Managing Snow Risks: The Case of City Governments and Ski Resorts

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1 Introduction

This paper proposes the risk management methods using “Snow Derivatives” for local city governments and ski resorts. We define snow derivatives as the weather derivatives whose underlying asset is index related to snowfall. First of all, this paper studies the impact of snowfall on the financial performance of ski resorts and the local city government. Our preliminary analysis shows that the revenues of the ski resorts and snowfall are in quadratic form (inverted U-shaped) while the snowfall has significant adverse impact on the revenues of the city government. We then design the snow derivatives in order to hedge the risks associated with snowfall and examine the contributions of proposed derivatives to the corporate value of the ski resorts and the local city government. In particular, we use Wang Transform model to incorporate the managers’ risk preference in the evaluation of snow derivatives. We would expect to show that our proposed snow derivatives contribute the value of ski resorts and the local city government. This paper also contributes to the literature providing the comprehensive analysis of weather risk management. We would expect this paper encouraging the use of snow derivatives for both ski resorts and local governments as few of them utilize the derivatives for snow risk management according to Bank and Wiesner (2011) which concludes that the reason why the weather derivatives are not frequently used in Australian markets is the lack of understanding to the weather derivatives.

2 Impact of Snowfall on Visitors for Ski Resorts

First of all, we estimate the impact of snowfall on financial performance of ski resorts. We use maximum snow depth as variable associated with snowfall in our preliminary analysis. We select three representative ski resorts in Niigata prefecture which is one of the most popular ski areas in Japan. We use OLS to estimate the impact of snowfall on the number of visitors.

2.1 Data

We retrieve the weather data from Japan Meteorology Agency (http://www.data.jma.go.jp/obd/stats/etrn/). We choose the Yuzawa as a weather observatory since this is the closest to these ski resorts. Data is retrieved from 1992 to 2012 but 2002 due to the missing data by

Yuzawa observatory.

We also retrieve the data of number of visitors to the ski resorts from several sources such as the white papers and publicly available information such as "List of Number of Visitors for each Ski Resort in each Year" (http://www.geocities.jp/kazu_atm/irikomi.htm) as well as private information provided by Minamiuonuma Tourism Association (Minamiuonuma Kanko Kyokai in Japanese). We initially pick up three ski resorts Joetsu International Ski Resort (Joetsu Kokusai), Gala Ski Resort, and Iwappara Ski Resort since they have relatively large number of visitors and their numbers of visitors are sufficiently available for our analysis.

2.2 Regression Analysis

We analyze the impact of snowfall on the number of visitors using regression analysis. Quadratic form is employed since linear form is not appropriate due to the untabulated analysis. The functional form we specify is

$$y_{i,t} = a_i + b_i x_t + c_i x_t^2 + \varepsilon_{i,t} \qquad (1)$$

Where $y_{i,t}$ is number of visitors of the ski resort i in season t, x_t is maximum snow depth observed in season t in Yuzawa.

2.3 Preliminary Results

Regression results are shown in Table 1.

Table 1 Snowfall Effects on the Number of Visitors (Unit: 10,000)

	Joetsu International	Gala	Iwappara
Intercept	-6.25	3.49	-19.90
	(20.72)	(9.43)	(47.82)
Maximum Snow Depth (m)	58.84***	24.59**	80.60*
	(19.24)	(8.76)	(44.40)
Maximum Snow Depth ^{2}	-13.69***	-5.40**	-18.55*
	(4.31)	(1.96)	(9.93)
Adj R2	0.31	0.25	0.08
N	19	19	19

Note: ***, **, and * indicate 1%, 5%, and 10% level of significance. Standard deviation is in parenthesis. Adj. R^2 indicates adjusted coefficient of determination, and N indicates number of sample.

Regression analysis shows that there is an optimal snow depth for each ski resort since the relationship between snow depth and number of visitors is specified by quadratic form. Coefficients to the square term are significant for all ski resorts.

3 Impact of Snowfall on Snow Removal Costs

We then analyze the impact of snowfall on the snow removal cost imposed to local city government. We use the financial data provided by the Uonuma city, which is close to the ski resorts analyzed in the previous chapter.

3.1 Regression Analysis

The equation specified in this analysis is given by

$$c_t = a + bx_t + \varepsilon_t \tag{2}$$

where c_t is cost of snow removal for Uonuma city in year t, x_t is maximum snow depth observed in season t in Yuzawa. We estimate these coefficients by generalized least square method since the we detect serial correlation in the preliminary analysis.

3.2 Regression Results

Regression results are shown in Table 2

Table 2: Impact of Maximum Snow Depth on Snow Removal Cost for Uonuma City

	Uonuma City
Intercept	265,753
	(146,656)
Maximum Snow Depth (m)	195,241***
	(33,101)
AIC	240.69
BIC	241.48
N	9

Note: *** indicates 1% level of significance. Standard deviation is in parenthesis. AIC and BIC indicate Akaike Information Criteria and Bayesian Information Criteria respectively.

