

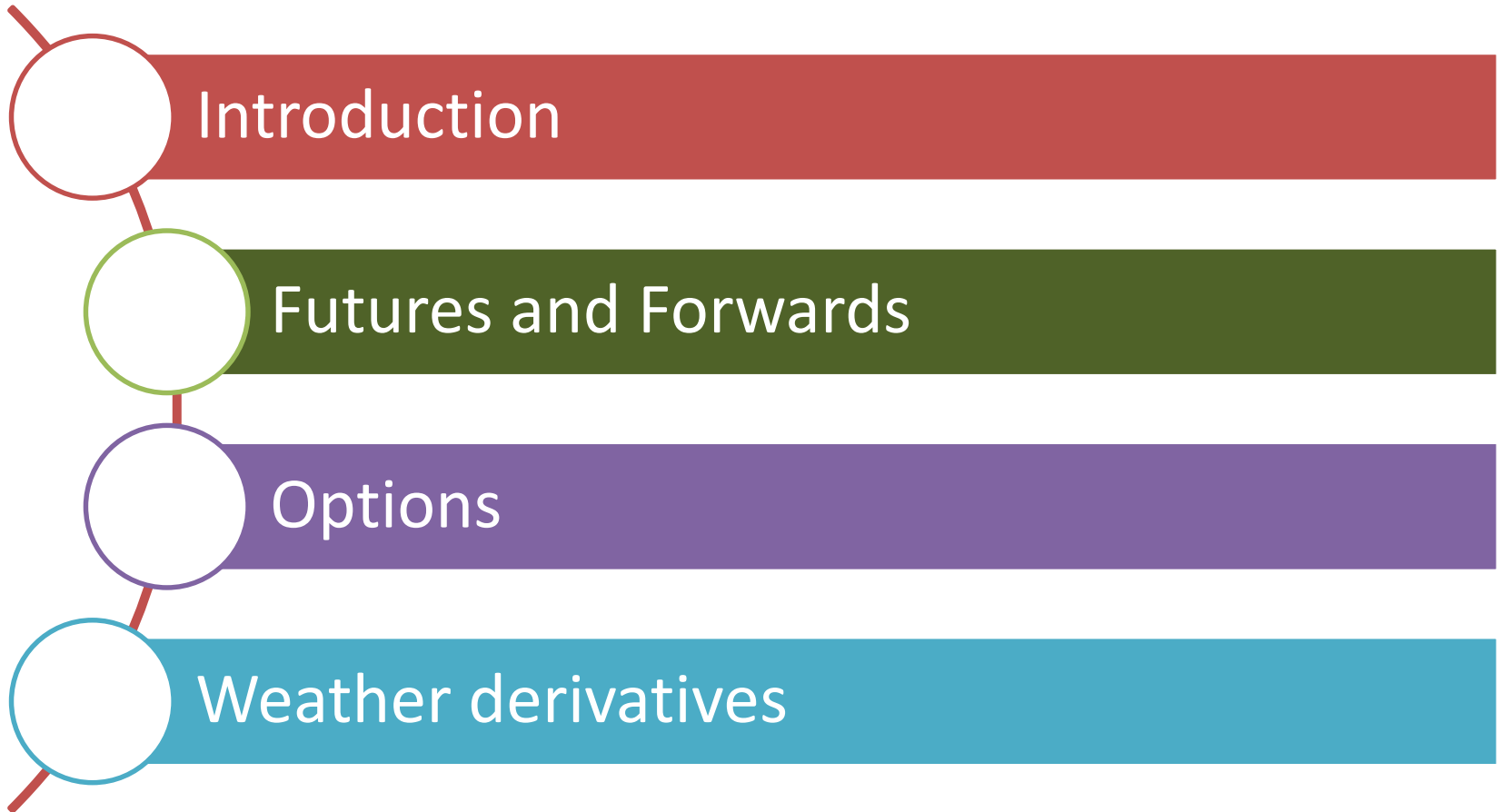
Derivatives & Agriculture

Lecture Notes

Sheri Liu

G Cornelis van Kooten

Outline



Markets for Trading Derivatives

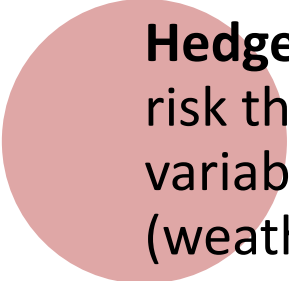
Exchange-traded market:

Individuals trade standardized contracts that have been defined by the exchange (e.g., Chicago Mercantile Exchange, International Continental Exchange or ICE in Winnipeg)

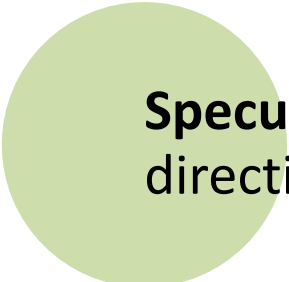
Over-the-counter (OTC) market:

Individualized contracts where the market consists of a telephone-and computer-linked network of dealers

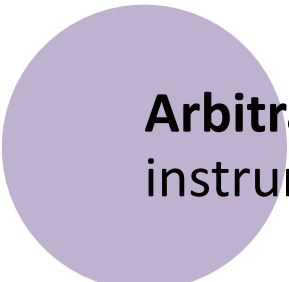
Types of Traders



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.

Main Types of Derivative Instruments

Common features:

a contract between two parties for trading something in the future with the terms and price agreed upon today; margin requirements (not for options buyers).

Futures
Forwards
Options
Swaps

Differences:

Futures: contracts are standardized, traded through futures exchanges, subject to daily settlement, guaranteed by a clearinghouse, and has marketability.

Forwards: contracts are non-standardized, traded OTC, and usually settled on the pre-determined date.

