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Prospect Theory and the Appeal of Catastrophe Bonds

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People tend to express strong dislike for default risk in their insurance coverage. Survey participants demand premium reductions of over 20% for a 1% risk of default. We suggest that a similar dynamic is evident in insurers' reinsurance purchases. Insurers are willing to pay significantly more for catastrophe (Cat) bond protection where the risk of default is minimal. The risk of default in traditional reinsurance coverage is generally small (much less than 1%) but it is sufficient to make Cat bonds appealing due their reducing this risk. This behavior is explained by the weighting function of prospect theory.

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1. INTRODUCTION

Catastrophe (cat) bonds have emerged in recent years as an alternative to traditional reinsurance coverage for insurers looking to transfer some of their exposure to natural catastrophes such as hurricanes and earthquakes. One feature of cat bonds that is appealing to insurers is that they have minimal default risk. This means that insurers can be confident that if a catastrophic event does occur the cat bond will pay out as expected.

Wakker, Thaler, and Tversky (1997; hereafter, WTT) highlight the degree to which people don't like default risk in their insurance coverage. They observe that survey participants demand premium reductions of over 20% to offset a 1% default risk. They explain this behaviour through the weighting function of prospect theory. WTT find a particular weighting function that is consistent with their survey results and with other related data.

Gotze and Gurtler (2022; hereafter, GG) find that insurers whose reinsurers have higher risk of default are more likely to replace reinsurance with cat bonds. In this paper we explore a simple model of catastrophe risk where an insurer has a choice between purchasing traditional reinsurance coverage or purchasing a cat bond to transfer this risk. We find that incorporating the same weighting function used by WTT into this model results in behaviour consistent with GG's empirical findings (whereas incorporating expected utility theory does not). We therefore suggest that the appeal of cat bonds to insurers due to their minimal default risk can be explained by the weighting function of prospect theory.

The paper is organized as follows. Section 2 provides a brief overview of prospect theory and reviews the results of WTT. Section 3 explains cat bonds and how they compare to traditional reinsurance coverage. Section 4 discusses the analysis of cat bond usage by GG, in particular their finding that insurers whose reinsurers have higher risk of default are more likely to replace reinsurance with cat bonds. Section 5 explains our simple model of catastrophe risk and how GG's findings are predicted by incorporating the weighting function of prospect theory in this model. Section 6 concludes.

2. PROSPECT THEORY

Prospect theory was introduced by Kahneman and Tversky (1979). Kahneman and Tversky noticed that in a number of studies, people's responses to survey questions related to making decisions under risk were not consistent with what would be predicted by expected utility theory. The responses were, however, consistent with prospect theory. Tversky and Kahneman (1992) introduced a revised version of prospect theory called cumulative prospect theory.

Under expected utility theory, people make choices based on comparing the expected utility of each option. The option with the highest expected utility is selected. The underlying utility function is assumed to be increasing and concave. Current wealth is assumed to be the reference point used for the comparisons.

In prospect theory (and cumulative prospect theory), the focus is on gains and losses relative to a reference point. The reference point needs to be determined as part of the analysis. For example, if insurance coverage is mandatory, purchasing insurance may be the appropriate reference point. Whereas if insurance coverage is optional, not purchasing insurance (i.e., current wealth) may be the reference point used. This differs from expected utility theory where current wealth is always used as the reference point.

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Instead of a utility function, prospect theory involves a value function which satisfies the properties of loss aversion and diminishing sensitivity. Loss aversion means that a loss of a certain amount is felt more keenly than a gain of the same amount. Diminishing sensitivity means that (for example) the increase in the value function from a gain of $100 compared to no gain, is greater than the increase between a $200 gain and a $100 gain.

The final assumption of prospect theory is probability weighting. This assumption says that rather than use actual (or estimated) probabilities as weights when making decisions, people use probability weights that overweight low probabilities and underweight high probabilities. This means that unlikely (and less likely) events loom larger when people are making decisions under risk. In prospect theory, it is this feature that can be used to explain the appeal of insurance (because low probability loss events are weighted more heavily) and lotteries (because the low probability of a big win is weighted more heavily).

WTT use the probability weighting function w(p)=exp(-(-ln p)^0.65) as it agrees with the data from Tversky and Kahneman (1992) and others.

We now discuss how probability weighting can be used to explain people's dislike of default risk.

WTT define probabilistic insurance as an insurance policy involving a small probability that the consumer will not be reimbursed.