4 Simulation Analysis and Value of Derivatives for Ski Resorts and Local City

We run the simulation analysis to generate the cash flows for ski resorts and local city government.

4.1 Net Cash Flow for Ski Resorts

$$NCF_{SR} = \tilde{n}_{visitor} \times sales\ per\ customer - cost$$

$$\tilde{n}_{visitor} = -4.50 \times \tilde{S}^2 + 20.72 \times \tilde{S} - 33.45$$

where NCF_{SR} indicates Net Cash Flow for ski resorts $n_{visitor}$ indicates number of visitors to the ski resorts. We assume that sales per customer are 3,000 JPY (250 USD), and cost indicates the cost to the ski resorts. We assume this is fix costs and amounts 140 million JPY (1.7 thousand USD). S indicates maximum snow depth, which is estimated by simulation. We assume S follows normal distribution with mean = 2.1821 meter and standard deviation = 0.6865 meter. Assumption of normal distribution is rejected by neither Jack-Bella test nor Kolmogorov-Smirnov test.

4.2 Net Cash Flow for the Local City Government

$$NCF_{City} = net\ revenue - \tilde{c}_{snowremovalcost}$$

$$\tilde{c}_{snowremovalcost} = 195{,}241 \times \tilde{S} - 265{,}753$$

where NCF_{City} indicates Net Cash Flow for local city government, net revenue is the revenue minus the cost other than snow removal cost. We assume net revenue is fixed and independent with snow depth. $c_{snowremovalcost}$ indicates snow removal cost for the local city government.

4.3 Simulation Results

Simulation results are summarized in Table 3. As Table 3 shows, the impact of snowfall on the ski resort is significant as the ski resort cash flow can be negative depending on the amount of snow depth.

Table 3: Summary Statistics of Simulation Results

	Ski Resort	City Office
	Cash Flow No Derivatives	Cash Flow No Derivatives
Mean	255,616	2,309,264
Median	293,171	2,308,983
Standard Deviation	95,823	134,586
Max	321,884	2,810,189
Min	(655,895)	1,827,356
Skewness	-2.856	0.029

5 Value of the Snow Derivatives

Based on the simulation and regression results, we design the snow derivatives for the ski resort and the city government. Then we evaluate the value of snow derivatives for these entities.

5.1 Mechanism of Snow Derivatives

For the Ski Resort the payoff of the weather derivative is given by Max [1,940,000 JPY × (2.3 - S), 0], where S is maximum snow depth measured in meter. 1,940,000 JPY is same as 16,167 USD. According to the regression results, the revenue would be maximized if snow depth is 2.3 m. Thus, the payoff is same as long position in put option. We assume the city office would be the seller of this put option. The payoff to the city government is - Max [1,940,000 JPY × (2.3 - S), 0].

5.2 Overview of the Wang Transform

We employ Wang Transform (Wang 2002) for the valuation of proposed snow derivatives since underlying assets of the snow derivative is maximum snow depth which is not traded in the markets. We need the valuation method under incompleteness. Wang Transform is given by

$$F^{Q}(x) = \Phi\left(\Phi^{-1}\left(F^{P}(x)\right) + \lambda\right) \tag{3}$$

where, $F^Q(x)$ is cumulative distribution function under risk-neutral measure, Q, (•) indicates cumulative distribution function of standard normal distribution, $\Phi^{-1}(\cdot)$ is inverse function of $\Phi(\cdot)$, $F^P(x)$ is cumulative distribution function under physical probability measure, P, λ is the coefficient of risk aversion. If the coefficient is positive, distribution function is shifted to left. The subjective probability for bad scenario (lower revenue) is higher and that for good scenario (higher revenue) is lower.

The issue when employing Wang Transforms is estimation of λ. Ito, Ai, and Ozawa (2014) employ survey method to estimate the λ distributing the questionnaire to the mangers of J. League, premier soccer league in Japan. Their estimation results show that most probable ranges of lambda is from 0.25 to 0.52. We employ the sensitivity analysis for the valuation analysis of weather derivatives depending on the λ and the premium to the weather derivatives.

5.3 Valuation Analysis of Snow Derivatives

We evaluate the value of snow derivatives for the team by

$$V = E^{Q}\left(NCF_{with\_hedge}\right) - E^{Q}\left(NCF_{without\_hedge}\right).$$

where,

$$E^Q\left(NCF_{without hedge}\right)=\sum_{i=1}^{I} NCF_{without\_hedge,i}\, f^Q\left(NCF_{without\_hedge,i}\right)$$
$$f^Q\left(NCF_{without\_hedge,i}\right)=F^Q\left(NCF_{without\_hedge,i}\right)-F^Q\left(NCF_{without\_hedge,i-1}\right)$$
$$E^Q\left(NCF_{with hedge}\right)=\sum_{i=1}^{I} NCF_{with\_hedge,i}\, f^Q\left(NCF_{with\_hedge,i}\right)$$
$$f^Q\left(NCF_{with\_hedge,i}\right)=F^Q\left(NCF_{with\_hedge,i}\right)-F^Q\left(NCF_{with\_hedge,i-1}\right).$$

Where i indicates ith smallest NCF among the simulation paths. NCF_{with_hedge} is equal to $NCF_{without\_hedge}$ + payoff from the snow derivatives minus the premium of weather derivatives.

