

Agenda

- Weather derivatives (contracts)
- Weather risks faced by the viticulture industry
- Hedging the risks of icewine production
- Bioclimatic index risk
- Harvest rainfall
- Winter injury
- Future research

Weather Derivatives

- Financial securities such as swaps and options with payoffs contingent on weather —related variables such as
 - average temperature
 - heating and cooling degree days
 - maximum or minimum temperatures
 - Frost days
 - Precipitation (rain or snow)
 - humidity
 - sunshine

Fundamentals

Five essential elements to every weather derivative contract:

- the underlying weather index or variable.
- the period over which the index accumulates, typically a season or month.
- the weather station reporting the weather variable.
- the dollar value attached to each move of the index value (Tick Value).
- the reference or strike price of the underlying index.

Potential for Use

Potential for use in many sectors of the economy to hedge the risks of adverse weather conditions to net revenues.

- 15% of industrialized economy is weather sensitive. (Hanley, 1999)
- 20% to 30% of US GDP is exposed to weather risk.

 (Dutton (2002), Larson (2006), Weatherbill (2008))
- world's production output could increase by greater than US \$250 billion if weather risks were hedged effectively

Not Insurance Contracts

Weather derivatives differ substantially from insurance.

Insurance Contracts

- generally intended to cover damages dues to infrequent high-loss events.
- moral hazard playing a significant role.
- Require the filing of a claim and proof of damages.

Weather Derivatives

- limited loss, high probability events such as adverse weather conditions.
- designed as a "hedge" on a weather variable.
- only requirement being an observable objective weather variable agreed upon by both parties.
- More transparent in many cases, than insurance contracts.

Growth of Weather Derivatives

First appeared in 1996: Contract between Enron and Florida Power and Light.

- Growth has been impressive:
 - Market Size: \$500 million in 1998 to \$15 billion in 2008-09.
 (Weather Risk Management Association)
 - Temperature related contracts comprise 80% of the market with energy industry the major participant.
 - Forecasted to be a \$200 billion dollar market within five years.

 (Weather Risk Management Association)

Growth of Weather Derivatives

Two Types of Contracts: Exchange Traded and OTC.

Chicago Mercantile Exchange Standardized Contracts.

- Commenced trading in 1999.
 - Standardized contracts based on the average daily temperature.
 - Major US, European (2003), Asian/Pacific (2004), Canadian (2006) and Australian (2009) cities.
 - Cooling Degree Days (CDD) = max $[T_i 65^{\circ}F(\text{ or }18^{\circ}C), 0]$.
 - Heating Degree Days (HDD)= max [65°F(or 18°C) T_i, 0].
 - Cumulative monthly or seasonal degree days.
 - Other contracts are written on snowfall (New York, Boston, Chicago Minneapolis, Detroit) and frost free days.

Over the Counter (OTC) Market

- Privately negotiated, individualized agreements made between two parties.
- Allows for the hedging of Non-standardized situations and risks.
 - Specialized needs relating to terms of the contract.
 - Specific location for variable measurement.
- Liquidity not as great underlying variable not traded.
- Price for contract must be agreed upon by the two parties.

Over the Counter (OTC) Market

- Phenomenal Growth over the past five or six years.
- Much of the growth has occurred in contracts written on weather variables other than temperature, primarily rainfall
- Fueled by the growth of financial intermediaries ready to structure contracts:
 - Firms Specialized in weather contracts (Weatherbill, Guaranteed Weather, Evomarkets among others)
 - Insurance Firms

-

Examples of OTC contracts

- Corney and Barrow wine bar chain use temperature options to hedge cool summer temperatures. (2000).
- Hedging of almond production risk in California (Richards et. A. 2004).
- Construction projects delays due to weather may result in penalties.
 (www.evomarkets.com)
- Brewery hedging against low beer consumption due to cooler summer temperatures (www.evomarkets.com).
- Golf courses hedging excessive rainfall during summer months.
- Atlanta hair salon hedges sunny weekends (2006)
- UN's World Food Program hedges drought in Ethiopia (2006)
- Canadian Travel Agency(Itravel 2000 Hedges Marketing Strategy (2007)
- Tourism Victoria BC hedges its "sunshine guarantee" (2009).

Use of Weather Contracts

Despite the general availability and potential benefits of weather contracts there is a surprising lack of use (and potential awareness).

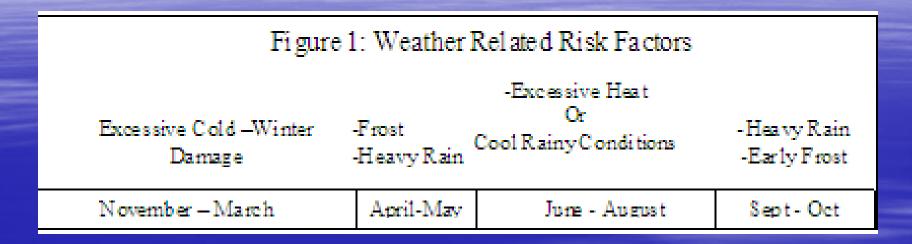
Chicago Mercantile Exchange/Storm Inc. 2009 Survey of senior managers of US and Canadian Firms:

- 82% believe global climate change will impact their business.
- 51% do not believe their firm deals effectively with current weather risks.
- 10% indicated they have attempted to hedge weather.
- 86% of those who have attempted to hedge have found it to be useful.

Agriculture Sector:

- 94% were moderately to extremely concerned about weather risks.
- 60% were concerned about increased weather variability due to climate change.
- 25% have attempted to quantify weather related risks.
- 8% have attempted to hedge weather related risks.

