Chapter 6: Structure and Mechanics of Options Markets

A. Option Contract Fundamentals

First, we will introduce a few option basics. A *stock option* is a legal contract that grants its owner the right (though, not obligation) to either buy or sell a given stock. There are two types of stock options: puts and calls. A *call* grants its owner to purchase stock (called underlying shares) for a specified exercise price (also known as a striking price or exercise price) on or before the expiration date of the contract.

Options can be classified into either the European variety or the American variety. *European options* may be exercised only at the time of their expiration; *American options* may be exercised any time before and including the date of expiration. Most option contracts traded in the United States (and Europe as well) are of the American variety. American options can never be worth less than their otherwise identical European counterparts. In fact, because most call options have time value in addition to their intrinsic or exercise value (calls on stocks that go ex-dividend before the call expires can be an important exception to this), we usually do not exercise American calls before exercise. As we will discuss later, this means that we can often value American call options (on non-dividend paying stock) as though they are European calls.

<u>Option Payoff Functions</u>

Terminal (expiration date T) payoff structures, that is, the expiration date payoff functions of calls (c_T) and puts (p_T) are functions of their exercise prices X and underlying asset prices (S_T) as follows:

$$c_T = MAX[0, S_T - X]$$
$$p_T = MAX[0, X - S_T]$$

For example, the owner of a call has the right to purchase the underlying asset with value S_T at time T by paying the call striking price X, and will do so as long as $S_T - X > 0$. The writer (seller) of the call is obliged to sell the underlying stock to the buyer under the terms of the call contract. The net profit to one equals the net loss to the other. Table 1 and Figures 1 to 4 below illustrate terminal payoff functions of long and short positions in calls and puts.

An investor can take any combination of positions in an underlying security and/or calls and puts that trade on the security. Long positions reflect purchases while short positions reflect sales. Table 1 describes a single long and short position in each of the six individual securities. Future (time T, expiration date) payoffs are given in the table. Long positions require time zero purchase payments of S_0, c_0 and p_0 to invest, while short positions resulting from sales result in time zero cash flows of S_0, c_0 and p_0 to the sellers.

Your Position	Payoff if $S_T \leq X$	Payoff if $S_T > X$	Notes on your Position
Long Underlying	S_T	S_T	You own the underlying asset
Short Underlying	$- S_T$	$- S_T$	You short sold the underlying asset
Long Call	0	$S_T - X$	You dispose of or exercise the call
Short Call	0	$-(S_T - X)$	You are obliged to allow exercise
Long Put	$(X - S_T)$	0	You exercise or dispose of the put
Short Put	$-(X - S_T)$	0	You are obliged to allow exercise

