of action is to state your maximum willingness to pay for the theft insurance contract.

- First, it does not make sense to state a buying price higher than your maximum willingness to pay since you may end up paying this high price.

- Second, it does not make sense to state a price lower than your maximum willingness to pay because if your stated price is lower than the selling price, you will not be permitted to

[32] Part 2 referred to coin collection B, and is not reported here.

purchase the theft insurance contract, even if you would be willing to pay the secret selling price.

- If you do not want to buy the theft insurance contract, please mark the appropriate box.

- Please do not announce your buying price to the others and do not ask questions that will allow others to guess your buying price.

As a reminder: We are still talking about the theft insurance contract for coin collection A.

- We will ask you to state your willingness to pay for four different insurance contracts.

- All four contracts have the same scope of indemnity, but each contract has a different level of default risk.

- Each contract has a secret selling price. All selling prices were chosen prior to today's experimental session and are each in a separate envelope on the front desk.

- You can purchase only one of the four insurance contracts (since there is only one coin collection A). The relevant contract will be determined at random. Thus, keep in mind that each purchase decision you make could turn out to be the relevant one.

At the end of today's experiment, you will find out whether or not you have purchased an insurance contract.

- At the end of today's experiment, one of the four insurance contracts will be randomly selected. That contract will then be relevant for all participants. A randomly determined participant will draw a card out of a box containing four cards. The cards are numbered from 1 to 4. The number of the drawn card defines the relevant insurance contract.

- The experimenter will then open the envelope and the secret selling price thus revealed will determine whether or not you have purchased an insurance contract.

- At this point, the experimenter will come to your seat and will note on your photo of coin collection A whether or not you have purchased an insurance contract and, if you have purchased one, at what price. Afterward, the experimenter will collect all photos.

Whether you are the person owning the real coin collection will be determined at the end of the experimental study in January 2008.

- An independent person will draw one photo out of all photos of coin collection A. The participant to whom this photo belongs is the owner of the real coin collection A and thus the owner of 800 Euro in cash.

- If this participant has purchased an insurance contract, he or she must pay the respective price to the experimenter.

- A bingo cage with 20 balls will be used to determine whether or not coin collection A will be stolen. The owner of the real coin collection will draw one ball from the bingo cage. If the ball with the number 1 is drawn, theft will occur. If that participant does not have an insurance contract, he or she will lose coin collection A, and thus 800 Euro. If a ball with a number between 2 and 20 is drawn, there will be no theft and the participant will keep the 800 Euro.

- Whether or not the insurance company will actually pay the claim in case of a loss (if you have purchased an insurance contract) will also be determined by a bingo cage. The number of balls in the bingo cage and which balls will determine whether or not a default has occurred depend on the level of default risk. Again, the owner of the coin collection will draw the balls.

  One Example: If the insurance contract has a default probability of 1%, there will be 100 balls in the bingo cage. If the ball with the number 1 is drawn, default occurs and the insurance company will not reimburse the value of the stolen coin collection. In this case, the owner of the coin collection will receive nothing. If a ball with a number between 2 and 100 is drawn, no default occurs and the insurance company will pay the owner of the coin collection 800 Euro.

You now have the opportunity to purchase a theft insurance contract against a possible loss of your coin collection A. An insurance agent offers you different insurance contracts. All these contracts will reimburse the value of the coin collection A, worth 800 Euro, in case of theft.

Remember, there is a 5% probability that your coin collection will be stolen, which, using the bingo cage as an example, means that the chance a theft occurs is comparable to the chance of drawing ball #1 out of 20 numbered balls in the bingo cage.

Each contract has a different level of default risk, i.e., the possibility that the insurer will not pay its valid claims in case of a loss. A 1% default risk can be interpreted as follows. One out of 100 policyholders who report a loss will not be reimbursed by the insurer. A 1% chance that a default occurs is comparable to the chance of drawing ball #1 out of 100 numbered balls in a bingo cage.

We now present you with four different insurance contracts. We ask you to state your maximum willingness to pay for each of the four contracts.

- Please keep in mind that any one of the four contracts could be the relevant one.

- Thus, you should be aware that each of your decisions could be the relevant one and thus constitute your only chance of buying theft insurance.

Risk Exposure	
Risk of theft	Loss of a coin collection valued at 800 Euro with a 5% probability of theft; 95% probability of no theft

Insurance contract 1:	
Insurance:	1-year theft insurance
Scope of indemnity	Loss due to theft of coin collection
Sum insured:	800 Euro
Default risk	**3%,** i.e., the insurer pays its valid claims in 97 out of 100 cases, and in 3 out of 100 cases the insurer will not pay!