Options: buyer of an option has right but no obligation while seller has the obligation to deliver when the option is exercised

Swaps: usually involves a series of cash flows at a few dates; fixed-floating



Main Types of Derivatives' Underlying Instruments

CME Group **TRADING** CLEARING REGULATION

All Products Home

Featured Products

- ZC** Corn
- ZS** Soybean
- CL** WTI Crude Oil
- NG** Henry Hub Natural Gas
- ES** E-mini S&P 500
- NQ** E-mini Nasdaq-100
- 6E** Euro FX
- GE** Eurodollar
- ZN** 10-Year T-Note
- ZF** 5-Year T-Note
- GC** Gold

Product Groups

- Agricultural
- Energy
- Equity Index
- FX
- Interest Rates
- Metals
- Options
- OTC
- Real Estate
- Weather

<https://www.cmegroup.com/trading/products/#pageNumber=1&sortAsc=false&sortField=oi>

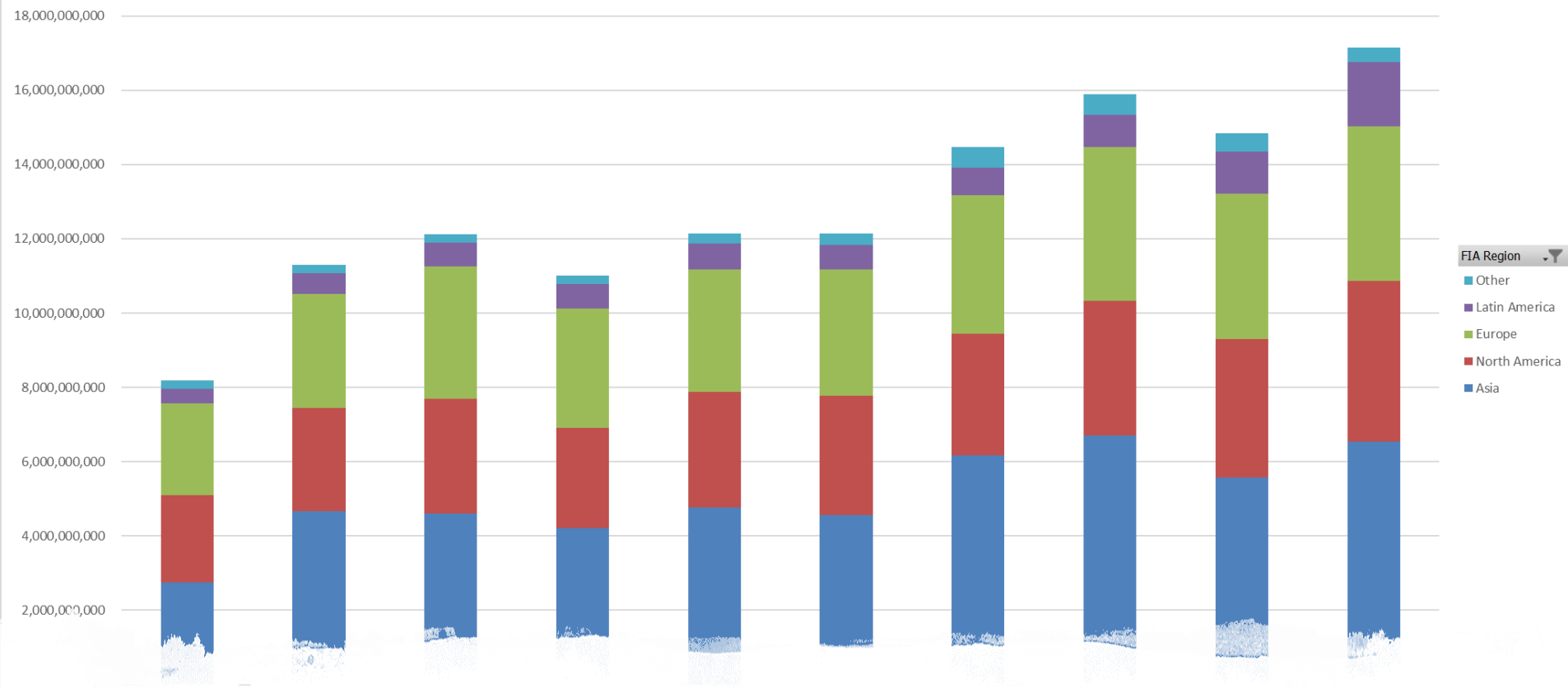
Futures & Forwards

Benefits of futures trading

Hedge risk: Futures trading enables producers to hedge the risks of planting a crop, say, by ensuring the price at harvest time

Enhance price discovery: A commodity firm making a large sale to an overseas buyer can immediately turn around and hedge the sale on a futures market; this transfers information from those who have it to those who do not





Promote storage and enhance efficiency: Prior to futures trading, there were wide swings in agricultural prices; futures trading made storage profitable.



- Futures contracts started with grains and agricultural products and gradually expanded to natural resources (e.g., metals and energy products) and financial futures.

- Trading volumes and number of markets have increased rapidly since 1970s.











All market data contained within the CME Group website should be considered as a reference only and should not be used as validation against, nor as a complement to, real-time market data feeds.

Product	Code	Contract		Last	Change	Chart	Open	High	Low	Globex Vol
Corn Futures	ZCK9	MAY 2019	OPT	365'2	-0'4		365'4	366'6	365'2	5,537
Soybean Futures	ZSK9	MAY 2019	OPT	897'2	+0'2		896'0	898'4	894'6	5,355
Soybean Oil Futures	ZLK9	MAY 2019	OPT	29.87	-0.12		29.99	30.04	29.85	3,673
Soybean Meal Futures	ZMK9	MAY 2019	OPT	303.6	+0.6		302.5	303.9	302.5	1,976

Futures Contracts for Agriculture

- Grains and Oilseeds (wheat, corn, soybeans, palm oil, rice, etc.)
- Livestock and meat (cattle, hogs)
- Dairy (milk, butter, cheese)
- Food and fiber (cocoa, coffee, sugar)

<https://www.cmegroup.com/trading/agricultural/#featured>

Month	Options	Charts	Last	Change	Prior Settle	Open	High	Low	Volume	Hi / Low Limit	Updated
MAY 2019	OPT		374'4	+1'2	373'2	374'0	375'4	373'4	16,411	398'2 / 348'2	23:31:55 CT 17 Mar 2019
JUL 2019	OPT		383'2	+1'0	382'2	383'0	384'4	382'6	6,612	407'2 / 357'2	23:30:26 CT 17 Mar 2019
SEP 2019	OPT		389'4	+0'6	388'6	389'2	390'2	389'0	2,386	413'6 / 363'6	23:27:53 CT 17 Mar 2019
DEC 2019	OPT		397'0	+1'0	396'0	396'2	397'4	396'0	3,862	421'0 / 371'0	23:30:29 CT 17 Mar 2019
MAR 2020	OPT		408'0	+1'0	407'0	407'0	408'2	407'0	343	432'0 / 382'0	23:14:33 CT 17 Mar 2019
MAY 2020	OPT		412'6	+0'4	412'2	412'4	413'2	412'4	31	437'2 / 387'2	21:58:05 CT 17 Mar 2019
JUL 2020	OPT		415'6	+1'0	414'6	415'0	416'0	415'0	20	439'6 / 389'6	23:27:53 CT 17 Mar 2019
SEP 2020	OPT		-	-	407'0	-	-	-	0	432'0 / 382'0	16:00:00 CT 17 Mar 2019
DEC 2020	OPT		409'6	+0'6	409'0	409'0	409'6	409'0	27	434'0 / 384'0	19:25:22 CT 17 Mar 2019
MAR 2021	OPT		-	-	416'4	-	-	-	0	441'4 / 391'4	16:00:00 CT 17 Mar 2019