Viticulture Faces a Myriad of Risk Factors



End uses in Agriculture and Retail appear to be the least informed as to the potential uses of weather derivatives.

(Brodsky, M. (2008), "Weather risk market: end users wanted", Risk and Insurance, June 8, 2008)

Potential use of OTC weather contracts in the Viticulture Industry

Canadian Icewine Production: A Case for the Use of Weather Derivatives. Cyr, D. and Kusy, M. (2007). Journal of Wine Economics 2(1). 1-23.

Hedging Adverse Bioclimatic Conditions Employing a Short Condor Position. Cyr, D., Kusy, M. and Shaw, A.B. (2008) Journal of Wine Economics 3(2). 149-171.

Climate Change and the Potential Use of Weather Derivatives to Hedge Vineyard Harvest Rainfall Risk in the Niagara Region. Cyr, D., Kusy, M. and Shaw, A.B. (2009) Working Paper

Hedging the Risks of Vineyard Winter Injury with an OTC Collar Contract Cyr, D., Kusy, M. and Shaw, A.B. (2009) Working Paper

Canadian researchers calculate fair prices for weather derivatives. Gedeon J. (2008a) Wine Business Monthly, 06/15/2008.

Wine industry is slow to warm up to weather derivatives: experts say various factors account for hesitation. Gedeon, J. (2008b) Wine Business Monthly, 06/15/2008.

Betting on the weather? How Canadian. Crosariol, B. (2008). The Globe and Mail, January 9th 2008, p. L3.

e Globe and Mail, Wednesday, Jan. 9, 2008

Betting on the weather? How Canadian

To protect against warmer winters, a study suggests vintners could cushion their icewine crop with a well-placed wager



n wine regions across the orthern hemisphere, Jan ary is a time of relative calm. ing, like Cashmere Mafia or me NFL playoff action

At many wineries in Canada

"I sit and watch The Weathe er on," says Bruce Nicholson rapes. "It's unlike a normal

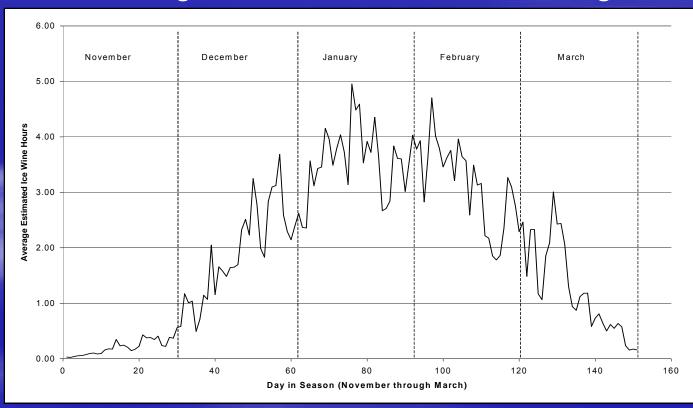


Brock University's Don Cyr proposed a model in which vintners bet on available ices

Hedging Icewine Production

<u>Icewine Production Hours:</u> Number of hours when the temperature is between -8 and -12 °C.

Average Number of Estimated Icewine Production Hours from November through March for the Years 1965-66 through 2005-06



Determination of a Stochastic Process for Weather Variables

- Campbell, S. and Diebold, F.X. 2005, Weather Forecasting for Weather Derivatives, Journal of the American Statistical Association
- Geman, H. and M. Leonardi, 2005, "Alternative Approaches to Weather Derivatives Pricing", Managerial Finance
- Cao, M. and J. Wei, 2004, Weather Derivatives Valuation and Market
 Price of Risk, The Journal of Futures Markets
- Richard, T.J., M.R. Manfredo and D.R. Sanders, 2004, Pricing Weather Derivatives, American Journal of Agricultural Economics

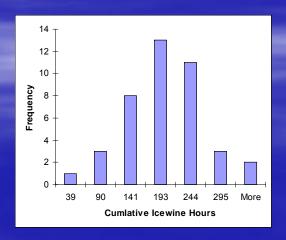
Hedging Icewine Production

Risk Factor: Cumulative Number of "Icewine hours" from November through January.

Table 2: Summary Statistics of the 41 observations of Cumulative Estimated Icewine Production Hours (CIWH_j) over the November through January months.

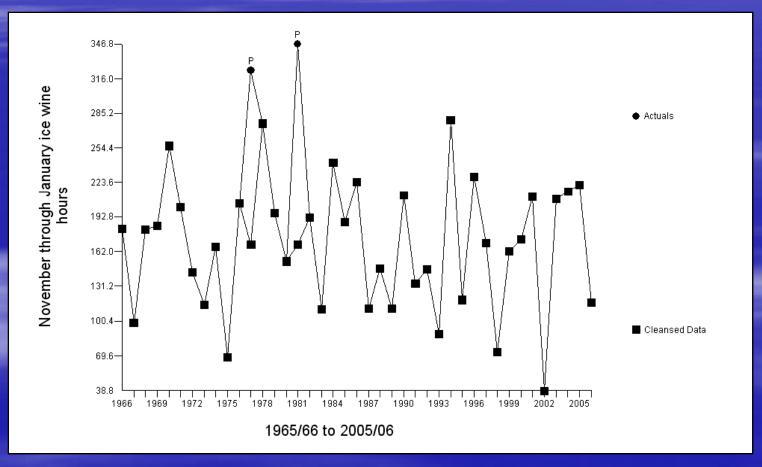
Summary Statistics					
Mean	176.02				
Standard Error	10.47				
Median	181.57				
Standard Deviation	67.04				
Sample Variance	4493.85				
Kurtosis	0.23				
Skewness	0.35				
Range	308.01				
Minimum	38.75				
Maximum	346.76				
Count	41				

Figure 5: Histogram of 41 Observations of Cumulative Estimated Icewine Hours Over the November through January Months.