Insurance contract 2:	
Insurance:	1-year theft insurance
Scope of indemnity	Loss due to theft of coin collection
Sum insured:	800 Euro
Default risk	**2%,** i.e., the insurer pays its valid claims in 98 out of 100 cases, and in 2 out of 100 cases the insurer will not pay!

Insurance contract 3:	
Insurance:	1-year theft insurance
Scope of indemnity	Loss due to theft of coin collection
Sum insured:	800 Euro
Default risk	**1%,** i.e., the insurer pays its valid claims in 99 out of 100 cases, and in 1 out of 100 cases the insurer will not pay!

Insurance contract 4:	
Insurance:	1-year theft insurance
Scope of indemnity	Loss due to theft of coin collection
Sum insured:	800 Euro
Default risk	**0%,** i.e., the insurer always pays its valid claims; so the insurer pays in 100 out of 100 cases!

Please state the maximum price you are willing to pay for each of the four insurance contracts.

Again, in making your decisions remember that you could be the actual owner of coin collection A and that each of the four contracts could be the relevant one, i.e., you have no choice in the matter of what contract to purchase. You will have to pay the insurance price only if you are the owner of the real coin collection A.

Insurance contract 1: **Default risk: 3%,** i.e., the insurer pays its valid claims in 97 out of 100 cases, and in 3 out of 100 cases the insurer will not pay!	o I'm willing to pay a maximum of _____ Euro. o I do not want to purchase this insurance contract.
Insurance contract 2: **Default risk: 2%,** i.e., the insurer pays its valid claims in 98 out of 100 cases, and in 2 out of 100 cases the insurer will not pay!	o I'm willing to pay a maximum of _____ Euro. o I do not want to purchase this insurance contract.
Insurance contract 3: **Default risk: 1%,** i.e., the insurer pays its valid claims in 99 out of 100 cases, and in 1 out of 100 cases the insurer will not pay!	o I'm willing to pay a maximum of _____ Euro. o I do not want to purchase this insurance contract.
Insurance contract 4: **Default risk: 0%,** i.e., the insurer always pays its valid claims; so the insurer pays in 100 out of 100 cases!	o I'm willing to pay a maximum of _____ Euro. o I do not want to purchase this insurance contract.

Appendix B: Determining the necessary risk management measures

Assume that the insurer promises a certain default probability, e.g. 1%. Depending on the offered insurance price, $\pi_{1\%}$, policyholders will pay $Q\pi_{1\%}$ premium income, which leads to a shareholder value of $SHV_{promised\_1\%}$. Note that $SHV_{promised\_1\%}$ represents the shareholder value for a 1% default risk assuming that either enough safety capital Y is on hand to obtain the 1% risk level or that the necessary risk management instruments are available without transaction costs. If equity capital E_0 remains constant after signing the contracts, the actually resulting default probability can deviate from the promised one. To obtain the promised level of default risk, the insurer will need to either undertake additional risk management or extract equity capital. The arbitrage-free value of such a risk management measure, $RM_{1\%}$, needed to achieve the promised safety level of 1% is the difference between shareholder value based on the default probability (given the initial amount of equity capital) before undertaking additional risk management ($SHV_{actual\_dp\%}$) and shareholder value at the 1% default level ($SHV_{promised\_1\%}$):

