1.3 Derivative securities

Derivative securities, or just derivatives, are financial contracts constructed in such way that its realized value in the future is determined by some specified underlying securities. Derivative securities are also referred to as contingent claims. The best-known among them are options, futures, forwards and swaps. The underlying securities could be stocks, bonds, currency, commodities and even interest rates and indexes—where the last two are not really securities—a notional asset has to be devised to reflect the price or index movement so that the settlement can be delivered in cash.*

Basically, an option is a right to buy or sell a security at certain price during certain time, while a future is not just a right but an obligation to do so.

Informal and unregulated trading in options and futures has a long history. The Flemish traders in the 12th century dealt with futures, and the 16th century feudal lords in Japan conducted option on rice.

In the past, derivative securities are often associated with negative connotations, due to some well-known examples of failure in the past, such as the spectacular collapse of the tulip bulb options in Holland in 1637 or the highly speculative activities and abuses in stock options in the 1920s and 30s. But with the introduction of more strict securities legislation and regulating bodies such as the SEC, there are now very few instances of major irregularities. (Even the well-publicized Nikkei index option trading associated with the Baring Bank failure in 1994 is not really an abuse of option trading *per se*.)

Indeed, with sound regulations in place, a rapidly increasing number of investors discover the use of derivative securities as versatile method in managing risk exposure—we will explain this in the next subsection.

1.3.1 Options

An option written on an underlying security is a contract issued by an individual, a corporation or an investment bank that gives the buyer of such contract the *right* to buy or sell the security at a particular price (jargon: *strike price* or *exercise price*) during a set time in the future before an *expiry* date specified in the contract. Notice that this is only a right—an option, so

^{*}More recently, derivative on weather is offered in places such as the Deutsche Börse for the purpose of hedging against financial risks due to weather fluctuation.

the buyer can decide whether or not to exercise such a right. (In contrast, for buyer of future contracts, it is not an option, but an obligation.)

The underlying

The security underlying an option is either a stock (usually a common stock), or a stock index (such as S&P 500), or a bond (such as T-bond), or a currency, or a commodity, in fact it could be anything of value. We call it a *stock option* (or *equity option*) if the underlying security is a stock. Likewise we may have index option, bond option, currency option, commodity option, ... *etc.* For definiteness and ease of describing basic features common to most options, for the rest of this subsection, we will concentrate on stock options, and by *the stock* we mean the security underlying the option.

Call and put

The party that sells the option is the *writer*, while the buyer is the *holder* (or *owner*). Generally each contract represent 100 shares of the stock and options are traded in whole numbers. A *call* or *call option*, is simply a contract that gives its holder the right to buy 100 shares of the stock at the strike price. Likewise, a *put* or *put option* gives the holder the right to sell at strike price. When the stock is actually purchased in a call (or bought in a put) at the strike price, we say that the right is *exercised*.

As a call option buyer, if the stock price is lower than the strike price, the holder would buy the stock at market price instead of exercising the option. On the other hand, if the stock price is higher than the strike price, then the holder will exercise the right and gets a profit by reselling it back to the market—provided the difference is greater than the cost of the option. Similarly, for a put option holder, it is exercised when the stock price is lower.

When an investor buys a call, he is anticipating a price upward movement in the stock before the expiry date; this is the *bullish* attitude. The investor buys a put, if he is anticipating downward movement—the *bearish* attitude.

Moneyness

During its lifespan, an option is classified as either *in-the money*, or *at-the-money* or *out-of-money*. It is called at-the-money if the strike price equals the market price of the stock.

A call is in-the-money if the stock is trading above the strike price. It is out-of-money if the stock trades below the strike price. But a put is in-the-money if the stock trades below the strike price and is out-of-money if it trades above the strike price. At and after expiry, option becomes worthless. But before that, it always has some value: When it is in-the-money, the difference between the strike price and market price of the stock gives it the *intrinsic value*. That is, the amount by which an option is in-the-money. In other cases, there is no intrinsic value. The intrinsic value is always less than the selling price of option. The positive difference is called the *time value*, this is the value for the chance that the price of the stock may move to the favorable direction before expiry date. With slight confusion, the time value is also referred to as the *premium over intrinsic value*.

Options closer to expiry has less time value, and hence are sold at lower premium.

It is worth noticing the following: Options are not issued by the corporation of the stock; nor is the corporation in anyway responsible for the trading activities and settlement; call holders have no rights to vote nor to receive dividends from the stock unless the option is exercised.