Corn Futures Quotes

https://www.cmegroup.com/trading/agricultural/grain-and-oilseed/corn_quotes_globex.html

Two Parties of A Futures Contract

Similar to a spot contract, which is an agreement to buy or sell an asset today, there are two parties to the contract:

- One party assumes a **long** position, agreeing to buy the underlying asset on a certain specified future date for a certain specified price
- Other party assumes a **short** position, agreeing to sell the asset on the same date for the same price

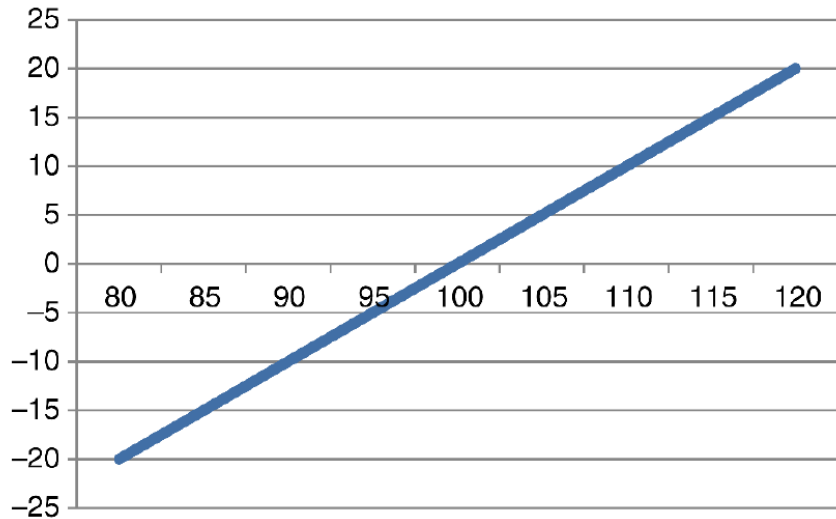
Long position: holder of the contract is obligated to buy the asset specified in the contract

- 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

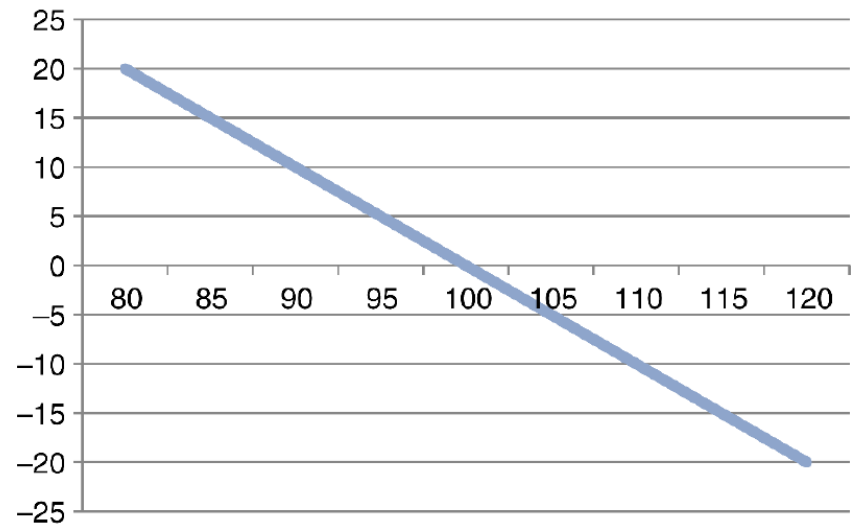
Short position: holder of contract is obligated to sell the asset specified in the contract

- Pay-off = $K - S_T \Rightarrow$ if future spot price < the price received by counter-party, the holder loses; otherwise, the holder gains.

A Simple Example for Payoffs



Long position payoff with $K = \$100$ at maturity
Source: Sacks 2015, p.11-12



Short position payoff with $K = \$100$ at maturity

Reference: Sacks, J. (2015). *Elementary financial derivatives : a guide to trading and valuation with applications*. Wiley.

Offset & Settlement

Because of the commission costs and the costs of storing and/or transporting commodities, the majority of the futures traders choose to offset their positions by taking an opposite position before the maturity of the contract, instead of taking delivery.

If a futures trader keeps the position open after the expiration date, the settlement can be either in physical form or in cash. Most of futures contracts are settled with a payment, instead of taking possession of the underlying asset.

One Key Component for Facilitating Futures Trading -- Clearinghouse (CH)

- A corporation that is separate from but associated with a futures exchange
- All futures trades are cleared through the CH at the end of the day
- Trades must be cleared through a member of the CH, with member paid a commission fee for this service
- CH balances books on outstanding futures accounts at the end of each trading day
- CH facilitates delivery on futures contracts

Illustration of Operation of Clearinghouse

(Carter 2003, p.70; Johnson 2017, p.8-9)

Time period	Futures buyer	Futures seller	Contract value	CH position	Open longs	Open shorts
1	A	B	\$19,450	A's seller, B's buyer	A	B
2	C	A	\$20,700	C's seller, A's buyer	C	B
3	B	C	\$18,150	B's seller, C's buyer	—	—

CH facilities delivery: in essence, the CH becomes each buyer's seller and each seller's buyer.

Suppose A takes a long position on a July corn futures worth \$19,450 (committed to buy 5000 bushels of corn for \$3.89/bu at the settlement date in July), while B takes a short position of the same transaction. It is the CH, however, which has committed to accept delivery from B and to deliver to A.

Suppose the next day, A sells a July corn futures contract to C at \$4.14/bu. Now A's position is closed and the CH pays A (through a broker) a total of \$1,250 $(=(4.14-3.89)*5,000)$.

Meanwhile, because the market moved 'against' B and B's commitment is 'marked to market', at the end of day 2, B receives a 'margin call' and will be required to input \$1,000 into his account (assuming initial and maintenance margins are same).

If C and B liquidate their positions at \$3.63/bu on day 3, how much does C lose and what is B's profit?

Options

Background – a few key features

Traded on exchange and OTC markets

An option gives the buyer the right to do something

Buyer does not have to exercise this right, unlike in a forward or futures contract, where seller (writer) is obligated to buy or sell the underlying asset if the option is exercised.