Table 1: Stock and Plain Vanilla Option Position Payoffs

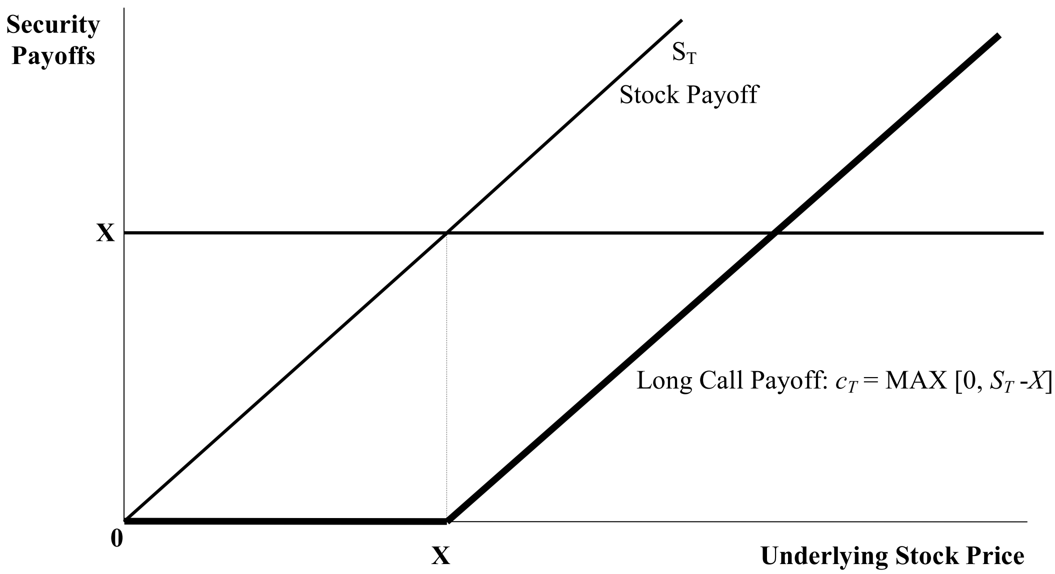

Figure 1: Terminal Payoff of a Long Position in an Equity Call

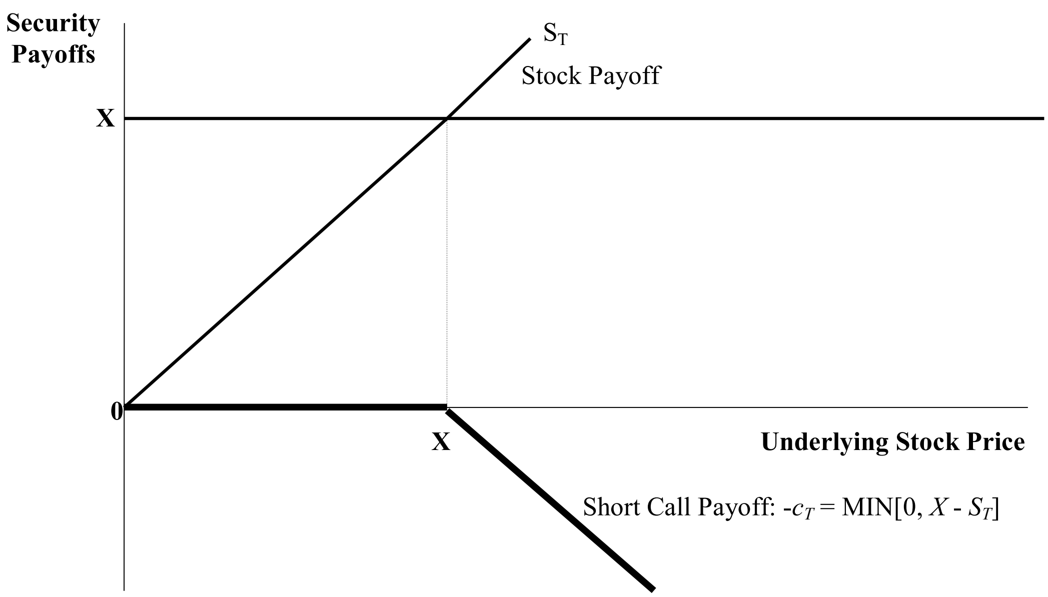

Figure 2: Terminal Payoff of a Short Position in an Equity Call

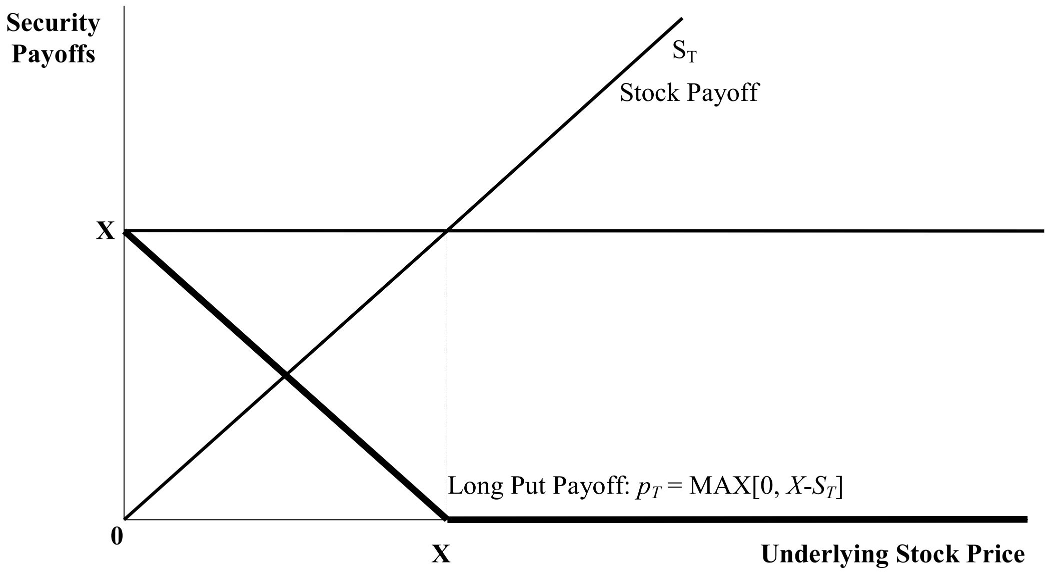

Figure 3: Terminal Payoff of a Long Position in an Equity Put

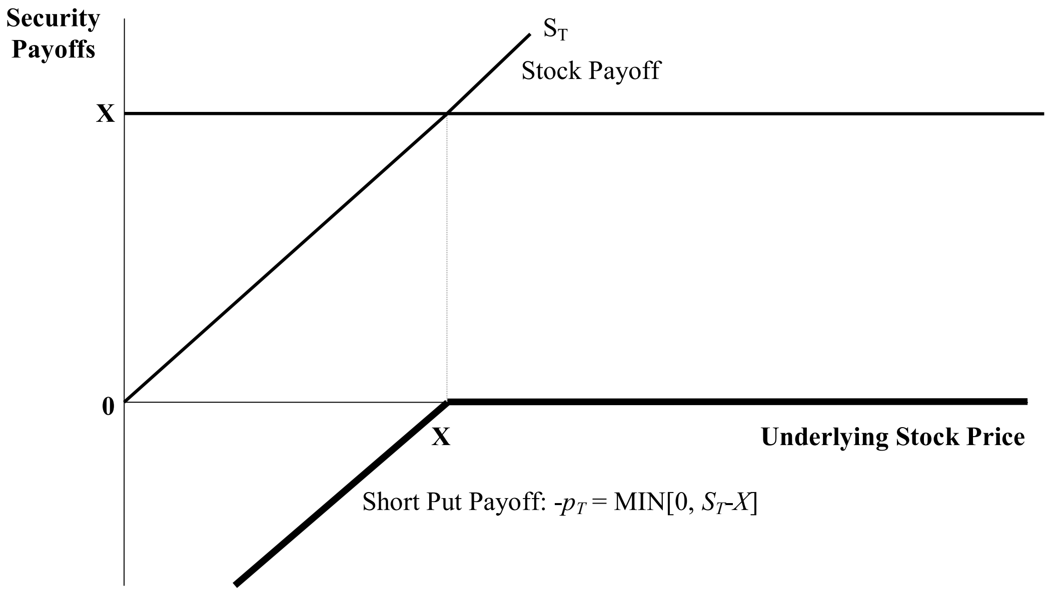

Figure 4: Terminal Payoff of a Short Position in an Equity Put

Option Payoff Functions: A Simple Illustration

Suppose, for example, that there is a call option with an exercise price of $90 on one share of stock. The option expires in one year. This share of stock is expected to be worth either $80 or $120 in one year, but we do not know which at the present time. If the stock were to be worth $80 when the call expires, its owner should decline to exercise the call. It would simply not be practical to use the call to purchase stock for $90 (the exercise price) when it can be purchased in the market for $80. The call would expire worthless in this case. If, instead, the stock were to be worth $120 when the call expires, its owner should exercise the call. Its owner would then be able to pay $90 for a share that has a market value of $120, representing a $30 profit. In this case, the call would be worth $30 when it expires. Let T designate the options term to expiry, S_T the stock value at option expiry and c_T be the value of the call option at expiry determined as follows:

(1) $$c_T = MAX[0, S_T - X]$$

If $S_T = 80$, $c_T = \text{MAX}[0, 80 - 90] = 0$
If $S_T=120$, $c_T = \text{MAX}[0, 120 - 90] = 30$

A put grants its owner the right to sell the underlying stock at a specified exercise price on or before its expiration date. A put contract is similar to an insurance contract. For example, an owner of stock may purchase a put contract ensuring that he can sell his stock for the exercise price given by the put contract. The value of the put when exercised is equal to the amount by which the put exercise price exceeds the underlying stock price (or zero if the put is never exercised).