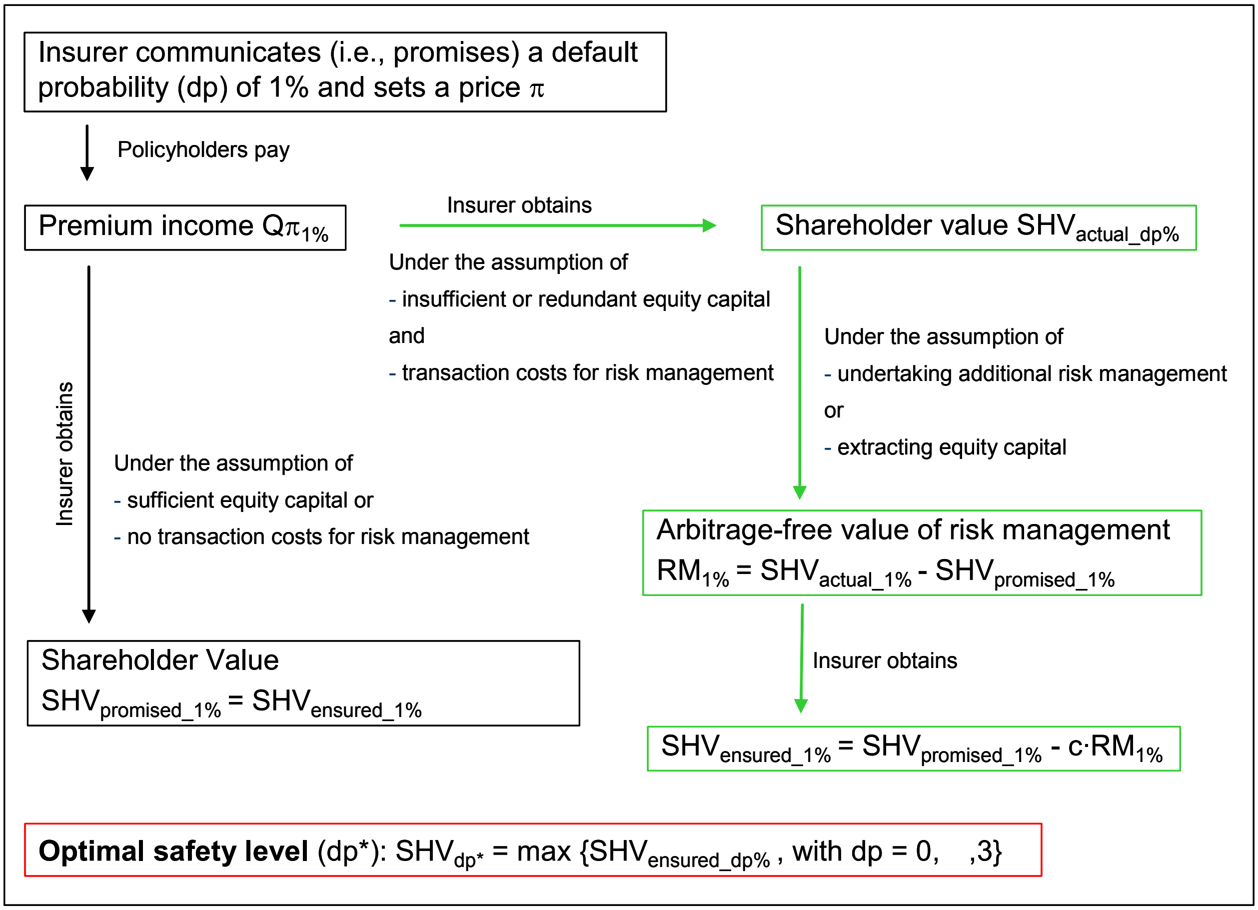
$$RM_{1\%} = SHV_{actual\_dp} - SHV_{promised\_1\%} . \tag{1}$$

If c represents the transaction cost factor of risk management measures, shareholder value for a safety level of 1% is described by

$$SHV_{ensured\_1\%} = SHV_{promised\_1\%} - c \cdot RM_{1\%} . \tag{2}$$

Shareholder value for a promised and targeted default situation of 1% ($SHV_{ensured\_1\%}$), given that risk management entails transaction costs, is thus the shareholder value for a promised safety level ($SHV_{promised\_1\%}$) less the transaction costs of the risk management ($c \cdot RM_{1\%}$) necessary to achieve the promised default risk. If the promised default situation is already the status quo or risk management has zero transaction costs ($c = 0$), then $SHV_{ensured\_1\%} = SHV_{promised\_1\%}$. Furthermore, if $RM_{1\%} < 0$, i.e., the actual shareholder value is lower than the promised one, the desired (lower) safety level can be achieved by extracting equity capital from the company. Assuming that lowering the level of risk management costs less than increasing it, for the sake of simplicity, we set c = 0 for the first case and c > 0 for the latter. Following this procedure, which is summarized in Figure B1, the optimal safety level can now be determined by simply comparing shareholder values for different promised, as well as ensured, levels of default risk.

Figure B1
Determination of optimal safety level



Note: The figure summarizes the procedure we use to determine the insurer's optimal safety level, taking the 1% default probability situation as an example.

