ECON 485: Agricultural Economics & Policy

Futures Markets & Options Contracts

Lecture Notes

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Markets for Financial Derivatives

- Two categories:
  1. exchange-traded market: individuals trade standardized contracts that have been defined by the exchange (e.g., Chicago Mercantile Exchange, International Continental Exchange or ICE in Winnipeg)
  2. over-the-counter (OTC) market: individualized contracts where the market consists of a telephone-and computer-linked network of dealers

REFERENCE BOOK: John C. Hull, 2012. Options, Futures, and Other Derivatives. 8th ed. (Pearson Education).

Types of Traders

- **Hedgers** use financial derivatives (such as options) to reduce the risk that they face from potential future movements in a market variable (crop prices, stock values) or even physical variable (weather).
- **Speculators** use financial derivatives to bet on the future direction of a market or other variable
- **Arbitrageurs** take offsetting positions in two or more financial instruments to lock in a profit.

Forward Contract

- An agreement to buy or sell an asset at a certain future time for a certain price.
- Traded in the over-the-counter (OTC) market
- Similar to a spot contract, which is an agreement to buy or sell an asset today. There are two parties to the contract:
  - One assumes a long position, agreeing to buy the underlying asset on a certain specified future date for a certain specified price
  - Other assumes a short position, agreeing to sell the asset on the same date for the same price
- **Long position**: holder of the contract is obligated to buy the asset specified in the contract
  - Pay-off = $S_T - K$, where S_T is spot price of asset at maturity T and K is the 'delivery price' or what the holder of the long contract has to pay for the asset
  - Example: Party agrees to pay $K per unit for 1,000 units (viz., wheat) delivered at time T; that person can then turn about and sell the 1,000 units at $\$S_T$ per unit.
- **Short position**: holder of contract is obligated to sell the asset specified in the contract
  - Pay-off = $K - S_T$ => if future spot price < the price received by counter-party, the holder loses; otherwise, the holder gains.
- Costs nothing to enter into a forward contract, except for an administration fee

Futures Contract

- Futures contract: an agreement between two parties to buy or sell an asset at a certain time in the future and for a certain price.
- Unlike forward contracts, futures contracts are formally traded in an exchange market

Option Contracts

- Traded on exchange and OTC markets
  - An option gives participant the right to do something
  - Holder does not have to exercise this right, unlike in a forward or futures contract, where holder is obligated to buy or sell the underlying asset.
  - There is a cost to acquiring an option, unlike with a forward or futures contract
- **Call option**: gives holder of an options contract the right to buy the underlying asset by a certain date for a certain price
- **Put option**: gives holder right to sell the underlying asset by a certain date for certain price
- **Strike Price**: the exercise price of the contract
- **Expiration Date**: time at which the option is due, or maturity date
- For call/put options, buyers are referred to as having **long positions**; sellers are referred to as having **short positions**

Options Trading

- Call option contracts on 16 stocks started to trade in 1973 on the Chicago Board Options Exchange (CBOE)
- Put option contracts started trading on CBOE in 1977.
- For over-the-counter options, financial institutions often act as market makers (defined below) for the more commonly traded instruments
- Disadvantage of OTC trades is potential credit risk – that the contract is not honored
- Exchanges have organised themselves to eliminate virtually all credit risk
- **American** option contracts can be exercised any time up to the expiration date
- **European** option contracts can only be exercised on the expiration date

Option Positions

- Two sides to every option contract
  1. Investor who takes a **long position** (i.e., agreed to buy option)
  2. Investor who takes a **short position** (i.e., has sold or written the option).
- For European Options:
  - Payoff from a long position with call option = $\max(S_T - K, 0)$, as the option is only exercised if $S_T > K$
  - Payoff from a short position with call option is $\max(K - S_T, 0)$
  - Payoff from a long position with put option = $\max(K - S_T, 0)$
  - Payoff from a short position with a put option is $\max(S_T - K, 0)$

Recall: Call option gives holder right to buy the underlying asset by a certain date for a certain price, while put option gives holder right to sell the underlying asset by a certain date for certain price.

Governance:
Options Clearing Corporation (OCC)

- Guarantees that options writers will fulfill their obligation under the terms of the options contracts
- Keeps a record of all long and short positions
- Ensures margins are met
- Mechanism for facilitating market clearing

- ISDA standards (Master Agreement standards of the International Swap and Derivatives Association) provide standardised contracts aimed at easing OTC transactions

Index Options

- One contract is usually to buy or sell 100 times the index at the specified strike price (e.g., in exchange-traded equity option markets, one contract is usually an agreement to sell 100 shares)
- Settlement is always in cash.