Long and short

There are different *positions* (or market commitments) that an investor can take. Long call or long put means the position of a call or put option holder. On the other hand, short call or short put means the position of an call or put option writer—who has an obligation to meet the terms of the option if it is exercised by its holder.

The terms *long* and *short* are also used in stocks. So *long stock position* is the position in which an investor has purchased and in possession of the stock. But *short stock position* (or *short selling*) refers to borrowing stock from a broker and selling it in the open market then at a later date buying it back (hopefully at lower price) and returning it to the broker.

The writer of a call may nor may not be long stock position. If he is writing a call against an equivalent amount of long stock, he is said to be a *covered writer* and the call is a *covered call*. Example: writing two XYZ May 60 Calls while owning 200 shares or more of XYZ stock. If the same writer is not in long stock position, but in long call position on at least the same amount of the same stock, he is also a covered writer.

Covered and naked

Likewise, a call writer on a stock not fully collateralized is an uncovered writer or naked writer, and the call is a uncovered call or naked call.

There is no covered put, but *uncovered put* or *naked put* referred to a position in which the writer is not short stock or long another put.

Naked option and short selling are allowed at a brokerage if the investor

has a margin account. This practice is called *trading on margin basis*. A margin account requires a deposit to collateralize an investment position, this could amount to for example 10% of the investment.

Before expiry, options can be freely traded in an exchange and the market price of buying it (determined by the marketplace) is called the *premium*.

Option exchanges

In the U.S., there are four standardized exchanges that trade options: Chicago Board Options Exchange (CBOE), AMEX, Pacific Stock Exchange (PSE)and Philadelphia Stock Exchange (PHLX). (All regulated by the SEC) The NYSE withdrew from the options trading business in 1997.

Opened on April 26, 1973, the CBOE is the first one among them. It is also the world's largest options marketplace and the founder of this product line. (In 1983, CBOE first introduced index option on S&P 100, and it immediately became very popular with investors.) All options traded on U.S. exchanges are issued, guaranteed and cleared by a clearing corporation called the Options Clearing Corporation (OCC). OCC is registered with SEC and was rated AAA by S&P.

There are over fifty option exchanges around the world. The London International Financial Futures and Options Exchange (LIFFE) is Europe's premier financial derivatives exchange and the third largest futures and options exchange in the world. MATIF is the French futures and options exchange. Most exchanges are working together with a clearing corporation similar to OCC. Each exchange has its own set of rules, products and customs. For example, in the U.S. the expiry date of options occurs on the Saturday immediately following the third Friday of every month and each option is assigned an expiry month. In Hong Kong Futures Exchange (HKFE), options are also assigned an expiry month, but the expiry date is usually the day after the last business day of the month.

An option may be traded on more than one exchange; for example one can write and sell option in one exchange and close his position on another.

Lifespan

Most options have short lifespan, *i.e.* expiry date of eight months or less. In recent years, long-term stock or index options are introduced in places such as CBOE. They are named *LEAPS*, or *Long-term Equity Anticipation Securities*. They are just like short-term options, available in calls and puts, but with expiry dates up to three years.

Why invest in options?

A major advantage of options is their flexibility. One can use options tailor positions to suit certain criteria of risk and reward. Often this is done by buying several call and put options with same or different expiry dates on the same or different stocks and securities. (Popular synthesis strategies such as *Strangle, butterfly, straddle ... etc.*)

Another advantage is the so-called *leverage*: with a call option, one can benefit a possible stock price upward movement by a much smaller amount than that required to buy the stock. If the stock increases by 10 percent, for example, the option might double in value.

Unlimited profit potential?

Options have features very different from stocks. on the other hand, as mentioned earlier, they are similar to bonds in that the lifespan is predetermined. They are also like insurance policy: for example, at expiry, a call buyer holding it loses at most the premium, while a stockholder of the same stock may lose much more. The same is true with puts. So buying an option has a predefined risk but a theoretically unlimited profit potential. (However, a short writer has unlimited theoretical risk.)

A *liquid* option market (*i.e.* with large volume and narrow spread between the ask and bid option price) tends to have a stabilizing and moderating effect on stock volatility, since the stock prices are "predicted" by the option premium and market psychology.

An example

Here is an example illustrating the jargons and situations mentioned so far.

On a newspaper options quotation page, "1 IBM RD for \$2" means that the put option of a share of IBM stock expiring in June with strike price \$120 is selling at the price of \$2. The letter "R" stands for put option that expires in June and the letter "D" stands for the strike price \$120.