Hedging Icewine Production

Figure 6: Graph of Cumulative Icewine Production Hours (November through January) for the 1965-66 through 2005-06 Period.



Pricing of Weather Derivatives Remains an Issue

Weather is a non-traded asset. Traditional arbitrage-free risk neutral valuation is not theoretically correct.

Actuarial Approaches

Jewson, S. and Brix, A. (2005), Weather Derivative Valuation: The Meteorological, Statistical, Financial and Mathematical Foundations, Cambridge University Press.

Consumption based asset pricing models

Cao, M. and Wei, J. (2004), "Weather derivatives valuation and market price of risk", *The Journal of Futures Markets*, Vol. 24, Vol. 11, pp. 1065-1089.

Richards, T.J., Manfredo, M.R. and Sanders, D.R. (2004), "Pricing weather derivatives", *American Journal of Agricultural Economics*, Vol. 86, No. 4, pp.1005-1017

Extended Risk Neutral Valuation

Turvey, C.G. (2005), "The pricing of degree-day weather options, *Agricultural Finance Review*, Spring 2005, p.59-85.

Indifference pricing – willingness to pay

Wei, X., Odening, M. and Musshoff, O. (2008), "Indifference pricing of weather derivatives", *American Journal of Agricultural Economics* 90(3); 979-993.

Hedging Icewine Production

Table 5: Burn Rate Analysis

– Historical Terminal Value
of Put Options (\$2,000 per
icewine hour) Given Varying
Strike Values Over the 196566 through 2005-06 seasons

ſ	Estimated Terminal Value (Payoff) of Put Option							
		CIWH (Nov-		Termina	Strike Value		Орион	
	Season	Jan)	170	150	130	110	90	70
ľ	1965-66	182.1	\$0	\$0	\$0	\$0	\$0	\$0
	1966-67	98.9	\$142,167	\$102,167	\$62,167	\$22,167	\$0	\$0
	1967-68	181.6	\$0	\$0	\$0	\$0	\$0	\$0
	1968-69	184.7	\$0	\$0	\$0	\$0	\$0	\$0
	1969-70	256.0	\$0	\$0	\$0	\$0	\$0	\$0
	1970-71	201.1	\$0	\$0	\$0	\$0	\$0	\$0
	1971-72	143.2	\$53,599	\$13,599	\$0	\$0	\$0	\$0
	1972-73	115.1	\$109,827	\$69,827	\$29,827	\$0	\$0	\$0
	1973-74	166.1	\$7,780	\$0	\$0	\$0	\$0	\$0
	1974-75	68.4	\$203,190	\$163,190	\$123,190	\$83,190	\$43,190	\$3,190
	1975-76	204.8	\$0	\$0	\$0	\$0	\$0	\$0
	1976-77	323.5	\$0	\$0	\$0	\$0	\$0	\$0
	1977-78	275.9	\$0	\$0	\$0	\$0	\$0	\$0
ŀ	1978-79	196.2	\$0	\$0	\$0	\$0	\$0	\$0
	1979-80	153.1	\$33,761	\$0	\$0	\$0	\$0	\$0
	1980-81	346.8	\$0	\$0	\$0	\$0	\$0	\$0
	1981-82	192.0	\$0	\$0	\$0	\$0	\$0	\$0
	1982-83	111.0	\$117,925	\$77,925	\$37,925	\$0	\$0	\$0
	1983-84	241.0	\$0	\$0	\$0	\$0	\$0	\$0
	1984-85	187.8	\$0	\$0	\$0	\$0	\$0	\$0
	1985-86	223.9	\$0	\$0	\$0	\$0	\$0	\$0
	1986-87	111.3	\$117,411	\$77,411	\$37,411	\$0	\$0	\$0
	1987-88	147.0	\$46,084	\$6,084	\$0	\$0	\$0	\$0
	1988-89	111.6	\$116,892	\$76,892	\$36,892	\$0	\$0	\$0
	1989-90	211.9	\$0	\$0	\$0	\$0	\$0	\$0
	1990-91	133.6	\$72,828	\$32,828	\$0	\$0	\$0	\$0
	1991-92	145.9	\$48,154	\$8,154	\$0	\$0	\$0	\$0
	1992-93	88.7	\$162,598	\$122,598	\$82,598	\$42,598	\$2,598	\$0
	1993-94	278.8	\$0	\$0	\$0	\$0 \$0	\$0	\$0
	1994-95	119.1	\$101,762	\$61,762	\$21,762	\$0 \$0	\$0	\$0
	1995-96	228.6	\$0 \$1.405	\$0 £0	\$0 \$0	\$0 \$0	\$0 £0	\$0 \$0
	1996-97 1997-98	169.3 72.9	\$1,495 \$194,260	\$0 \$154.260	\$0 \$114.260	\$0 \$74,260	\$0 \$34,260	\$0 \$0
	1997-98	72.9 162.3	\$194,260	\$154,260 \$0	\$114,260 \$0	\$74,260 \$0	\$34,260 \$0	\$0 \$0
	1996-99	172.5	\$15,393	\$0 \$0	\$0 \$0	\$0 \$0	\$0 \$0	\$0 \$0
	2000-01	210.3	\$0 \$0	\$0 \$0	\$0 \$0	\$0 \$0	\$0 \$0	\$0 \$0
	2000-01	38.8	\$262,496	\$222,496	\$182,496	\$142,496	\$102,496	\$62,496
	2001-02	36.6 208.4	\$202,490	\$222,496	\$102,490	\$142,496	\$102,496	\$62,496 \$0
	2002-03	215.0	\$0 \$0	\$0 \$0	\$0 \$0	\$0 \$0	\$0 \$0	\$0 \$0
	2003-04	213.0	\$0 \$0	\$0 \$0	\$0 \$0	\$0 \$0	\$0 \$0	\$0 \$0
	2004-05	116.7	\$106,584	\$66,584	\$26,584	\$0 \$0	\$0 \$0	\$0 \$0
		e Payout	\$46,687.94	\$30,628.72		\$8,895.40	\$4,452.29	\$1,602.10
		tion Value	\$45,763.46	\$30,020.72	· /	\$8,719.26	\$4,364.13	\$1,570.37