WTT capture people's dislike of probabilistic insurance through three surveys. In one survey, 86 university students were asked how much they would pay for a fire insurance policy on a home with full replacement cost of $125,000 where the probability of loss is 1/200. The median response was $700. They were then asked how much they would pay for the same fire insurance policy if there was a 1% chance that in the event of a fire their claim would not be paid. The median response in this case was $500 — a reduction of 29%. (This is less than the expected value so an insurer would of course be unlikely to offer coverage at this price.)

The same students were also asked for their responses if the full replacement cost were doubled (i.e., $250,000). Median responses were $1,300 (no default risk) and $900 (1% default risk) — a very similar reduction of 31%.

The two other surveys — one of university students, and one of money managers — gave similar results, with a 1% risk of default resulting in premium reductions of 25%-30%. In these two other surveys, the no default scenario premium was specified and respondents were asked how much less they would pay in the 1% default risk scenario.

WTT consider the premium reductions that would be demanded based on expected utility theory. Twenty utility functions are examined and for all these functions, the predicted reduction in premium is close to 1% and never exceeds 1.4%. Thus, the results observed in the three surveys are not consistent with expected utility theory.

WTT then consider the probability weighting function w(p)=exp(-(-ln p)^0.65). They show that for a probability of loss p and probability of default q, the premium reduction (discount) demanded is w(qp)/w(p). For p=0.5% (ie 1/200), a default risk of 1% results in a premium reduction of 23% which is consistent with the survey data.

Thus WTT show that people's dislike of default risk as captured through survey results is in line with what is predicted by prospect theory with the weighting function w(p)=exp(-(-ln p)^0.65), and that this behaviour is very different from what is predicted by expected utility theory.

In his review of applications of prospect theory, Barberis (2012) mentions several areas where the weighting function of prospect theory appears to provide insight including:

- average long-term returns for stocks that conduct an initial public offering are lower than stocks of firms that are similar to the issuing firms but do not do an offering (because the small chance that such firms could be the next Google is overweighted; this makes such stocks more attractive to investors and so their prices are higher, and their returns lower).
- in P&C insurance, the small chance of having to pay the deductible is overweighted so people are willing to pay quite a bit more for a low/no deductible.

3. CATASTROPHE BONDS

The first cat bonds were written in the aftermath of Hurricane Andrew, which struck Florida in 1992. The losses due to Hurricane Andrew were unprecedented and resulted in a number of insurers becoming insolvent and stretched the resources of reinsurers. Although reinsurance is a global market and major reinsurers are well positioned to handle significant catastrophic events, very large events (e.g., a repeat of the 1926 Miami hurricane) could result in loss amounts representing more than 25% of global reinsurance capital. Such events could pose a threat to the solvency of reinsurers, so reinsurers may not offer the coverage that primary insurers would like and/or charge very high premiums for the coverage.

Cat bonds offer an alternative way for insurers to transfer the risk of such very large events, with the risk being taken on by capital markets investors instead of a reinsurer. In a cat bond, funds are provided to the sponsor (e.g., an insurer) by investors for a specified event (e.g., Florida hurricane) for a specified period (e.g., 3 years). The full amount of coverage (e.g., $100m) is provided upfront by investors and these funds are invested in safe, liquid assets (e.g., Treasury bonds). Investors receive money market returns (from the invested $100m) plus premium (from the insurer). If the specified event does not occur in the specified period, the funds are returned in full to investors. If the specified event does occur, the funds are used to pay insurer claims resulting from the event.

Cat bonds are appealing to insurers because they are structured in a way that reinsurer default risk is essentially eliminated. Cat bonds are appealing to investors because they offer good returns that are not correlated with broader financial markets.

Sponsoring a cat bond is quite expensive, so currently they are only practical for relatively high coverage/premium amounts.

The cat bond market has been growing steadily since the 1990s and now accounts for approximately 15% of global reinsurance capital. Insurers and reinsurers are the main sponsors of cat bonds but other sponsors have included governments (e.g., Mexican government earthquake and hurricane bonds) and the World Bank (e.g., pandemic bonds which paid out for the Covid-19 pandemic).

4. CAT BONDS OR TRADITIONAL REINSURANCE?

With the emergence of cat bonds as an alternative to traditional reinsurance coverage, how does a primary insurer choose between sponsoring a cat bond and purchasing traditional reinsurance coverage to transfer the risk from catastrophic events?