Symbols for other call/put, expiry and strike are given in the two tables on the following page.

Month	Call Code	Put Code
January	Α	M
ebruary	в	Ν
Aarch	С	0
April	D	Р
May	Е	Q
une	\mathbf{F}	R
uly	G	S
lugust	н	т
leptember	I	U
October	J	v
lovember	К	w
December	\mathbf{L}	х

Table 1.1 Expiry Month

Table 1.2 Strike Price Symbol

Code	Striking Prices	Code	Striking Prices
A	5 105	N	70 170
В	10 110	0	75 175
С	15 115	Р	80 180
D	20 120	Q	85 185
\mathbf{E}	25 125	R	90 190
F	30 130	S	9 5 195
G	35 135	т	100 200
н	40 140	U	$7\frac{1}{2}$ $37\frac{1}{2}$
Ι	45 145	v	$12\frac{1}{2}$ $42\frac{1}{2}$
J	50 150	Ŵ	$17\frac{1}{5}$ $47\frac{1}{5}$
K	55 155	х	$22\frac{1}{5}$ $52\frac{1}{5}$
\mathbf{L}	60 160	Y	$27\frac{1}{5}$ $57\frac{1}{5}$
М	65 165	Z	$32\frac{f}{2}$ $62\frac{f}{2}$

Styles of options

Although options are divided into two types: call and put, they are also categorized into different *styles* according to the way it is allowed to exercised. In fact the expiry date, strike price, market price of the stocks together with various ways of exercising the options give rise to infinitely many possible styles. But the most well-known ones are the following three styles:

• European options: An option contract that may be exercised only at the expiry.

- American option: An option contract that may be exercised at an arbitrary instant between the purchase date and the expiry.
- Barrier option or capped option: An option contract that may be exercised only during a specified period prior to expiry, and is active only the underlying asset price meets certain conditions with respect to a predefined barrier price. Commonly it comes in four varieties:
 - down-and-out: the option is active as long as the lower barrier (which is lower than the spot price at the beginning) is not touched before expiry;
 - up-and-out: the option is active as long as the upper barrier (which is higher than the spot price at the beginning) is not touched before expiry;
 - down-and-in: the option is inactive unless the lower barrier (which is lower than the spot price at the beginning) is touched before expiry;
 - up-and-in: the option is inactive unless the upper barrier (which is higher than the spot price at the beginning) is touched before expiry.

So combining the possibility of call/put, they make eight varieties in total. Of course one can also put more than one barriers, or non-constant barriers, ...

• Digital options: An option contract that may be exercised only during a specified period prior to expiry with payoff 0 if the underlying price is below the strike and \$1 if it is at or above the strike. This is a prime example of a discontinuous payoff function.

An ice-cream connection: vanilla and exotic

There are various other styles, such as Asian option, lookback options, ... etc, they are lumped together and given the name exotic options as versus the vanilla options: plain European option with no restriction on the underlying price movements (*i.e.* no barrier conditions) and can be exercised only at expiry.

Premium: Black-Scholes formula

Writing an option consists of specifying three important numbers: the *premium*, *expiry date* and the *strike price*. While the last two figures are easy to set, how does one set the premium for each style? So a major question is to determine the premium from the following data: strike price and expiry date, the stock characteristics (stock price, dividend and volatility) and the market characteristic (the "risk-free" interest rate). This was solved in the 1973 classic paper [Black and Scholes, 1973], which gives a model and a formula that uses the above data to evaluate a fair value of the option. This formula is used by investors as a guide to determine the premium. (For LEAPS—long-term options, volatility of the interest rate needs to be taken into account as well.)

Of course, the actual market price is affected by both market forces and individual investor's psychology which cannot be analyzed quantitatively.

1.3.2 Other derivative securities

In this subsection, we will very briefly review other derivative securities, such as forwards, futures and swaps.

Forwards and futures

Both forward contract (or just forward) and A future contract (or just future) have structure similar to an option, except that the buyer of such contracts is not given a right, but an obligation to buy or sell the underlying asset. Such a contact is a legal obligation to buy (in the case of a call) or to sell (in the case of a put) at a specified date at a specified price (*i.e.* strike price; also: forward price). These types of derivative securities are in fact older than options, for many centuries these contracts were written between farmers and merchants, the underlying assets were grains, corn, flour, ..., mostly for the purpose of hedging against future uncertainty related to price and production.