Hedging Icewine Production

Table 6: Monte Carlo Simulation of Put Option Prices for Different Strike Values

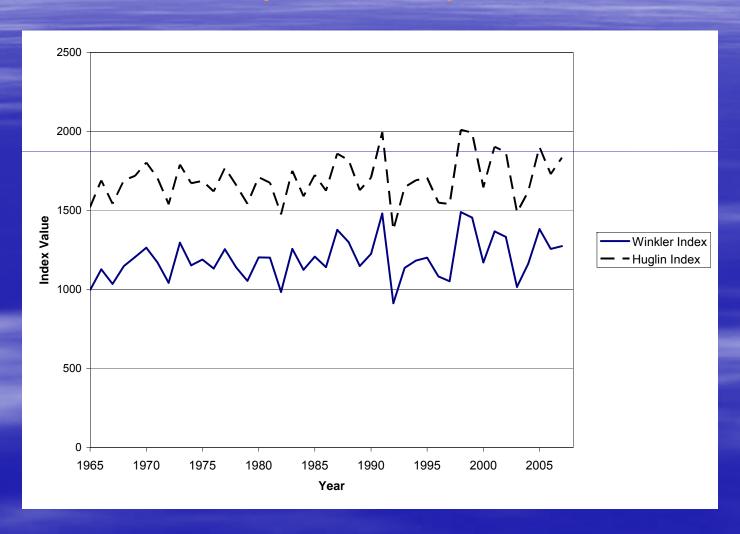
	Strike Values					
Diffusion Assumptions	170	150	130	110	90	70
Normal (μ = 168, σ = 58)	\$46,745.77	\$29,323.03	\$1 7,003.98	\$9,021.80	\$4,315.77	\$1,814.4 7
Normal ($\mu = 176.02$, $\sigma = 67.04$)	\$45,318.70	\$29,505.06	\$18,011.16	\$10,205.04	\$5,284.30	\$2,430.57
Mixed Normal and Poission Jump $(\mu = 168, \sigma = 58, \lambda = .049, \mu 2 = 167.5, \sigma 2 = 11.5)$	\$44,473.78	\$27,832.01	\$16,272.41	\$8,680.78	\$4,116.81	\$1,726.19

Hedging Bioclimatic Index Risk

- Winkler Index
- Niagara area averages approximately 1200-1300 growing degree days (GDDs) for April through September, falling into Region II defined as ranging from 1200 to 1500 GDDs.
- Huglin Index (HI)
- With an average seasonal cumulative value of 1700 the Niagara Region falls into the HI-1 Group (Temperate Cool) defined as having cumulative HI values that ranging from 1500 to 1800 for the period of April through September.

Index	Definition	Reference
Winkler index (WI)	Σ ((Tmax+Tmin)/2)-10°C)	AMERINE and WINKLER 1944
Huglin index (HI)	$\Sigma ((Tavg-10^{\circ}C)+(Tmax-10^{\circ}C)/2)*d$	HUGLIN 1978
Branas Heliothermic index (BHI)	Σ (Tavg-10°C)* Σ Ie*10-6)	BRANAS 1974
Hydrothermic index (Hyl)	Σ (Tavg* Pgs)	BRANAS et al. 1946
bioclimatic index (HBI)	Σ (Tavg-10°C)* Σ Ie*10-6) / Pa	HIDALGO 2002
Dryness index (DI)	Σ Wo+P–Tv-Es	RIOU et al. 1994
Cool night index (CI)	NH=Tmin(Sept); SH=Tmin(March)	TONIETTO 1999
Continentality index (CT)	NH=Tavg(July)-Tavg(Jan); SH=Tavg(Jan)-Tavg(July	1992

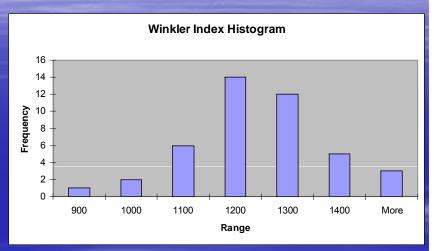
Huglin and Winkler Indices for the Niagara Region (1965 – 2007)

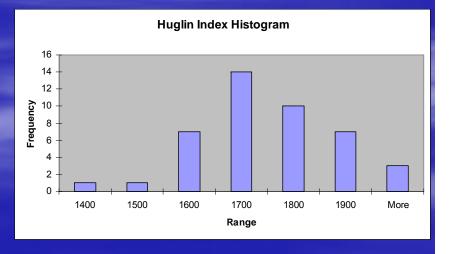


Summary statistics of the 43 (1965-2007) observations of seasonal Winkler and Huglin Indices .