GG empirically analyzed if and under what circumstances cat bonds can substitute for traditional reinsurance. In particular, they test four hypotheses on the determinants of substitution between reinsurance and cat bonds. We focus on one of these four hypotheses; namely what GG refers to as the reinsurer default risk hypothesis.

GG first note that a study by Park, Xie, and Rui (2019) shows that a reinsurer's financial strength rating is a suitable proxy for its default risk. Therefore, they assume that the average rating of an insurer's reinsurance counterparties can be used as a measure for its exposure to default risk. So, their reinsurer default risk hypothesis is stated as: "Insurers whose reinsurance counterparties exhibit a weaker average rating replace reinsurance with cat bonds."

Based on their empirical analysis of insurer, reinsurer and cat bond data from 2004 to 2017, GG conclude as follows: "Our reinsurer default risk hypothesis, which suggests that cat bonds are valuable for insurers with high reinsurer default risk, is supported by the majority of our analysis."

5. DEFAULT RISK AND THE APPEAL OF CAT BONDS

In Section 2 we saw how people's dislike of insurer default risk can be explained by the weighting function of prospect theory. We will now see how insurers' dislike of reinsurer default risk (as shown by GG's empirical analysis supporting their reinsurer default risk hypothesis) can similarly be explained by the weighting function of prospect theory.

S&P analyzed how default risk varies by financial strength rating in the period 1981 to 2020. This analysis is summarized in Table 1 which is taken from Table 4 of S&P Global (2020). The default risks are the long-term weighted average of corporate defaults (i.e., not specifically reinsurers). As of August 31, 2020, the median rating for the top 40 global reinsurers was 'A'. These reinsurers account for the vast majority of global reinsurance premium.

In GG, the mean expected loss for cat bonds included in their analysis was 2.4%.

We consider a simple model of catastrophe risk where an insurer has a choice between purchasing traditional reinsurance coverage or purchasing a cat bond to transfer this risk.

We assume the following (model assumptions):

- If a loss does occur, it is for the full coverage amount
- If a reinsurer defaults, it is for the full loss amount
- There is no default risk for the cat bond

We will further assume that the weighting function w(p)=exp(-(-ln p)^0.65) used by WTT is also appropriate for our analysis.

Any prospect theory analysis needs to be based around a selected reference point. For our analysis we assume that the appropriate reference point is the purchase of traditional reinsurance.

Our approach is as follows: we consider probabilities of loss (p*) in the range 0.4% to 8%, as this is the range of expected loss for the vast majority of cat bonds. We consider probabilities of default (q) in the range 0.01% to 1% as this is the range of default risk for the vast majority of reinsurers.

In Table 2 we show the reduction in premium that would be demanded for various values of p* and q based on the weighting function w(p)=exp(-(-ln p)^0.65).

The final column of Table 2 converts the premium discount demanded to compensate for default risk into the equivalent premium increase (surcharge) that would be acceptable in order to eliminate default risk. For our simple model, we can interpret this premium increase as how much more an insurer would be willing to pay to transfer the risk through a cat bond rather than through traditional reinsurance.

We saw in Section 2 that for q=1% and p*=0.5% the required premium discount is 23%. The equivalent premium increase in this case is 29% (=23%/(1-23%)). Recall that in general, the premium reduction (discount) demanded is w(qp*)/w(p*).

For a probability of loss of 2.4%, even with very low expected reinsurer default risk (e.g., q=0.01%), insurers would be willing to pay about 6% more in premium to eliminate this risk. This jumps to about 11% higher premium to eliminate a default risk of 0.1%. The results are similar for other values of p* shown in Table 2.

Thus, our simplified model based on the weighting function of prospect theory suggests that even for the very low default probabilities of well under 1% that are typical for reinsurers, insurers are willing to pay materially higher premiums (i.e., 5%-10% or more) in order to eliminate or significantly reduce this default risk; and that the amount of this higher premium that they are willing to pay increases materially as this default risk increases. The fact that cat bonds do eliminate or significantly reduce this default risk is therefore very appealing to insurers especially to those who face higher reinsurer default risk.