Appendix C: Demand curves

To estimate aggregate demand curves (or price-response curves)[33] from the willingness to pay data, we employed several parametric models commonly used in the literature.[34] In a first step, we analyze separately the relationship between price and demand for each level of default risk. Table C1 summarizes the results for the different models. The best overall fits between the data and the models were obtained from the nonlinear model $q_{dp} = e^{b\pi + c}$, where q_{dp} characterizes the percentage of the sample willing to purchase theft insurance at the price of π. The parameters b ($b < 0$) and c represent the regression coefficients to be estimated. We applied this model for each default probability dp (dp = 0%, 1%, 2%, and 3%) and thus obtained four different price-demand curves. All quantities were obtained directly from the frequency distributions of individual willingness to pay responses for the respective insurance contract (N = 181 for each contract type).

[33] *Note*: In a monopolistic market environment, the price-response curve equals the market-demand curve. See Phillips (2005, p. 38) for more details on the difference between price-response and demand curves.

[34] See, e.g., Phillips (2005) for an overview of price-response models.

Table C1
Estimated aggregate price-demand curves

Model	Parameter	Estimate	Std. error	T-ratio	Adj. R^2
$q_{3\%} = e^{b\pi}$	b	-0.272	1.13E-03	-24.10	0.968
$q_{3\%} = \frac{e^{a+b\pi}}{1+e^{a+b\pi}}$	a	1.049	6.09E-02	17.23	0.989
	b	-0.039	1.74E-03	-22.17	
$q_{3\%} = a + b\pi$	a	0.476	3.23E-02	14.74	0.452
	b	-0.002	2.40E-04	-6.57	
$q_{3\%} = a + b\pi + c\pi^2$	a	0.609	2.60E-02	23.40	0.774
	b	-0.005	4.05E-04	-11.74	
	c	6.75E-06	7.96E-07	8.48	
$q_{3\%} = e^{b\pi+c}$	b	-0.021	6.56E-04	-31.24	0.993
	c	-0.206	1.61E-02	-12.82	

Note: The table reports the regression results of all estimated price-demand curves for a 3% default probability. The dependent variable in Rows 1–5 is the percentage of the respective sample willing to purchase theft insurance contracts ($N = 181$).

In a second step, we estimate a price-default-demand curve, i.e., demand is not only a function of the offered price, but also of the insurer's default situation. Table C2 summarizes the results for the different models. The model $q = e^{adp+b\pi+c}$ has the best fit, where q, again, represents the percentage of individuals willing to buy insurance at price π, but this time the insurer's default probability dp is included as an independent variable. The parameters a, b, and c are estimated. Again, all quantities are derived from the frequency distributions of 181 respondents' willingness to pay statements for all insurance contracts ($N = 724$). Figure C1 illustrates the price-default-demand curve for the model with the best fit.

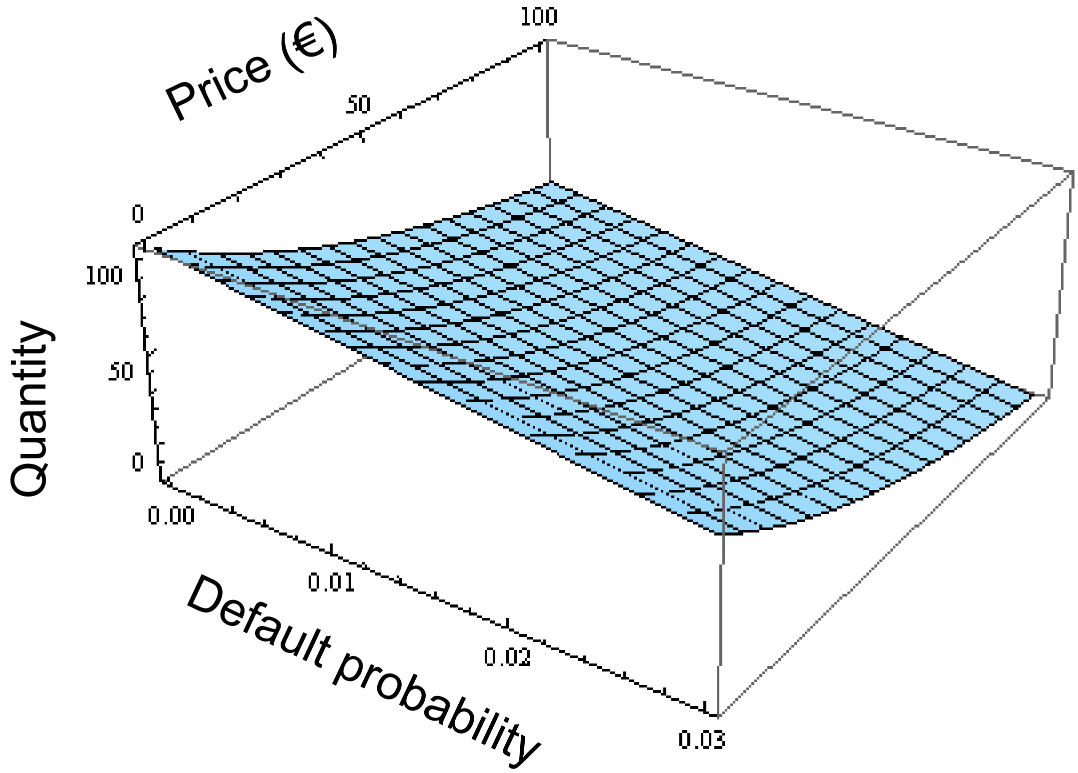
For our analysis, we use the single price-demand curves for each default risk because the fit with real data is more precise than with the price-default-demand curve. Figure C2 illustrates this more precise fit by showing the fit between the actual demand data and the estimates of demand for insurance with 3% default risk by using either the price-demand curve or the price-default-demand curve.