Summary Statistics of the Winkler and Huglin Indices for the Region from 1965 to 2007

	Winkler Index	Huglin Index
Mean	1194.07	1697.91
Standard Error	20.05	21.89
Median	1182.75	1690.23
Mode	1256.75	1753.47
Standard Deviation	131.47	143.54
Sample Variance	17283.37	20603.54
Kurtosis	0.08	-0.01
Standard Error of Kurtosis	0.75	0.75
Skewness	0.34	0.28
Standard Error of Skewness	0.37	0.37
Minimum	913.00	1376.60
Maximum	1489.75	2010.17
Count	43	43





Estimation of Stochastic Process for Winkler Index (WI)

No indication of ARCH/GARCH effects after including an AR(9) Employed ARIMA modeling with Intervention Analysis

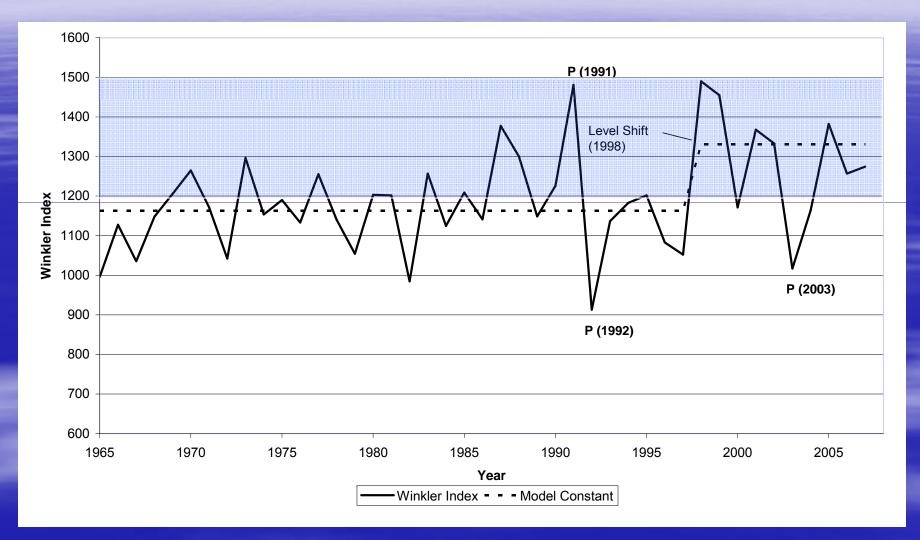
$$WI_j = \mu + e_j$$

where μ = 1162.62 and $e_i \sim N(0, 96.85)$

Three time periods identified as "pulse" outliers 1991 (pos), 1992 (neg), 2003 (pos)

Also a positive step or level shift was statistically identified from 1998 onwards.

Estimation of Stochastic Process for Winkler Index



Estimation of Stochastic Process for Huglin Index (WI)

No indication of ARCH/GARCH effects after including an AR(9) Employed ARIMA modeling with Intervention Analysis

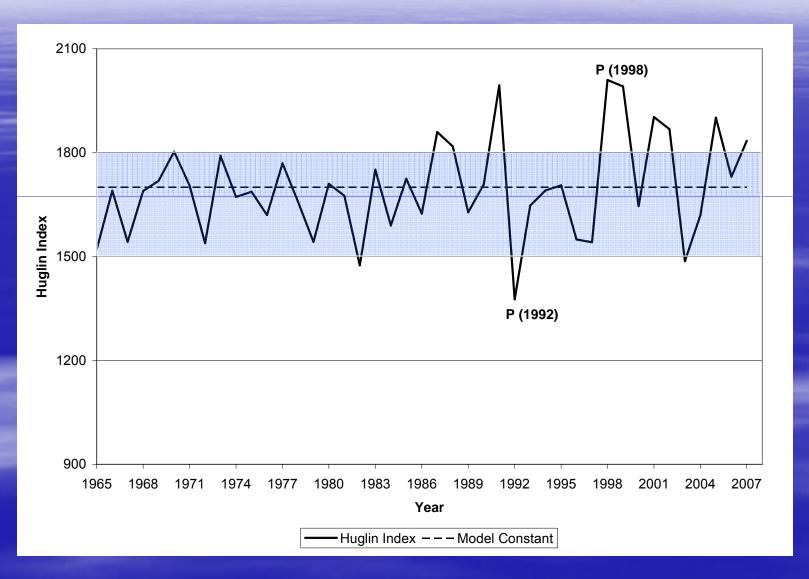
$$HI_{j} = \mu + e_{j}$$

where μ = 1700 and $e_{j} \sim N(0, 128.89)$

Two time periods identified as statistically significant outliers through intervention analysis.

1992 (negative) and 1998 (positive)

Estimation of Stochastic Process for Huglin Index

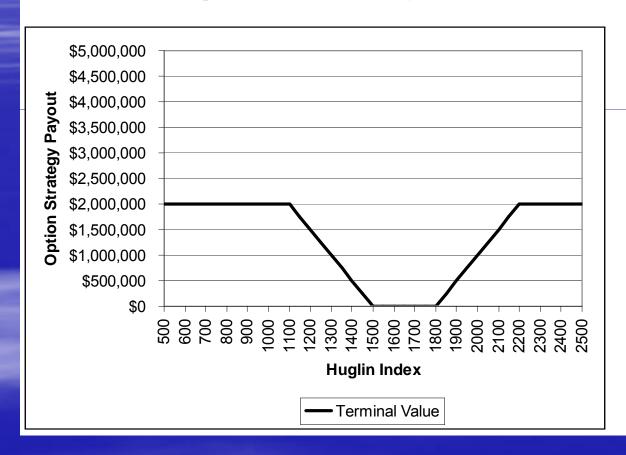


Short Condor Contract

- Allows for Contract payouts at both lower and upper values (strikes) of Huglin index. (Lower = 1500, Upper = 1800).
- Tic size = value of payout per Huglin Index unit above (below) upper (lower) strike value (\$5,000).
- Specifies a maximum payout (\$2,000,000).