Forward and future only differ in the way they are traded. Futures are usually designed and traded in formal exchanges, and the price at which the contract to buy or sell is amended everyday. The debiting or crediting is recorded in a margin account; the contract is settled everyday and a new contract is written everyday. This process is called *marking to market*. On the other hand, forwards contracts are specially designed directly between the writer and buyer without any intermediary, and they are traded overthe-counter.

As with options, the underlying asset for these contracts could be a commodity, a stock, a currency, ... It is very common for an importer to devise a forward contact on foreign currency to hedge against the fluctuation of currency exchange rate. In this case, the importer will be guaranteed the foreign currency at a preset exchange rate on for example the day of delivery of his goods. Thus the risk of exchange rate instability is transferred to the buyer of this contract; of course the buyer is betting on a possible profit due to more favorable exchange rate on the expiry of the contract.

Future indices

Future on indices, such as S&P 500 and other stock indices are very popular form of investment in many parts of the world. Theoretically, this has the same as buying a future on a basket of stocks which are included in the index. But the settlement is in cash instead of delivery of the basket of stocks. (Just imagine the transaction costs involved. However, to simplify our models, we often ignore commission and transaction fees, we say that we are working under the assumption that the market is *frictionless*.)

Exchanges

Many of the option exchanges such as CBOE, LIFFE, MATIF deal with future as well. Other well-known futures are: Chicago Board of Trade (CBOT), Chicago Mercantile Exchange (CME), Kansas City Board of Trade (KCBT), HKFE, Tokyo International Financial Futures Exchange (TIFFE) and St. Petersburg Futures Exchange. CBOT was founded in 1848 in the middle of America's *Bread Basket*. The development of a futures market was a natural responds to the problem of supply and demand, transportation, and storage of grains. But most other futures markets have much shorter history. (TIFFE was established in 1989.)

Swaps

Swap is a new kind of contract that appeared about 20 years ago. It involves trading one cash flow with another between two agents, *i.e.* the counterparties. The more common form of swap is an *interest rate swap*—a contract between two counterparties under which the series of payments due to floating interest rate is exchanged for the series of payments due to a fixed interest rate.

Interest rate swaps are used by banks, corporates and government agencies. The main advantage is that it gives both parties lower cost of funding and flexibility in dealing with interest rate uncertainty. Here is a typical scenario: A corporate, say AA rated by S&P, finds it cheaper to raise fund by borrowing at floating interest rate—this is often the case for corporates with higher credit rating. But due to its financial situation, it prefers to borrow at fixed interest rate (under more favorable terms available to it) in order to hedge against uncertainty. On the other hand, there is a, say, BBB rated corporate that has access to borrowing at fixed interest rate, but prefer to bet on interest rate uncertainty and borrow at floating interest rate under more favorable terms available to it. It may just happen that trading between themselves the whole or part of the borrowing is a solution for both parties.

In practice, there is no need to perform an actual exchange of the principal that both are borrowing, because it is the same amounts. Instead the comparison is based on a notional amount of principal. There is also no need to make direct exchange of one party's series of interest payments on fixed rate with that of the other party on floating rate; it simply suffices to transfer the necessary *difference* from one party to another party. So the actual contract stipulates that during a preset period, each counterparty agrees to make a stream of payments to the other based on the interest rates difference and the notional amount of principal.

LIBOR rate

Sometimes the calculation of the floating rate is based on the LIBOR (London Interbank Offered Rate) and the interest rate of Treasury Bills. Notice that, at inception of the contract, the value of a swap is zero. The reason is clear: the swap is supposed to be an equitable exchange deal and the difference between fixed and floating interest rates is fairly determined by market force. So, unlike options, there is no premium for either party to pay. But as time passes, this is may no longer be the case anymore. There may be movement in floating rate interest the causes the swap to have positive value for one party and negative value for the other. Due to such changes, one party may desire to arrange termination of the swap or a reverse swap with a third party. In order to do so, pricing of the swap becomes necessary so that the party may either pay the original party an amount to get out of the swap deal or pay a third party to take only the rest of the commitments.

Pricing swaps

Pricing an interest rate swap requires a "prediction" of the floating interest rate. This can be calculated from the *bond yield* of government bonds—such as T-bills—with the appropriate range of maturities. That is, the *forward interest rates* can be determined from bonds of long enough maturity.

So in essence, pricing an interest rate swap is the same as pricing a forward written on a bond. This area of study is called the *term structure* of interest rate.