There is a cost (premium) to acquiring an option, unlike with a forward or futures contract

Background – some concepts

Call (Put) option: gives holder of an options contract the right to buy (sell) the underlying asset by a certain date for a 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**

American option contracts can be exercised any time up to the expiration date
European option contracts can only be exercised on the expiration date

Background – related to option 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 (**OTC**) 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 but not **basis risk** -- the value of a derivatives contract does not move in line with that of the underlying exposure

Background – Market Makers (1)

Exchanges use market makers to facilitate trading. Market maker quotes both a bid and an offer price on an instrument.

In general, bid is a price at which a trader is prepared to buy

Similarly, offer (ask) is a price at which a trader 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. For example, exchange specifies 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.

BIDS	PRICE	OFFERS
	10.19	Investor
	10.08	Market Maker A
	10.07	Investor
	10.04	Market Maker B
	10.03	Investor
Market Maker A	10.01	
Investor	9.99	
Investor	9.98	
Market Maker B	9.95	
Investor	9.85	

Fig. 1. Liquid market with investors and market makers, the bid-offer spread is only 2 cents wide & there are a number of buyers & sellers

Background – Market Makers (2)

Source:

<http://wildwoodtrading.com/what-is-market-making/>

BIDS	PRICE	OFFERS
	10.19	Investor
	10.08	Investor
	10.07	Investor
	10.04	Investor
	10.03	Investor
	9.50	Investor
	9.42	Investor
	9.40	Investor
	9.10	Investor
Investor	8.45	

Fig. 2. Illiquid market without market makers during a large imbalance. There are mostly sellers and a single buyer with a low bid

BIDS	PRICE	OFFERS
	9.55	Market Maker C
	9.50	Investor
	9.46	Market Maker B
	9.45	Market Maker A
	9.42	Investor
	9.40	Investor
Market Maker C	9.32	
Market Maker B	9.30	
Market Maker A	9.27	
Investor	8.45	

Fig. 3. Market makers balance and restore liquidity by stepping in to buy the product when other investors do not

Background – Market Makers (3)

EXHIBIT 5: LIQUIDITY PROVIDERS AND THEIR OBLIGATIONS

Liquidity Provider	Description	Obligations
Broker-dealers	Broker-dealers facilitating block orders for customers.	<ul style="list-style-type: none"> No obligations.
Exchange-registered market makers	Exchange liquidity provider as defined by the rules and liquidity programs established by each exchange.	<ul style="list-style-type: none"> Must be registered on the exchange, maintain adequate capital requirements, and provide continuous two sided quotations. Market makers may have exchange obligations to quote at minimum spreads or sizes for specified proportions of the trading day. Market makers may be required to stand in and facilitate auctions. Compensated by better tiers for fees/rebates, direct payments for providing liquidity, or priority on orders.
Wholesale / OTC market makers	Market maker that specifically makes markets to smaller regional or retail brokers.	<ul style="list-style-type: none"> Must guarantee client execution but can fulfill this obligation by routing flow out to an exchange instead of committing capital. Generally need to demonstrate and compete on price improvement metrics and execution quality statistics.
Electronic market makers	Automated high frequency market makers that seek to capture the bid/offer spread and exchange rebates as a risk premium for providing liquidity.	<ul style="list-style-type: none"> No obligations.
High Frequency Arbitrageurs	Proprietary trading firms which employ high frequency trading strategies to conduct statistical or index arbitrage to capture mispricing between correlated or related assets.	<ul style="list-style-type: none"> No obligations.

An Example of An Option Contract

KC HRW Wheat Options Contract Specs

View Another Product ▼

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[Settlements](#)
[Volume](#)
[Time & Sales](#)
[Contract Specs](#)
[Margins](#)
[Calendar](#)

[Futures](#)
[Options](#)

Type: American Options ▼

Contract Unit	One KC HRW Wheat Futures contract (5,000 bushels)	
Minimum Price Fluctuation	1/8 cent per bushel (\$6.25 per contract)	
Price Quotation	Cents and eighths of a cent per bushel	
Trading Hours	CME Globex:	Sunday – Friday, 7:00 p.m. – 7:45 a.m. CT and Monday – Friday, 8:30 a.m. – 1:20 p.m. CT
	Open Outcry:	Monday – Friday, 8:30 a.m. – 1:15 p.m. CT with Post session until 1:20 p.m. CT immediately following the close
Product Code	CME Globex: OKE CME ClearPort: KW Open Outcry: Put: HP Call: HC Clearing: KW	
Listed Contracts	Monthly contracts listed for 3 consecutive months with 6 months in the March, May, July, September, December cycle and a second July contract month.	

Settlement Procedures	Open Outcry Settlement Team
Termination Of Trading	Trading terminates on the last Friday which precedes by at least two business days the last business day of the month prior to the contract month. Trading in expiring options ceases at the close of the regular CME Globex trading session for the corresponding futures contract.
Position Limits	CBOT Position Limits
Exchange Rulebook	CBOT 14L
Block Minimum	Block Minimum Thresholds
Price Limit Or Circuit	Price Limits
Vendor Codes	Quote Vendor Symbols Listing
Strike Price Listing Procedures	Ten (10) cents per bushel for standard options, and five (5) cents per bushel for serial options and for standard options when they become the third listed contract month. Levels of strike price increments: 30 (30 above and 30 below ATM to a minimum strike of 1.00)
Exercise Style	American
Settlement Method	Deliverable
Underlying	KC HRW Wheat Futures

Two Parties of An Options Contract

Same as a futures contract, there are two parties to the contract:

- Investor who takes a **long** position (i.e., agreed to buy option)
- Investor who takes a **short** position (i.e., has sold or written the option)