Short Condor Contract

Figure 6
Graph of Terminal Value (Payout) of Short Condor Contract



Burn Rate Analysis

Tic Size	\$ 5 ,0 0 0	lower strike = 1500
M ax Payout	\$ 2,000,000	upper strike = 1800
Year	Huglin Index Value	C ontract Payout
1 9 6 5	1 5 2 0 .0 0	\$ 0
1966	1 6 9 0 . 2 3	\$ 0
1967	1 5 4 2 . 7 6	\$ 0
1968	1 6 8 9 . 2 8	\$ 0
1969	1718.68	\$ 0
1 9 7 0	1803.02	\$ 1 5 ,0 7 5
1971	1 7 0 5 .3 7	\$ 0
1 9 7 2	1 5 3 8 . 5 4	\$ 0
1 9 7 3	1790.76	\$ 0
1 9 7 4	1 6 7 2 .0 5	\$ 0
1 9 7 5	1 6 8 7 . 2 9	\$ 0
1976	1619.98	\$ 0
1977	1769.03	\$ 0
1 9 7 8	1659.66	\$ 0
1979	1 5 4 2 . 2 7	\$ 0
1980	1710.06	\$ 0
1981	1 6 7 5 . 8 1	\$ 0
1 9 8 2	1 4 7 4 . 8 3	\$ 1 2 5 ,8 4 4
1 9 8 3	1 7 5 1 .1 3	\$ 0
1 9 8 4	1 5 8 9 . 5 5	\$ 0
1 9 8 5	1 7 2 4 .6 1	\$ 0
1986	1 6 2 3 . 9 2	\$ 0
1987	1 8 5 9 . 5 4	\$ 2 9 7 ,6 8 1
1 9 8 8	1 8 1 8 . 3 4	\$ 9 1 ,6 8 1
1989	1 6 2 8 . 0 7	\$ 0
1990	1 7 0 8 . 3 8	\$ 0
1991	1 9 9 4 . 7 2	\$ 9 7 3 ,6 1 9
1992	1 3 7 6 . 6 0	\$ 6 1 7 ,0 2 5
1993	1 6 4 7 . 3 6	\$ 0
1994	1 6 9 1 .1 3	\$ 0
1995	1 7 0 5 . 8 1	\$ 0 \$ 0
1996 1997	1549.22	\$ 0 \$ 0
	1 5 4 1 .2 7	· ·
1998 1999	2 0 1 0 .1 7 1 9 9 1 .6 3	\$ 1,050,869 \$ 958,169
2 0 0 0	1 6 4 5 .5 5	\$ 9 3 8 , 1 0 9 \$ 0
2 0 0 0	1 9 0 3 .0 5	\$ 5 1 5 , 2 6 9
2001	1867.97	\$ 3 3 9 , 8 5 5
2002	1 4 8 7 .0 9	\$ 6 4 , 5 5 9
2 0 0 3	1619.96	\$ 0
2 0 0 5	1 9 0 0 .8 9	\$ 5 0 4 , 4 5 4
2006	1 7 3 0 .1 2	\$ 0
2007	1 8 3 4 .3 7	\$ 1 7 1 ,8 6 7
Average Payor		\$ 1 3 3 , 1 6 1 . 9 8
	·	w , - O / O

A verage Payout \$133,161.98 E stim ated 6-m onth contract price \$130,525.20

Monte Carlo Simulation of Contract Values

Assumptions

Huglin Index follows a Jump Diffusion Process μ_1 = 1700, σ_1 = 128.89, λ = .0465, μ_2 = -5, σ_2 = 322 Risk Free Rate = 4%

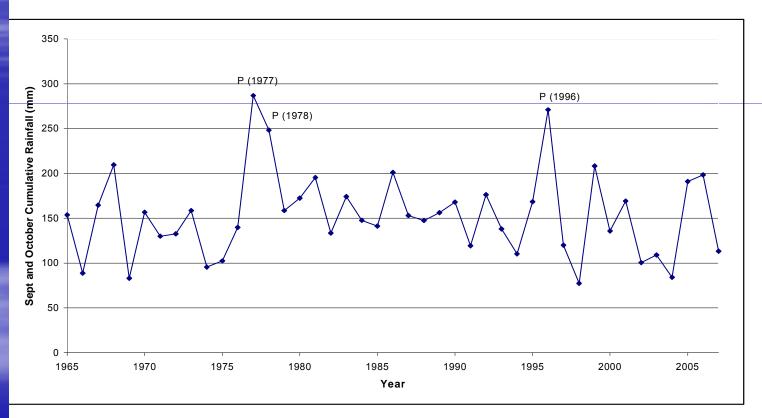
Time to Maturity = 6 months

 ${\it Table~6}$ Monte Carlo Simulation of Short Condor Prices for Varying Strike and Limit Parameters

		Upper Strike Lower Strike	1750 1550	1800 1500	1850 1450	1900 1400	1950 1350	2000 1300
Ī	t	\$500,000	\$154,124	\$88,566	\$47,676	\$25,031	\$13,386	\$7,559
	Payout Limit	\$1,000,000	\$200,402	\$112,447	\$60,770	\$33,087	\$19,148	\$12,183
	⁄out	\$1,500,000	\$214,665	\$120,899	\$66,212	\$36,732	\$21,611	\$13,608
	Рау	\$2,000,000	\$220,730	\$125,385	\$69,053	\$38,564	\$23,014	\$14,943