To continue the above example, suppose that there is a put option with an exercise price of $90 on one share of stock. The put option expires in one year. Again, this share of stock is expected to be worth either $80 or $120 in one year, but we do not know which yet. If the stock were to be worth $80 when the put expires, its owner should exercise the put. In this case, its owner could use the put to sell stock for $90 (the exercise price) when it can be purchased in the market for $80. The put would be worth $10 in this case. If, instead, the stock were to be worth $120 when the put expires, its owner should not exercise the put. Its owner should not accept $90 for a share that has a market value of $120. In this case, the call would be worth nothing when it expires. Let p_T be the value of the put option at expiry, determined as follows:

(2) $$p_T = \text{MAX}[0, X - S_T]$$

When $S_T=80$, $p_T = \text{MAX}[0, 90 - 80] = 10$
When $S_T=120$, $p_T = \text{MAX}[0, 90 - 120] = 0$

Thus, Table 1 can be rewritten for our example as Table 2. In Table 2, the total Time 1 payoff from purchasing and selling the underlying asset is either 80 or 120. The total Time 1 payoff from short selling and then repurchasing is either -80 or -120. The short seller sells to the buyer at Time 0; the buyer sells to the short seller at Time 1. The short-seller must repurchase the stock.

The Time 1 profit from purchasing the call, ignoring the Time 0 premium paid at purchase, is either 0=MAX[0, 80-90] or 30=MAX[0,120-90]; in the first instance, the call is disposed of, in the second, the call is exercised. The Time 1 profit from selling (writing) the call, ignoring the Time 0 premium, is either 0 = -MAX[0, 80-90] or -30 = -MAX[0,120-90].

The Time 1 profit from purchasing the put, ignoring the Time 0 premium at its sale, is either 10= MAX[0, 90-80] or 0 = MAX[0,90-120]; in the first instance, the put is exercised, in the second, the put is disposed of. The Time 1 profit from selling (writing) the put, ignoring the Time 0 premium, is either -10 = -MAX[0, 90-80] or 0 = -MAX[0,90-120].

Your Position	Payoff if $S_1 \leq 90$	Payoff if $S_1 > 90$	Notes on your Position
Long Underlying	80	120	You own the underlying asset
Short Underlying	- 80	- 120	You short sold the underlying asset
Long Call	0	30	You dispose of or exercise the call
Short Call	0	- 30	You are obliged to allow exercise
Long Put	10	0	You exercise or dispose of the put
Short Put	- 10	0	You are obliged to allow exercise

Table 2: Stock and Plain Vanilla Option Position Payoffs Example

Long for Option; Short for Obligation

The owner of the option contract may exercise his right to buy or sell; however, he is not obligated to do so. Stock options are simply contracts between two investors issued with the aid of a clearing corporation, exchange and broker, which ensure that investors honor their obligations to each other. The corporation whose stock options are traded will probably not issue and does not necessarily trade these options. Investors, typically through a clearing corporation, exchange and brokerage firm, create and trade option contracts amongst themselves.

For each owner of an option contract, there is a seller or "writer" who creates the contract, sells it to a buyer and must satisfy an obligation to the owner of the option contract. The option writer sells (in the case of a call exercise) or buys (in the case of a put exercise) the stock when the option owner exercises. The owner of a call is likely to profit if the stock underlying the option increases in value sufficiently over the exercise price of the option (he can buy the stock for less than its market value); the owner of a put is likely to profit if the underlying stock declines in value sufficiently below the exercise price (he can sell stock for more than its market value). Since the option owner's right to exercise represents an obligation to the option writer, the option owner's profits are equal to the option writer's losses. Therefore, an option must be purchased from the option writer; the option writer receives a "premium" from the option purchaser for assuming the risk of loss associated with enabling the option owner to exercise. Next, we begin the process of determining the call and put values at time zero.

Minimum Option Values

We discussed terminal payoff functions for above. Similarly, on any date ($0 < t < T$) prior to option expiration, American calls and puts must be worth at least as much as the difference between the stock price and the call exercise price:

$$c_t \geq MAX[0, S_t - X]$$
$$p_t \geq MAX[0, X - S_t]$$

Option Combinations

Many investors find it useful to combine different options to as to achieve specific overall payoff structures or risk profiles. Many of these combinations have specific names such as straddle or spread, and some options exchanges and markets will even accept orders for such combinations in addition to the individual options that comprise the combinations. Option combination payoff structures are additive, so that they reflect the simple sum of the payoffs that comprise them.