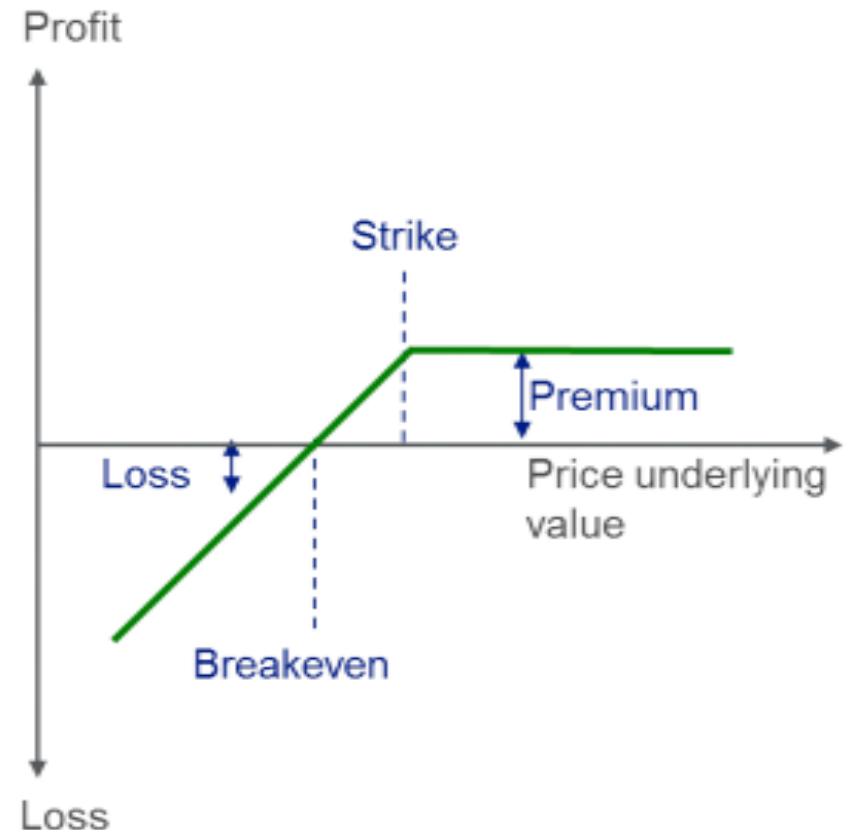
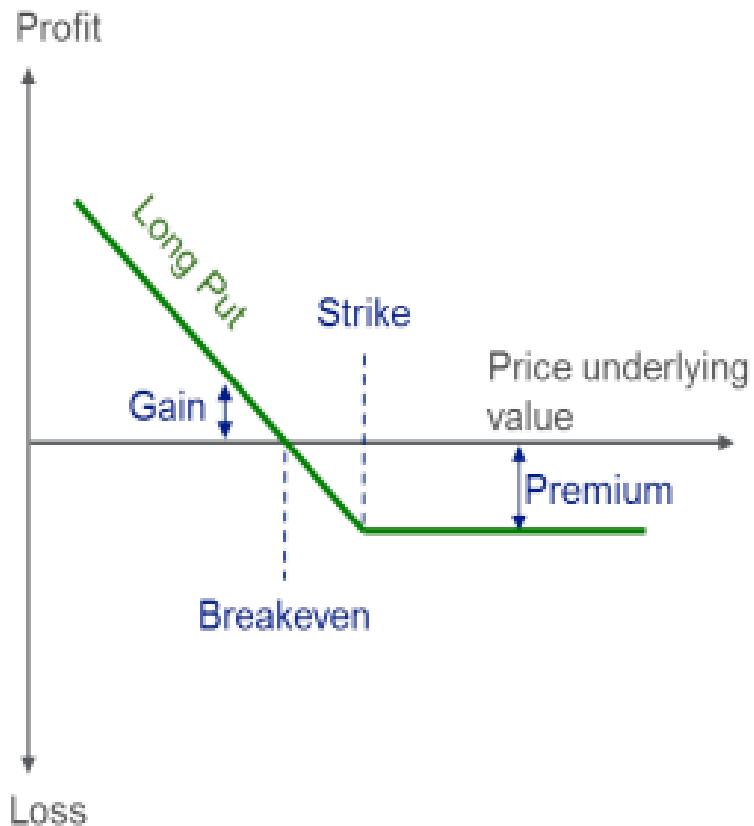
Long position: holder of the contract has right (no obligation) to buy (long call) or sell (long put) the asset specified in the contract

- Long call: Payoff = $\max(S_T - K, 0)$, as the option is only exercised if $S_T > K$, where S_T is spot price of asset at maturity T and K is the strike price
- Long short: Payoff = $\max(K - S_T, 0)$

Short position: holder of contract is obligated to buy (short put) and sell (short call) the asset specified in the contract

- Short call: Payoff = $\max(K - S_T, 0)$
- Short put: Payoff = $\max(S_T - K, 0)$

A Figure for Showing Payoffs with Premium



Questions

Q1

Suppose we purchased a \$3.65 July KC wheat put option for 18 cents a bushel via CME. What is the underlying instrument, strike price, premium?

Q2

To protect against falling prices, should we buy a call or a put option?

Illustration of Wheat Futures Options: May 17, 2002 WSJ (Carter 2003)

Wheat (CBT)

5,000 bu.; cents per bu.

Price	Jly	Sep	Dec	Jly	Sep	Dec
260	18.500	25.250	...	2.000	4.250	4.000
270	11.625	18.750	28.125	5.125	7.750	7.000
280	6.750	13.750	22.375	10.250	12.375	11.125
290	4.000	10.000	17.625	17.500	18.750	16.125
300	2.125	7.250	14.000	25.625	25.500	22.375
310	1.125	5.250	11.250	34.625	33.500	29.375

← Calls
 Puts →

Buyer of an options contract in wheat can choose strike prices ranging from \$2.60/bu to \$3.10/bu. Suppose he chooses to go long on a July wheat options contract at a strike price of \$2.80/bu. The premium for this option is $\$0.0675/\text{bu} \times 5,000 \text{ bu} = \337.50 , which is paid immediately. If wheat July futures price falls below \$2.80/bu, he chooses not to exercise the option, lets the option expire and loses \$337.50. If July price exceeds \$2.80/bu, he exercises the option and acquires a long position in the futures market. If July price exceeds \$2.8675/bu, he will exercise and earn positive net profit. Of course, he can choose to sell a call on a July wheat options contract to offset his position.