Table 4 and 5 summarize the value of the snow derivatives for the ski resort and the city government depending on the premium of weather derivatives and λ.

Table 4: Value of Proposed Weather Derivatives for Ski Resort by Wang Transform (in thousand JPY)

	Value of Hedging Instrument					
λ	0%	5%	10%	15%	20%	60%
0	0	(3,291)	(6,583)	(9,874)	(13,166)	(39,497)
0.1	1,318	(1,973)	(5,265)	(8,556)	(11,847)	(38,179)
0.2	2,889	(402)	(3,694)	(6,985)	(10,277)	(36,608)
0.25	**3,772**	**480**	**(2,811)**	**(6,103)**	**(9,394)**	**(35,726)**
0.3	**4,720**	**1,428**	**(1,863)**	**(5,155)**	**(8,446)**	**(34,777)**
0.4	**6,815**	**3,524**	**232**	**(3,059)**	**(6,350)**	**(32,682)**
0.5	**9,177**	**5,886**	**2,594**	**(697)**	**(3,988)**	**(30,320)**
0.52	**9,682**	**6,390**	**3,099**	**(193)**	**(3,484)**	**(29,816)**
0.6	11,805	8,513	5,222	1,930	(1,361)	(27,693)
0.7	14,693	11,401	8,110	4,818	1,527	(24,805)
0.8	17,834	14,543	11,252	7,960	4,669	(21,663)
0.9	21,220	17,929	14,637	11,346	8,055	(18,277)
1	24,838	21,546	18,255	14,964	11,672	(14,659)

Note: Second column indicate the safety loading. 5% implies premium of the snow derivatives is 1.05 times E [Max (1,940,000 JPY × (2.3 - S),0)] = 1.05 × 65,820 = 69,111. Bold value indicate the most probable range of λ by Ito, Ai, and Ozawa (2014).

Table 5: Value of Proposed Weather Derivatives for Ski Resort by Wang Transform (in thousand JPY)

	Value of Hedging Instrument					
λ	0%	5%	10%	15%	20%	60%
0	0	3,292	6,583	9,875	13,166	39,497
0.1	7,382	10,674	13,965	17,257	20,548	46,879
0.2	14,221	17,513	20,804	24,095	27,387	53,718
0.25	**17,437**	**20,728**	**24,020**	**27,311**	**30,603**	**56,934**
0.3	**20,519**	**23,810**	**27,101**	**30,393**	**33,684**	**60,016**
0.4	**26,279**	**29,571**	**32,862**	**36,154**	**39,445**	**65,776**
0.5	**31,515**	**34,807**	**38,098**	**41,389**	**44,681**	**71,012**
0.52	**32,501**	**35,792**	**39,084**	**42,375**	**45,667**	**71,998**
0.6	36,242	39,533	42,824	46,116	49,407	75,739
0.7	40,478	43,770	47,061	50,353	53,644	79,975
0.8	44,249	47,540	50,831	54,123	57,414	83,746
0.9	47,580	50,872	54,163	57,455	60,746	87,077
1	50,502	53,793	57,085	60,376	63,668	89,999

Note: Second column indicate the safety loading. 5% implies premium of the snow derivatives is 1.05 times E [Max (1,940,000 JPY × (2.3 - S),0)] = 1.05 × 65,820 = 69,111. Bold value indicate the most probable range of λ by Ito, Ai, and Ozawa (2014).

Table 4 shows that the snow derivatives would contribute to improvement of the corporate value if the price of weather derivatives is reasonably low and managers risk aversion is relatively high. Table 5 also shows that in any case, this type of derivatives would contribute to the value of city government. Thus low premium trading would be possible if the city government is the underwriter of this contracts.

6 Summary and Future Study

We preliminary analyze the impact of snow depth on the financial performance of snow resort and local city government. We would like to refine the model by pursuing the better definition of snowfall such as using the number of snow days setting up several thresholds in regard to snowfall. Also we would like to introduce the control variables such as macroeconomic factors in order to assure our analysis is robust. We also plan to apply maximum value theorem in order to model the distribution of maximum snow depth. While we would not reject the normal distribution assumption on the distribution, generalized extreme value distributions might fit better to the historical distribution of snow depth than normal distribution. We also plan to estimate the risk aversion of managers in order to make our model more practical to implement risk management for ski resorts and local governments.

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