Consider, for example, a long straddle which, is simply a long position in a call combined with a long position in a put with the same exercise terms (same underlying asset, striking price and expiry date). As represented in Figure 5, the payoff structure for the straddle is the simple sum of payoff structures for its component call and put. An investor who believes that the price of the underlying is likely to be significant, but does not know the direction, might want to go long in a straddle. Alternatively, she might want to short the straddle. Many such combinations are traded, including collars (long put and short call, discussed later), spreads (many varieties), strangles, strips, straps, etc. Combinations can be used to replicate the cash flow structure of the underlying stock (in effect, create synthetic stock), such a long position in a call, a short position in a put and a sum of money equivalent to the present value of exercise price invested in riskless bonds:

$$S_T = MAX[S_T - X, 0] - MAX[X - S_T, 0] + X$$

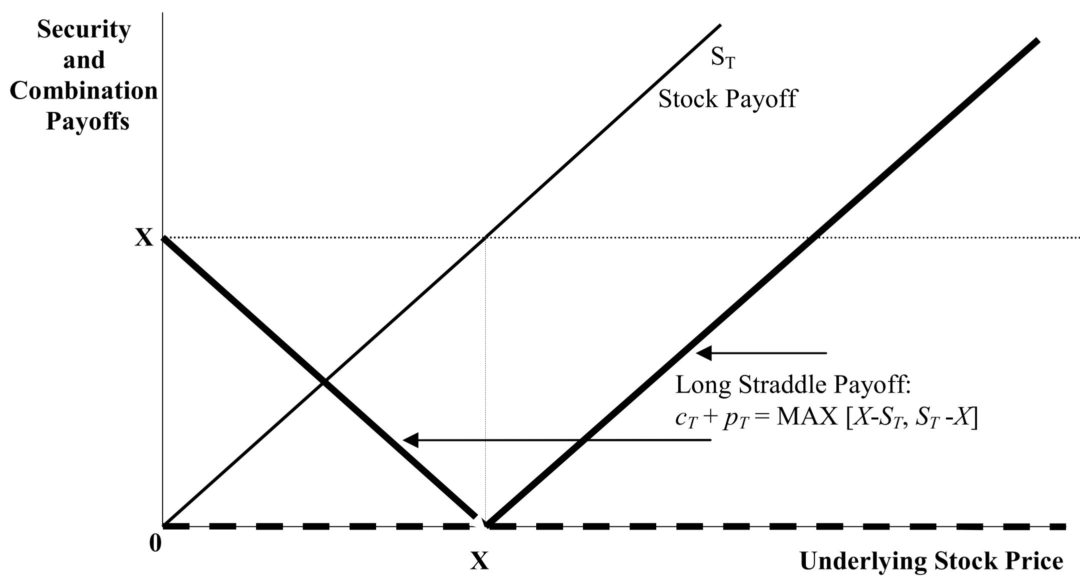

Figure 5: Terminal Payoff of a Long Position in an Equity Straddle

B. Option Exchanges

Most stock options in the United States are traded on one of the options exchanges. The oldest and largest U.S. stock options exchange is *Cboe Global Markets Incorporated* (formerly the *Chicago Board Options Exchange* [CBOE]), which also owns the C2 Options Exchange. Cboe is followed in size by the NASDAQ OMX Group, which operates the NSDQ and PHLX (formerly the Philadelphia Exchange). The New York Stock Exchange (NYSE) has grown in stature in options markets with NYSE Amex and NYSE Arca, acquired through the takeover of the American Exchange and its merger with the Archipelago Exchange. In addition, the Boston Options Exchange (BOX, which is jointly owned by the TMX Group and seven broker dealers) and the ISE (owned by Eurex) both maintain stock option markets. Table 3 below provides sample volume data for all of these and other equity options exchanges.

The *Options Clearing Corporation* (OCC), jointly owned by the U.S. options exchanges, is technically the counterparty for all listed options transactions in the United States. This means that all option buyers own options that were written by the OCC and all option writers are obligated to the OCC. This arrangement, given the financial stability of the OCC and each of the exchanges that own and back its obligations and all of the brokerage firms that back the obligations of the exchanges have effectively eliminated default risk in listed options trading.