Option Prices

Comprised of two parts:

- Intrinsic value
- Time value

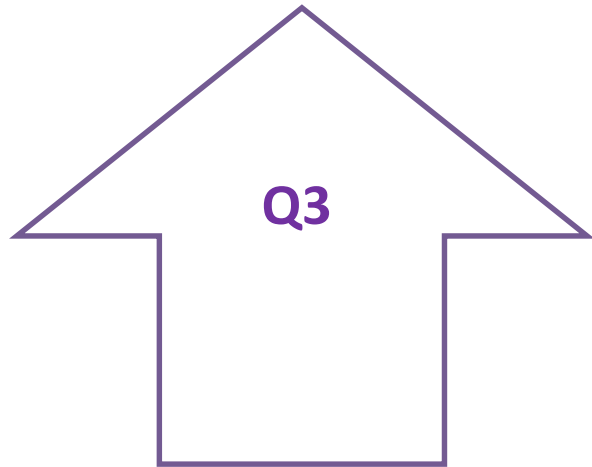
Intrinsic value:

- In the money
- At the money
- Out of the money

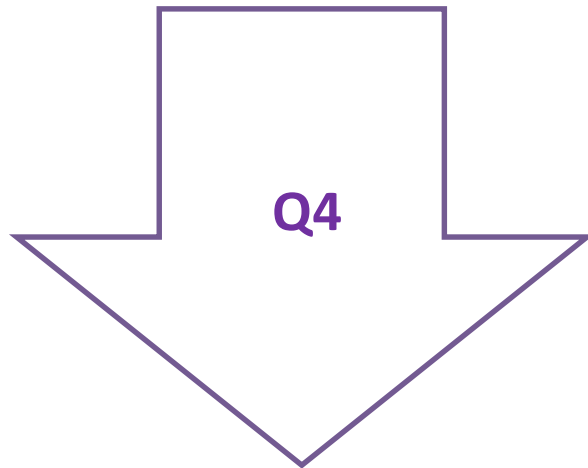
Main factors that affecting time value:

- Time to expiration, T
- Volatility of the underlying instrument, σ
- Risk-free interest rate, r
- Intrinsic value
- Dividends that are expected to be paid if applicable

Questions



If CME May corn futures are trading at \$4.25 and the \$4.00 May corn call option is priced at 50 cents per bushel, what is the premium, intrinsic value and time value?



Suppose you sold a CME \$4.50 July corn call and CME July corn futures fell to \$4.25 on the expiration date, is it possible that you will be required to fulfill the obligation to sell a July corn futures contract?

More Questions

Q5

If you sell a CME September \$3.90 wheat call option at \$0.6, what is your maximum net loss per bushel in theory?

If what you sell is a put option at \$0.4, what is your maximum net loss per bushel in theory?

Q6

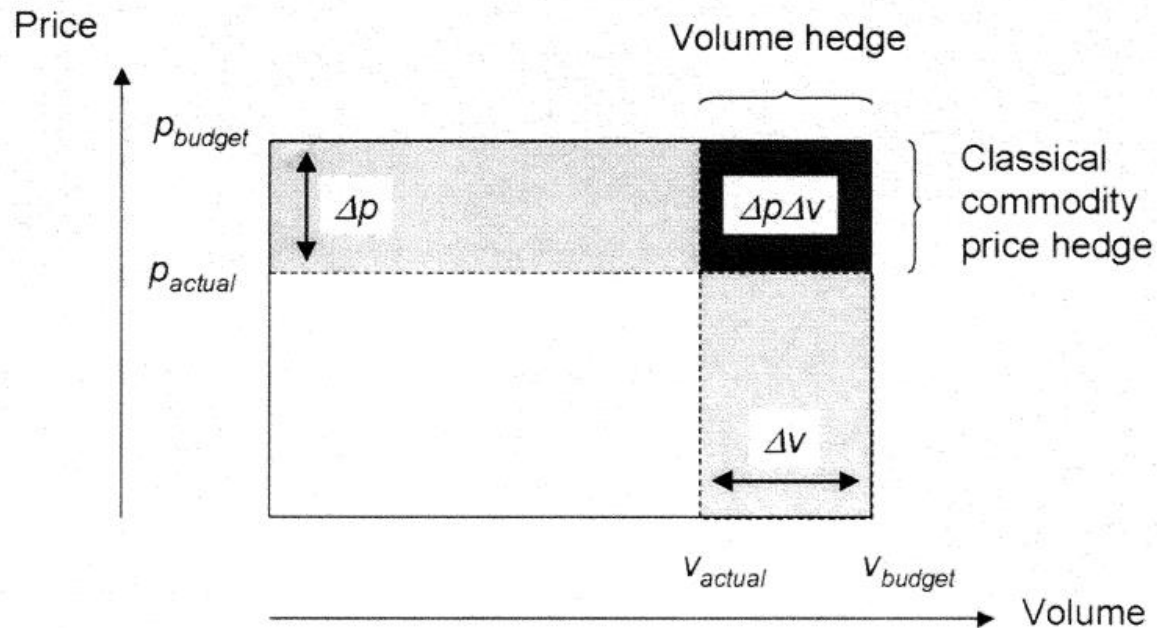
Suppose a producer purchases a November soybean put option with a strike price of \$4.5 for a premium of \$0.5.

In October, the price of soybean drops to \$4.0 and the premium rises to \$0.8.

The producer offsets his option position and sells his soybean simultaneously (assuming no basis risk and costs). What is her net price?

Weather Derivatives

- Derivatives are designed based on outcomes of weather indexes, which are not traded in other markets.
- The prime objective is to hedge against volume risk, rather than price risk.



Müller, A., & Grandi, M. (2000). Weather Derivatives: A Risk Management Tool for Weather Sensitive Industries. *The Geneva Papers on Risk and Insurance*. Vol 25. No. 2, 273- 287.

Types of Weather Indexes

Temperature is the main underlying weather factor for derivatives.

- 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
- Cumulative average temperature (CAT): the cumulative amount of temperature over a period, which can be seasonal or monthly.

Rainfall, early frosts, hail, snowfall et cetera, can all be used as weather indexes.

Formulas and An Example

$$HDD = \sum_{d=1}^D \text{Max}(65 - \bar{T}_d, 0)$$

$$CDD = \sum_{d=1}^D \text{Max}(\bar{T}_d - 65, 0)$$

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

$$CAT = \sum_{d=1}^D \bar{T}_d$$

$$\bar{T}_d = \frac{T_{min} + T_{max}}{2}$$

Note: 18 °C is used as the benchmark in EU

Current Weather



Mostly Cloudy
Temperature: 55°F
Dew Point: 24°F

RH: 28%
Wind: S 8 mph
Pressure: 1013 mb

Day	Hi	Low	Average	Weather	HDD	\$Impact
THU	54°	34°	44		21°	\$420
FRI	52°	37°	45		20°	\$400
SAT	52°	37°	45		20°	\$400
SUN	56°	37°	47		18°	\$360
MON	54°	37°	46		19°	\$380
TUES	58°	37°	48		17°	\$340
WED	61°	30°	46		19°	\$380
					Total \$2680/ per contract	

Source: <https://www.investopedia.com/trading/market-futures-introduction-to-weather-derivatives/>