Position Limits and Exercise Limits

- The CBOE often specifies a position limit for option contracts. This defines the maximum number of option contracts that an investor can hold on one side of the market.
- For this purpose, long calls and short puts are considered to be on the same side of the market.

Trading: Market Makers

- Options exchanges use market makers to facilitate trading. The market maker will quote both a bid and an offer price on an option
- Bid is price at which the market maker is prepared to buy
- Offer (or ask) is price at which market maker is prepared to sell
  - Offer always exceeds the bid with the difference referred to as the bid-offer spread
  - Exchange sets upper limits for the bid-offer spread (e.g., specify that spread not exceed $0.25 for options priced at less than $5; $0.50 for those priced between $5 and $10; $0.75 for those priced between $10 and $20; and $1 for options priced over $20
  - Market makers make their profits from the bid-offer spread.

Trading: Offsetting Orders

- Investor who purchased an option can close out the position by issuing an offsetting order to sell the same position
- Investor who has written an option can close out the position by issuing an offsetting order to buy the same option

Trading: Commissions

- Limit order specifies the least favorable price at which the order can be executed. Actual amount charged calculated as a fix cost plus a proportion of the value of the trade.
- If an option position is closed out by entering an offsetting trade, the commission must be paid again. If the option is exercised, the commission is the same as it would be if the investor placed an order to buy or sell the underlying stock.
- A hidden cost in option trading is market maker's bid-offer spread.
- A "fair" price of an option is halfway between the bid and the offer price.

Trading: Margins

- Buying on margin: Investor can borrow up to 50% of option for shares purchased in U.S.
- Margin call: Broker requests investor to deposit additional cash if share price falls so that loan exceeds more than 50% of stock's current value
- If margin call is not met, broker sells the stock
- If one buys an option that matures in less than 9 months, payment in full is required
- For options with maturities greater than 9 months investors can buy on margin, borrowing up to 25% of the option value

Exercising an Option

- When investor notifies a broker to exercise an option, the broker notifies the OCC member clearing its trades.
- OCC member then places an exercise order with the OCC. The OCC randomly selects a member with an outstanding short position in the same option. Member then selects an investor who has written the option using a procedure established in advance.
- An exchange specifies the size of the contract, the precise expiration time, and the strike price. In the U.S.:
  - one stock option contract gives the holder the rights to buy or sell 100 shares
  - Expiration of a stock option contract is always at 10:59 p.m.
  - Strike prices are at $2.5, $5 or $10 intervals, depending on the stock price

Factors Affecting Price of a Stock Option

1. current stock price, S_0
2. strike price, K
3. time to expiration, T
4. volatility of the stock price, σ
5. risk-free interest rate, r
6. dividends that are expected to be paid.

If call option is exercised at future date t, payoff = $(S_t - K)$, or amount by which stock price exceeds strike price

For a put option, payoff = $(K - S_t)$, or amount by which the strike exceeds the stock price

Volatility

- Volatility measures uncertainty about future stock price movements. Values of calls and puts increase as volatility increases.

Upper and Lower Bounds for Option Prices

- An American or European call option gives holder the right to buy one share of a stock for a certain price
- An option can never be worth more than the stock price (non-dividend paying stock), so the stock price is an upper bound to the option price, $P_{call} \leq S_0$.
- An American put option gives holder the right to sell one share of a stock for K. The option can never be worth more than K, $P_{put} \leq K$
- For European options, the option cannot be worth more than K at maturity; therefore, it cannot be worth more than the current value of K: $P_{option} \leq Ke^{-rT}$

Financial Weather Derivatives and Crop Insurance

- Crop insurance is major mechanism for stabilizing and subsidizing farm incomes
- Public provision of crop insurance reduces the scope for using financial markets; yet there remains a role for the private sector
- Private sector role in areas of:
  - Re-insurance (governments sell insurance contracts to private sector reinsurers)
  - Provision of financial weather products

Financial Weather Derivatives

- Financial derivatives based on outcomes of weather indexes
- Weather-indexed insurance contracts are alternative instruments that can be used to hedge production risks related to weather outcomes.
- Financial weather derivatives avoid two problems associated with traditional crop insurance based on yields:
  1. moral hazard and
  2. adverse selection.
- How? The value of a weather index does not depend on the individual actions or numbers of market participants