☐ Heavy rains prior to harvest induces excessive uptake of water causing splitting and dilution of the juice resulting in lower Brix levels (Jackson and Spurling, 1995) ☐ Lower Brix levels (lower alcohol and lower degree of ripeness) results in lower grape prices. For example, Cabernet franc which is the most widely planted red variety in the Niagara Peninsula has Brix levels that typically range from 14.9 to 24.9 would command prices ranging from \$348 to \$2,322 per tonne respectively. ☐ Thin-skinned and/or tight bunched varieties such as Pinot Noir, Chardonnay and Riesling are especially susceptible to "bunch rot" following a period of heavy rains. □ Excessive rains during the ripening period may induce growers to pick early in order to avoid deterioration of the crop. High rainfall may also delay the process of ripening.

 ${\it Figure~6} \\ {\it Graph~of~Cumulative~Rainfall~for~September~through~October~for~1965~through~2007.}^1$



¹Note: "P" indicates a statistically significant pulse intervention or outlier observation.

Burn Rate Analysis: Historical terminal value of call options (\$2000 per mm of cumulative rain) given varying strike values over the 1965 to 2007 harvest seasons

Year	CHR for Sept and Oct (mm.)	Strike Va	lue (mm. o	f cumulati	ve harvest	rainfall)
	oet (mm.)	150	175	200	225	250
1965	153.6	\$7,200	\$0	\$0	\$0	\$0
1966	88.8	\$0	\$0	\$0	\$0	\$0
1967	164.6	\$29,200	\$0	\$0	\$0	\$0
1968	209.6	\$119,200	\$69,200	\$19,200	\$0	\$0
1969	83.1	\$0	\$0	\$0	\$0	\$0
1970	156.7	\$13,400	\$0	\$0	\$0	\$0
1971	129.9	\$0	\$0	\$0	\$0	\$0
1972	132.5	\$0	\$0	\$0	\$0	\$0
1973	158.5	\$17,000	\$0	\$0	\$0	\$0
1974	95.5	\$0	\$0	\$0	\$0	\$0
1975	102.4	\$0	\$0	\$0	\$0	\$0
1976	139.7	\$0	\$0	\$0	\$0	\$0
1977	286.8	\$273,600	\$223,600	\$173,600	\$123,600	\$73,600
1978	248.2	\$196,400	\$146,400	\$96,400	\$46,400	\$0
1979	158.6	\$17,200	\$0	\$0	\$0	\$0
1980	172.4	\$44,800	\$0	\$0	\$0	\$0
1981	195.4	\$90,800	\$40,800	\$0	\$0	\$0
1982	133.4	\$0	\$0	\$0	\$0	\$0
1983	174	\$48,000	\$0	\$0	\$0	\$0
1984	147.6	\$0	\$0	\$0	\$0	\$0
1985	141.2	\$0	\$0	\$0	\$0	\$0
1986	201	\$102,000	\$52,000	\$2,000	\$0	\$0
1987	153	\$6,000	\$0	\$0	\$0	\$0
1988	147.4	\$0	\$0	\$0	\$0	\$0
1989	156.2	\$12,400	\$0	\$0	\$0	\$0
1990	168	\$36,000	\$0	\$0	\$0	\$0
1991	119.4	\$0	\$0	\$0	\$0	\$0
1992	176.2	\$52,400	\$2,400	\$0	\$0	\$0
1993	138	\$0	\$0	\$0	\$0	\$0
1994	110.2	\$0	\$0	\$0	\$0	\$0
1995	168.4	\$36,800	\$0	\$0	\$0	\$0
1996	271	\$242,000	\$192,000	\$142,000	\$92,000	\$42,000
1997	120	\$0	\$0	\$0	\$0	\$0
1998	77.4	\$0	\$0	\$0	\$0	\$0
1999	208.2	\$116,400	\$66,400	\$16,400	\$0	\$0
2000	135.8	\$0	\$0	\$0	\$0	\$0
2001	169.2	\$38,400	\$0	\$0	\$0	\$0
2002	100.4	\$0	\$0	\$0	\$0	\$0
2003	109	\$0	\$0	\$0	\$0	\$0
2004	84.2	\$0	\$0	\$0	\$0	\$0
2005	190.9	\$81,800	\$31,800	\$0	\$0	\$0
2006	198.4	\$96,800	\$46,800	\$0	\$0	\$0
2007	113.2	\$0	\$0	\$0	\$0	\$0
	erage Payout	\$39,019	\$20,265	\$10,456	\$6,093	\$2,688
Burn Rate	Call Option Values	\$38,246	\$19,864	\$10,249	\$5,972	\$2,635

Table 5
Monte Carlo Simulation of Call Option Prices for Different Strike Values

		Strike Values (mm rainfall)							
Diffusion Assumptions	150	175	200	225	250				
Case 1: Normal									
$(\mu = 145, \sigma = 36.22)$	\$23,696.09	\$8,117.82	\$1,995.38	\$338.39	\$38.65				
Case 2: Normal									
$(\mu = 153, \sigma = 47.54)$	\$38,865.17	\$18,265.00	\$7,059.55	\$2,194.16	\$538.22				
Case 3: Mixed Normal									
and Poission Jump	\$38,283.82	\$20,686.96	\$11,528.23	\$7,179.65	\$4,141.21				
$(\mu_1 = 145, \sigma_1 = 36.22, \lambda =$,				,				
.0696									
$(\mu_2 = 124, \ \sigma_2 = 19.08)$									

Major weather related risk to vineyards located in Northern regions.
☐ Generally occurs during the months of November through March
☐Time of low temperature and duration are important factors.
□Extreme minimum temperatures can also result in trunk splitting and infestation by the crown gall bacterium, Agrobacterium tumefacien, ultimately reducing the life span of the vine and complete replacement in the case of less-cold tolerant varieties. (Sauvignon Blanc, Syrah and Merlot).
□ 5% - 10% of world grape production lost due to winter injury each year.
☐ Niagara region: 40 acre vineyard can lose up to \$700,000 in a year due to winter injury in spite of active management.
☐ Winters of 2003 and 2004 resulted in 2005 crop of only half that of 2002.