Table C2
Estimated aggregate price-default-demand curves

Model	Parameter	Estimate	Std. error	T-ratio	R^2
$q = adp + e^{b\pi + c}$	a	-0.752	5.67E-02	-13.26	
	b	-0.014	1.33E-04	-105.18	0.944
	c	-0.126	5.88E-03	-21.42	
$q = a + b\pi + cdp$	a	0.362	6.41E-03	56.51	
	b	0.000	1.54E-05	-27.08	0.504
	c	-2.292	2.38E-01	-9.62	
$q = e^{adp + b\pi + c}$	a	-13.841	0.28717	-48.20	
	b	-0.015	9.19E-05	-163.25	0.970
	c	0.055	5.49E-03	10.01	

Note: The table reports the regression results of all estimated price-default-demand curves. The dependent variable in Rows 1–4 is the percentage of the respective sample willing to purchase theft insurance contracts ($N = 724$).

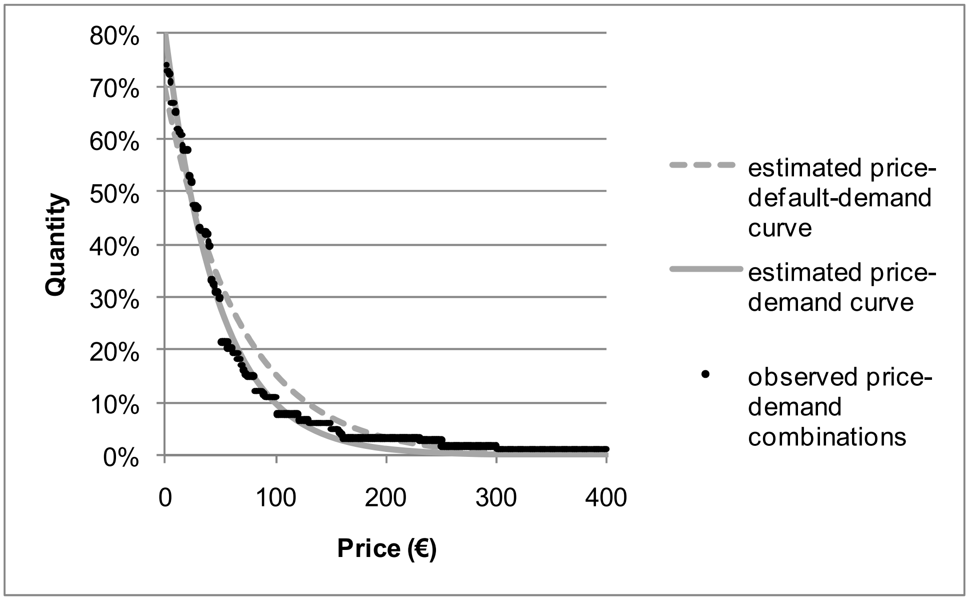
Figure C1
Price-default-demand curve



Note: The figure shows the estimated price-default-demand curve. Demand is expressed as the percentage of the market size.

Figure C2

Consumer demand for a theft insurance contract with 3% default risk



Note: The figure displays the estimated price-demand curve, the estimated price-default-demand curve, and the actual demand data for an insurance contract with 3% default risk.

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