Types of Weather Indexes

- Number of days/hours that temperature in certain weeks in late Fall is between –5°C and –8°C → for grapes used in making ice wine
- Heating degree days (HDDs): number of days when temperatures are below 65°F and space heating services are required
- Cooling degree days (CDDs): number of days when temperatures are above 65°F and space cooling services are required
- Growing degree days (GDDs): during growing season, the number of days that temperatures are above 5°C and there is enough heat for crop growth
- Rainfall, early frosts, hail, et cetera, can all be used as weather indexes

$$HDD = \sum_{d=1}^{D} Min(18 - \overline{T}_d, 0)$$

$$CDD = \sum_{d=1}^{D} Max(\overline{T}_d - 18, 0)$$

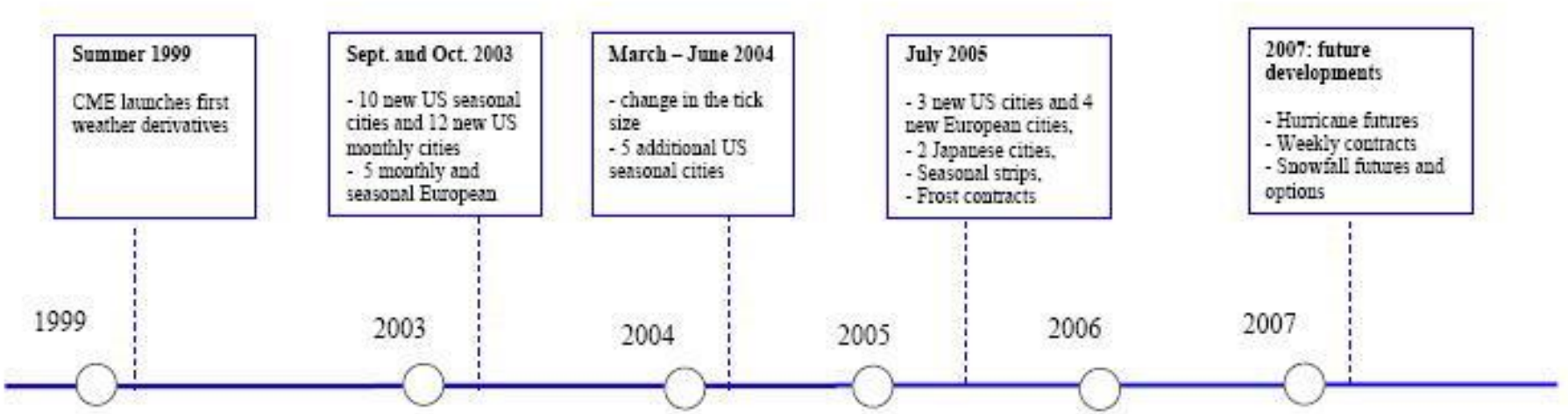
$$GDD = \sum_{d=1}^{D} Max(\overline{T}_d - 5, 0)$$

- Use **burn analysis** based on historical data to establish a link between a weather index and crop yields (Schlenker and Roberts 2006; Robertson 2012)
- How to hedge weather risks? Financial weather derivatives traded in either the exchange market or OTC, but where are they traded?

Where to get financial weather products?

- 1997: First weather transactions (OTC) took place between Enron and Koch Industries. based upon some temperature indices to compensate the energy producer in case of a mild winter
- 1998: First European deals took place between Enron and Scottish Hydro Electric on a similar basis
- 1999: Trading in weather derivatives began on the Chicago Mercantile Exchange (CME), with HDDs

Key Dates on Chicago Mercantile Exchange



CME offers contracts for 18 American cities (Las Vegas, Atlanta, Chicago, Cincinnati, New York, Dallas, Philadelphia, Portland, Tucson, Des Moines, Boston, Houston, Kansas City, Minneapolis, Sacramento, Salt Lake City, Detroit, Baltimore); 6 Canadian cities (Calgary, Edmonton, Montreal, Toronto, Vancouver, Winnipeg); 9 European cities (London, Paris, Amsterdam, Berlin, Essen, Stockholm, Rome, Madrid, Barcelona); and 2 Japanese cities (Tokyo, Osaka).

Weather Derivatives

- CME market:
  - Standard contracts and easy to write
  - Carry **basis risk**
    - Precipitation varies too much, even across local landscape
    - Temperatures measured in Calgary not helpful for farm in Regina
- OTC market:
  - Written on index measured locally, even at farm level
  - Flexible
  - Potential high **credit risk**

Payoffs

A call option can be claimed when the value of the weather index is above a specified strike value, while a put option can be claimed when the value of the weather index is below a specified value

$$p(w)_{put} = \begin{cases} \lambda(K_1 - w), & if \;\; w \le K_1 \\ 0\ , & if \;\; w > K_1 \end{cases}$$

$$p(w)_{call} = \begin{cases} 0\ , & if \;\; w < K_2 \\ \lambda(w - K_2), & if \;\; w \ge K_2 \end{cases}$$

where $p(w)$ is the payoff; λ is the tick size (dollar value per unit of the weather index); K_1 and K_2 are the strike values, respectively; and w is the weather index.