This means (for example) that for two insurers — insurer 1 facing little/no reinsurer default risk and insurer 2 facing high reinsurer default risk — the price of the cat bond (when compared to the price of traditional reinsurance coverage) would appear relatively more attractive to insurer 2

Table 1. Default risk by S&P financial strength rating

Rating	AAA	AA	A	BBB	BB	B	CCC/C
Default risk %	0.00	0.02	0.05	0.16	0.63	3.34	28.30

Table 2. Acceptable premium increase to eliminate default risk

Prob of default	Prob of loss	Premium Discount	Premium Increase	Comments
1.00%	0.50%	23%	29%	Example from WTT
1.00%	2.40%	20%	25%	GG: Mean 2.4% expected loss
0.50%	2.40%	16%	19%	
0.20%	2.40%	12%	14%	
0.10%	2.40%	10%	11%	
0.05%	2.40%	8%	9%	A rating: 0.05% prob of default
0.02%	2.40%	6%	7%	AA rating: 0.02% prob of default
0.01%	2.40%	5%	6%	
1.00%	1%	22%	27%	assuming 1% prob of loss (i.e., low prob)
0.10%	1%	11%	13%	
0.01%	1%	6%	6%	
1.00%	0.40%	23%	30%	assuming 1/250 event (i.e., very low prob)
0.10%	0.40%	12%	14%	
0.01%	0.40%	7%	7%	
1.00%	4%	19%	23%	assuming 4% prob of loss (i.e., quite high prob)
0.10%	4%	9%	10%	
0.01%	4%	5%	5%	
1.00%	8%	17%	21%	assuming 8% prob of loss (i.e., very high prob)
0.10%	8%	8%	9%	
0.01%	8%	4%	5%	

and so this insurer would be more likely to purchase the cat bond.

Note that these conclusions are very different from what would be predicted by expected utility theory. Under expected utility theory, the amount of premium discount/surcharge would be close to the default risk. This means that the cat bond would not be materially more appealing than traditional reinsurance coverage, and we would also not expect insurer 2 to be materially more likely than insurer 1 to purchase the cat bond.

The results in Table 2 are therefore consistent with GG's reinsurer default risk hypothesis and provide a theoretical explanation for GG's finding that "insurers whose reinsurance counterparties exhibit a weaker average rating replace reinsurance with cat bonds".

This analysis suggests that the dislike of default risk that was seen in university students and money managers in a lab setting in WTT for a default risk of 1% is also evident in insurers in the risk transfer market for cat events for default risks of significantly less than 1%. And in both settings, this dislike of default risk can be explained by the weighting function of prospect theory.

Please note that although our model is a simple one, it does capture the premium reductions that would be demanded due to default risk based on a weighting function that has been proven effective in similar settings, and loss and default probabilities that are appropriate for analyzing cat bonds.

The results should therefore be interpreted qualitatively rather than as a precise quantitative prediction. For example, the WTT weighting function was used for illustrative purposes and a different weighting function may be more appropriate in a specific cat risk transfer scenario. And the simple model assumptions allowed us to use the formula w(qp*)/w(p*) to easily calculate the premium discounts: relaxing these model assumptions would mean that the premium discount calculations would be more complicated but would not change the pattern of materially higher discounts for increasing probabilities of default.

6. CONCLUSIONS

The fact that people dislike default risk in their insurance coverage is intuitively appealing. The economist and Nobel

laureate Robert Merton shares this intuition. He says the following (about life insurance coverage) in Merton (1993): "Even if the insurance company offers an actuarially fair reduction in the price of the insurance, to reflect the risk of insolvency, a risk averse customer would prefer the policy with the least default risk. Indeed, on introspection, I doubt that many real world customers would consciously agree to accept non-trivial risk on a $200,000 life insurance policy in return for a large reduction in the annual premium, say from $400 to $300."

WTT's analysis of survey data supports this intuition by showing that survey participants demand premium reductions of over 20% for a 1% risk of default. These survey results are consistent with prospect theory using a particular weighting function.

We considered a simple model of cat risk based on WTT's analysis and showed that in order to transfer this cat risk, insurers would be willing to pay significantly higher premiums (5%-10% or more) to eliminate the default risk typically seen in a reinsurance context, and that insurers facing higher reinsurer default risk would be willing to pay materially higher premiums to eliminate this default risk compared to insurers facing less reinsurer default risk. These results provide a theoretical explanation for GG's empirical finding that insurers with higher reinsurer default risk are more likely to replace traditional reinsurance coverage with cat bonds.

In Section 2, we noted that Barberis (2012) highlights a number of examples in a variety of fields where the weighting function of prospect theory appears to provide insight. Our suggestion that insurers' dislike of reinsurer default risk can be explained through the weighting function of prospect theory should be seen as part of this wider context.

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