Payoffs

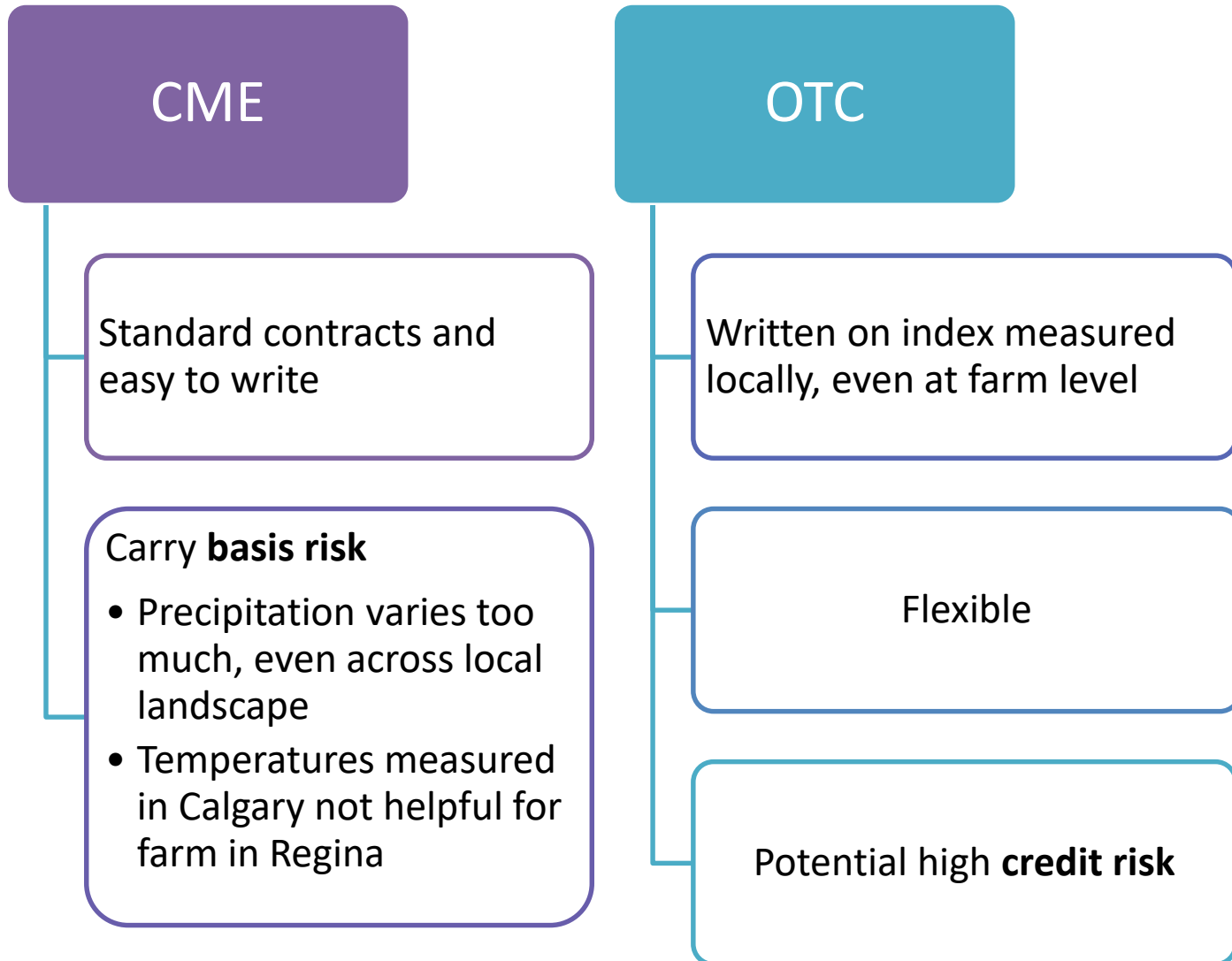
A call option can be claimed when the value of the weather index is above a specified strike value, while a put option can be claimed when the value of the weather index is below a specified value

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

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

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.