TABLE 3: U.S. Equity Options Exchanges (Data from January 1 through April 30, 2017)

Exchange	Cleared Contracts	Total Premiums	Avg. Daily Contracts	% of Contracts
AMEX	40,052,656	$7,194,355,365	494,477	6.23
ARCA	46,398,747	$9,835,963,150	572,824	7.21
BATS	80,526,945	$13,236,975,848	994,160	12.52
BOX	19,523,025	$3,402,861,794	241,025	3.03
C2	12,654,695	$2,228,564,252	156,231	1.97
CBOE	114,005,724	$22,220,467,876	1,407,478	17.72
EDGX	8,272,243	$1,252,798,162	102,126	1.29
GEM	39,509,887	$6,994,957,378	487,776	6.14
ISE	56,012,033	$15,048,479,569	691,507	8.71
MCRY	1,226,017	$263,865,500	15,136	0.19
MIAX	41,402,081	$5,584,565,629	511,137	6.44
MPRL	886,941	$171,216,079	10,950	0.14
NOBO	5,103,126	$681,069,918	63,002	0.79
NSDQ	71,436,631	$12,703,227,700	881,934	11.10
PHLX	106,360,933	$27,025,495,817	1,313,098	16.53
TOTAL	643,371,684	$127,844,864,169	7,942,860	100.00

Source: The Options Clearing Corporation.

Options trading took place entirely over the counter until the 1973 opening of the Chicago Board Options Exchange (CBOE). The nature of options trading lends itself to technological development at every stage of the trading process. First, because of option-trading strategies' emphases on relative valuation and stochastic processes, the valuation and portfolio analyses require mathematical analyses that are computer-based. Maintenance of these strategies requires abilities to rapidly trade in and out of multiple positions simultaneously, relying on electronic communication technologies capable of handling large amounts of data instantaneously. Technologies offered through the Internet offer these capabilities, forcing exchanges to anticipate and quickly improve on developments in order to compete.

Competition among options exchanges continues to intensify, fostered by myriad new technologies and the introduction of equity option multiple listings beginning in the fall of 1999. The International Securities Exchange was launched in May 2000 as the first fully electronic exchange in the United States, adding a significant dimension of competition to the then largely floor-based markets offered by the CBOE, AMEX, and PHLX. In addition, the ISE traded options with well-established markets on the other exchanges. In addition to the ISE, well-established foreign exchanges such as Eurex electronically trade contracts on U.S. equity instruments, further intensifying competitive pressures on major U.S. options exchanges. In fact, practically all European and Asian securities and derivatives exchanges have become entirely or almost entirely electronic. This increased competition has led to a number of important results, including narrowing spreads (8% between 1999 and 2000 alone according to a Securities and Exchange Commission (SEC) study; also see Battalio, Hatch, & Jennings, [2004]), highly uncertain futures for competitors, and the development and implementation of innovative quotations and trading systems.

Table 4 depicts option prices for a variety of Tesla calls and puts expiring on June 21, 2021. Prices were taken from the Nasdaq market close as of December 24, 2020 when Tesla stock was selling for $661.77. Exercise prices are provided in the center column of Table 4.

Options Technology

Options exchanges have innovated substantial technological advances to maintain and even anticipate developments in other markets. For example, exchange-initiated technological advances include NASDAQ's automated exchange, SuperMontage. Options exchanges have experienced launching of the Chicago Board Options Exchange CBOE Command in 2012 as CBOE's trade platform and engine located in Secaucus New Jersey. Such trading systems provide for instantaneous filling and confirmation of orders at the best prices along with transparency of trades. Asset managers rely on such systems to obtain speedy access to information, to route and execute orders, and to obtain trade confirmations.

Several exchanges provide for off-site market makers such as the CBOE Remote Market Makers (RMMs). These systems facilitate trading by off-floor investors and enhance liquidity by expanding the membership of market makers. They offer market makers direct access to the trading floor, enabling them to participate in the provision of market liquidity and subjecting them to the same market-enhancing responsibilities without requiring their physical presence.