Premiums

The premium (price of option) is calculated from the expected payoff:

$$c = \mathrm{e}^{-r(T-t)}\, E_p$$

where c is the premium, r is a risk-free periodic market interest rate, t is the date the contract is issued, T is the date the contract is claimed, and E_p is the expected payoff:

$$E_p = \int_{-\infty}^{\infty} p(w)\, f(w)\, \mathrm{d}w$$

where $f(w)$ is the probability density function of the weather index w, often taken to be a normal distribution (or log-normal if w cannot take on negative values), and $p(w)$ is the payoff

Efficiency of Weather Derivatives

Farmer's revenue with no financial hedge:

$$R(w) = P\, y_j(w),$$

where $y(w)$ is yield as a function of the weather index and P refers to price

With a put option on w:

$$R(w, q, K) = P\, y(w) + q[\alpha(K - w) - O(K)]$$

where

α = tick size ($/$w$)

K = strike (trigger) level for the put option

$O(K)$ = option price (premium) as a function of strike level

$\alpha(K - w) - O(K)$ = net payoff to the option

q = number of options purchased.

- Option price or premium is a function of the strike level:

$$O(K) = \int_0^K \frac{1}{w\sqrt{2\pi\sigma^2}} e^{-\frac{(lnw-\mu)^2}{2\sigma^2}} dw,$$

- where premium equals area under lognormal density function up to the strike level, μ = mean of ln(w), and σ^2 = Var[ln(w)]

Consider farmer wishing to buy a weather-indexed option to protect against too low temperatures during the growing season. Two Strategies:

- Pure Strategy:
  - Write a put option based on the local GDD index in OTC market.

- Multi Strategy:
  - Combine an exchanged-based CDD put option and an OTC-based GDD put option (i.e., basis put option), which is based on the gap between the CDD index at the remote location and the local GDD index

Method

- Relation between CDD and GDD

$$
\begin{aligned}
CDD &= \sum_{d=1}^{D} Max(0, \overline{T}_d - 18) \\
&= \sum_{d=1}^{D} (\overline{T}_d - 18) + \sum_{d=1}^{D} Max(0, 18 - \overline{T}_d) \\
&= \sum_{d=1}^{D} \overline{T}_d - 5D - 13D + \sum_{d=1}^{D} Max(0, 18 - \overline{T}_d) \\
&\approx GDD - 13D + HDD
\end{aligned}
$$

Method (cont)

- Mean Variance Analysis
  - To derive efficient hedging portfolio

$$U(W) = E(W) - \lambda \sigma^2(W)$$

- Hedging Effectiveness Parameter
  - To find out the more efficient portfolio

$$HE = (\sigma_{OTC} - \sigma_{multi})/\sigma_{OTC}$$

Empirical Analysis

- Exchange-based contract – Calgary
- OTC-based contract – Rural Municipality 280, Saskatchewan

Temperature Indices from 1997 to 2011

	Calgary International Airport			RM280		
	GDD	CDD	HDD	GDD	CDD	HDD
Mean	1107.3	43.3	548.0	1252.9	98.0	456.5
σ^2	7384.9	375.4	6433.5	25450.5	2287.1	17653.7
σ	85.9	19.4	80.2	159.5	47.8	132.9

Hedging Effectiveness Parameter under Different Level of Strikes and Credit Risk

p	1	0.99	0.98	0.97	0.96	0.95
(1-p)	0	0.01	0.02	0.03	0.04	0.05
Strike						
0σ	0.29%	0.42%	0.55%	0.68%	0.81%	0.93%
0.1σ	2.05%	2.15%	2.26%	2.37%	2.47%	2.58%
0.2σ	3.72%	3.80%	3.89%	3.97%	4.05%	4.13%
0.3σ	4.13%	4.20%	4.27%	4.34%	4.41%	4.48%
0.4σ	3.11%	3.18%	3.25%	3.32%	3.40%	3.47%
0.5σ	1.62%	1.69%	1.76%	1.83%	1.90%	1.97%
0.6σ	0.11%	0.18%	0.25%	0.32%	0.39%	0.46%
0.7σ	-1.22%	-1.15%	-1.09%	-1.02%	-0.95%	-0.89%
0.8σ	-2.75%	-2.69%	-2.62%	-2.56%	-2.49%	-2.43%

Conclusions

- Hedging effectiveness parameter increases in credit risk.
- The CDD exchanged-based option in multi strategy could eliminate part of credit risk, presenting smaller variance.
- Multi strategy is preferable to pure strategy.
- Further study: the differences in hedging effectiveness across cities and countries.