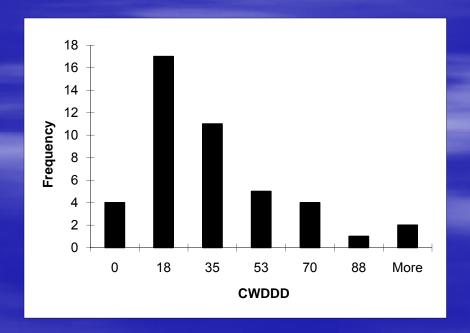
Cumulative Winter Degree Days (CWDD) = the cumulative number of degrees below -15°C of the daily minimum temperature over the months of November through March.

Similar to the idea of HDD on CME standardized exchange contracts.

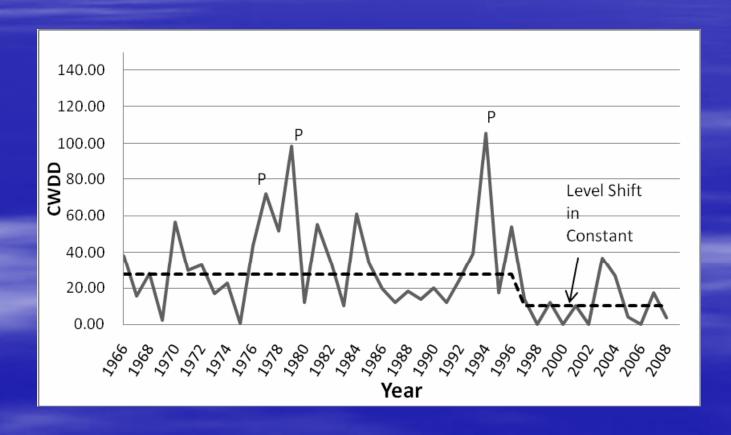
Summary Statistics of the 43 (1966-2008) observations of CWDD

Mean	27.24
Standard error	3.7898
Median	19.5
Standard deviation	24.85
Kurtosis	2.1513
Starndard error of kurtosis	0.5283
Skewness	1.4242
Standard error of skewness	0.3735
Minimum	0
Maximum	105.5

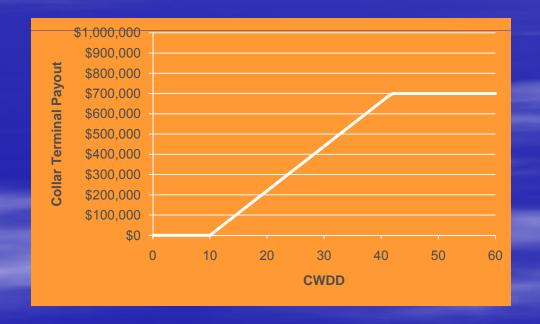
Histogram of the 43 (1966-2008) observations of CWDD



Graph of CWDD observations for 1966 through 2008 with significant pulse and level shift outliers identified.



Graph of Collar Contract Terminal Value Assuming a Strike value of 10 CWDD, tick size of \$22,000 and payout cap of \$700,000¹



Monte Carlo simulation of collar prices for various strike values. Tick Size = \$22,000, Payout Cap = \$700,000

	Strike Values (CWDD)						
Diffusion Assumptions	10	20	30	40	50		
Case 1: $(\mu = 10.3, \sigma = 14.91)$	\$171,526	\$67,750	\$18,494	\$3,685	\$501		
Case 2: $(\mu = 10.3, \sigma = 24.85)$	\$324,452	\$213,598	\$128,696	\$70,858	\$35,514		
Case 3: Mixed and Poisson Jump $(\mu_1 = 10.3, \sigma_1 = 14.91, \lambda = .0698 $ $(\mu_2 = 67.26, \sigma_2 = 19.0)$	\$206,215	\$106,974	\$61,907	\$45,773	\$38,077		

Future Research

Issue of Estimating a Mixed Jump Diffusion Process

Ait-Sahalia, Y. (2004), "Disentangling diffusion from jumps", Journal of Financial Economics, Vol. 74, No. 3, pp. 487-528.

He, C., Kennedy, J. S., Coleman, T. F. and Forsyth, P. A., et al. (2006), "Calibration and hedging under jump diffusion", *Review of Derivatives Research*, Vol. 9, No. 1, pp. 1-35.

Duvelmeyer, D. and Hofmann, B. (2006), "A multi-parameter regularization approach for estimating parameters in jump diffusion processes", *Journal of Inverse and Ill Posed Problems*, 14(9); 861-880.

Future Research

□Determination of a wine production index that would aggregate the various weather related risks. Correlations between these risks may reduce the cost of hedging overall.

□Optimal methods of determining appropriate contract terms in order to minimize basis risk.

Conclusions

☐ Weather contracts represent a relatively new form of financial security that has the potential to help grape growers and wine producers mitigate many weather related risks.

□Climate change research suggests that weather related risks will increase in the future.