Where to Buy Weather Derivatives

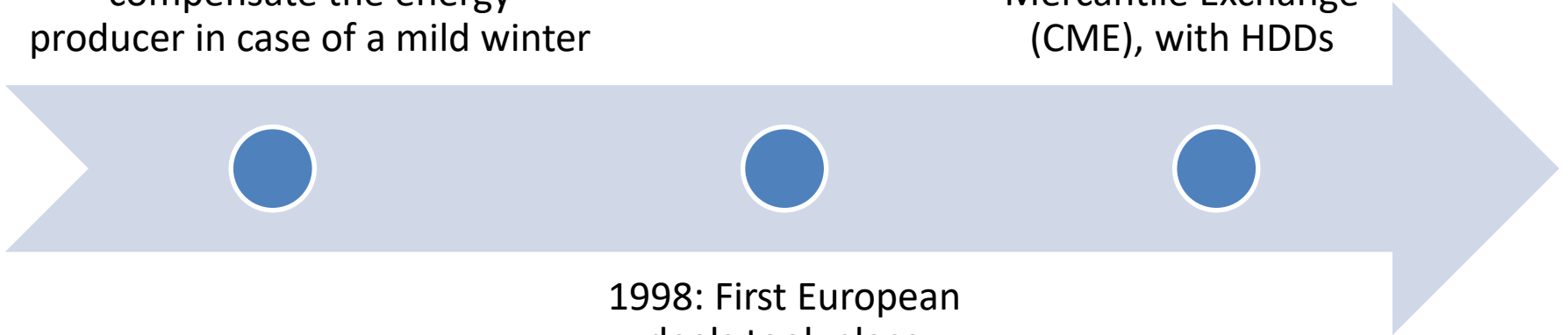


The Beginning of Weather Derivatives

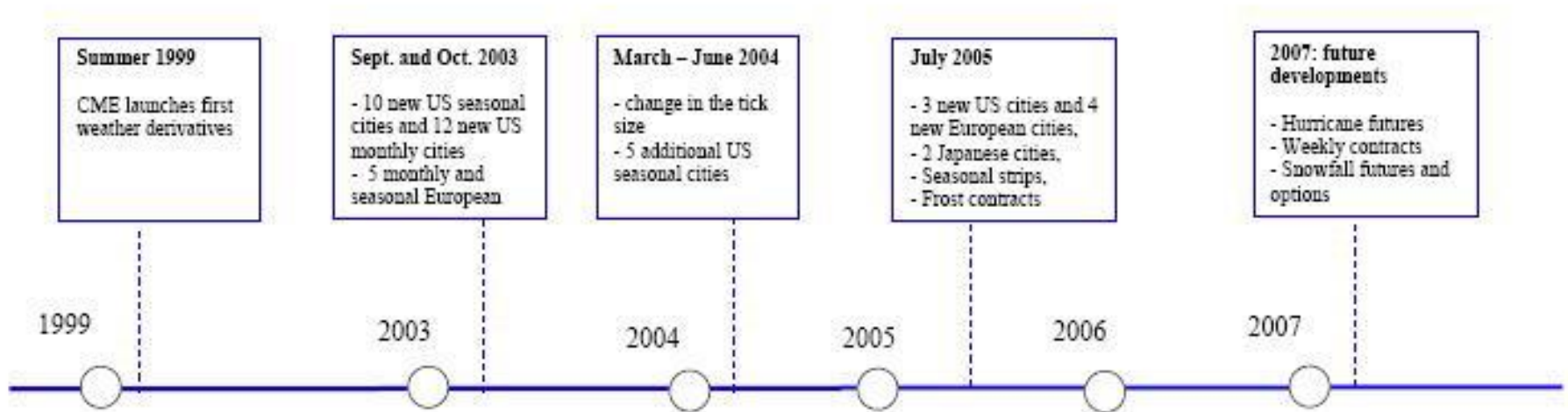
1997: First weather transactions (OTC) took place between Enron and Koch Industries, based upon some temperature indices to compensate the energy producer in case of a mild winter

1999: Trading in weather derivatives began on the Chicago Mercantile Exchange (CME), with HDDs

1998: First European deals took place between Enron and Scottish Hydro Electric on a similar basis

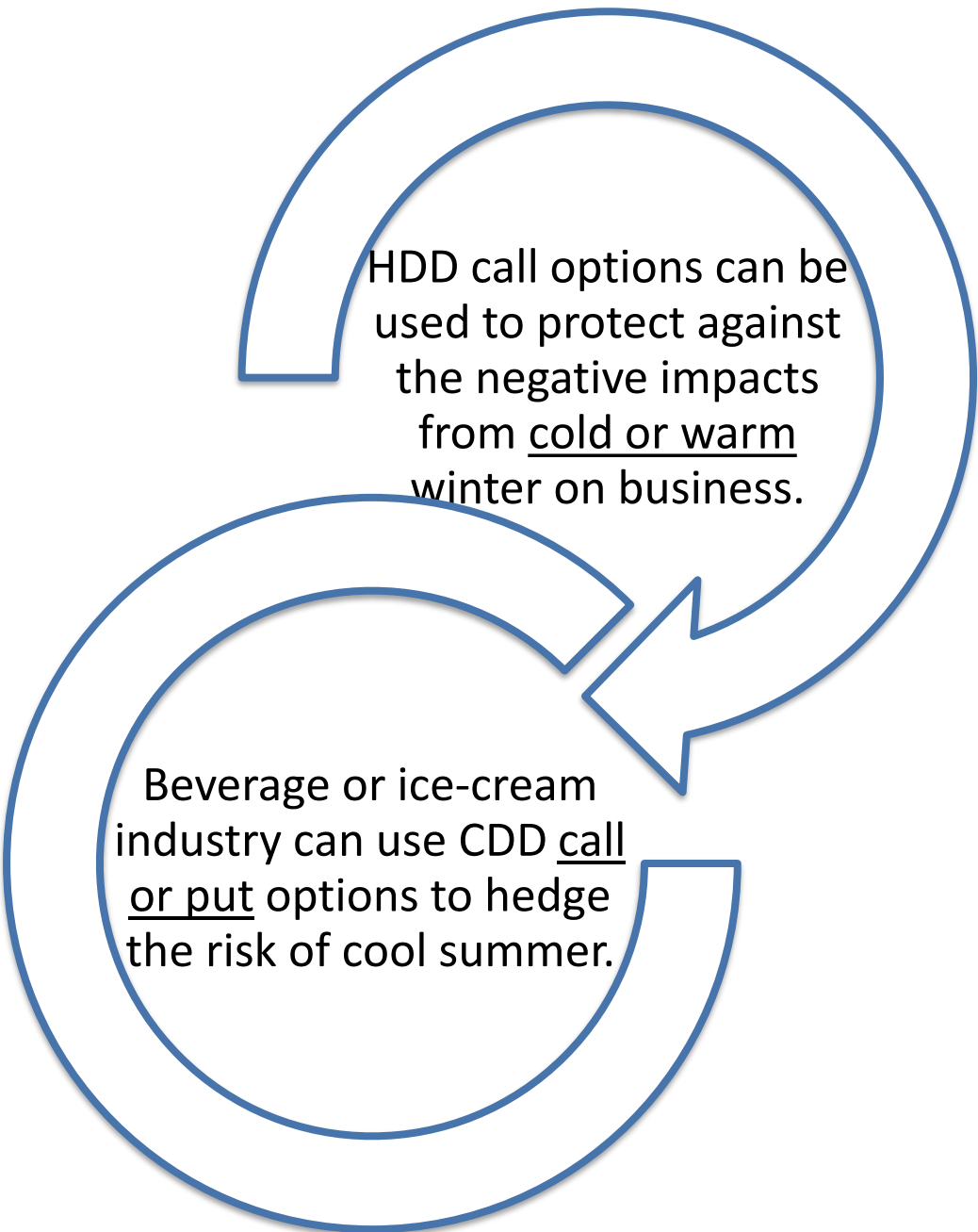


Some Key Dates on CME



However, many derivative products could not draw enough traders and were unlisted. Now CME offers HDD and CDD contracts for 8 American cities (Las Vegas, Atlanta, Chicago, Cincinnati, New York, Dallas, Minneapolis, Sacramento); HDD and CAT contracts for 2 European cities (London, Amsterdam).

Questions



HDD call options can be used to protect against the negative impacts from cold or warm winter on business.

Beverage or ice-cream industry can use CDD call or put options to hedge the risk of cool summer.

Examples:

<https://www.cmegroup.com/education/articles-and-reports/weather-options-overview.html>

Pricing Weather Derivatives

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

$$c = e^{-r(T-t)} Ep$$

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 Ep is the expected payoff:

$$Ep = \int_0^{\infty} p(w) f(w) dw$$

where $f(w)$ is the probability density function of the weather index w , $p(w)$ is the payoff, and the integral is from 0 to ∞ because w cannot take on negative values.

Modelling Weather Variables

- **Two methods**
- Time series (econometrics)
- Stochastic processes (simulation)

Daily
Temperatures



- **Two aspects**
- Frequency (2 state Markov chain)
- Magnitude (distribution)

Daily
Precipitation