Options Clearing

We described clearinghouses, clearing firms and the clearing functions earlier in Chapters 1 and 4. Most U.S. options exchange transactions are cleared through and guaranteed by the Options Clearing Corporation (OCC), which is jointly owned by the major options exchanges. The OCC clears transactions for options and futures on equity instruments, stock index contracts, currencies, and certain interest rate contracts as well as a number of contracts in other markets. As we discussed earlier, the OCC also serves as the counterparty to every options transaction that is executed on its affiliated exchange. In addition to issuing option contracts, serving as counterparty on all transactions and clearing transactions, option clearinghouses will handle the process of option exercise.

TSLA Option Chain

Date	Option	Calls & Puts	Moneyness	Type
March 2021	Composite	Calls & Puts	Near the Money	All (Types)

	Calls							Puts					
Exp. Date	Last	Change	Bid	Ask	Volume	Open Int.	Strike	Last	Change	Bid	Ask	Volume	Open Int.
March 19, 2021													
Mar 19	115.60	+8.35 ▲	114.80	116.70	296	19576	600.00	53.46	-6.24 ▼	52.95	53.85	1233	4640
Mar 19	108.10	+8.25 ▲	108.65	110.75	47	3642	610.00	57.85	-5.63 ▼	57.15	58.30	98	1246
Mar 19	102.80	+6.45 ▲	103.35	105.75	37	3048	620.00	61.55	-8.33 ▼	61.75	62.90	59	729
Mar 19	101.00	+8.80 ▲	98.25	100.55	65	797	630.00	66.75	-8.11 ▼	66.55	68.10	52	353
Mar 19	93.00	+6.18 ▲	93.60	95.00	79	1089	640.00	71.64	-8.03 ▼	71.50	73.05	49	473
Mar 19	89.72	+7.07 ▲	89.50	89.70	530	12369	650.00	78.55	-7.70 ▼	77.05	78.30	68	859
Mar 19	85.04	+6.69 ▲	83.85	85.55	197	1264	660.00	83.30	-7.20 ▼	82.45	83.75	220	307
Mar 19	80.60	+6.05 ▲	79.50	81.65	134	733	670.00	88.50	-7.70 ▼	87.60	89.35	13	501
Mar 19	76.50	+6.60 ▲	75.30	77.35	41	1743	680.00	94.40	-8.00 ▼	93.75	95.15	8	75
Mar 19	71.02	+4.93 ▲	71.30	73.30	29	331	690.00	101.80	-7.90 ▼	99.20	101.15	4	70
Mar 19	68.57	+6.32 ▲	67.75	69.00	322	9322	700.00	107.57	-7.18 ▼	105.70	107.30	91	569
Mar 19	60.15	+4.67 ▲	60.30	62.00	98	1125	720.00	119.45	-12.00 ▼	117.95	120.10	7	204

LAST TRADE: $661.77 (AS OF DEC 24, 2020)

Table 4: Tesla Option Prices, December 21, 2020. From Nasdaq.

References

Battalio, R. J., B. Hatch and R. Jennings (2004). Does a national market system exist for U.S. exchange-listed equity options? *Journal of Finance*, 59, pp. 933-962.

Exercises

1. Call and put options with an exercise price of $30 are traded on one share of Company X stock.

a. What is the value of the call and the put if the stock is worth $33 when the options expire?

b. What is the value of the call and the put if the stock is worth $22 when the options expire?

c. What is the value of the call writer's obligation stock is worth $33 when the options expire? What is the value of the put writer's obligation stock is worth $33 when the options expire?

d. What is the value of the call writer's obligation stock is worth $22 when the options expire? What is the value of the put writer's obligation stock is worth $22 when the options expire?

e. Suppose that the purchaser of a call in part a paid $1.75 for his option. What was the profit on his investment?

f. Suppose that the purchaser of a call in part b paid $1.75 for his option. What was the profit on his investment?

Solutions

1. a. c_T = \$33 - \$30 = \$3; p_T = 0
   b. c_T = 0; p_T = \$30 - \$22 = \$8
   c. c_T = -\$3; p_T = 0
   d. c_T = 0; p_T = -\$8
   e. \$3 - \$1.75 = \$1.25
   f. \$0 - \$1.75 = -\$1.75