Chapter Nine

Futures and Options on Foreign Exchange

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Chapter Objective:

This chapter discusses exchange-traded currency futures contracts, options contracts, and options on currency futures.

Chapter Outline

- Futures Contracts: Preliminaries
- Currency Futures Markets
- Basic Currency Futures Relationships
- Eurodollar Interest Rate Futures Contracts
- Options Contracts: Preliminaries
- Currency Options Markets
- Currency Futures Options

Chapter Outline (continued)

- Basic Option Pricing Relationships at Expiry
- American Option Pricing Relationships
- European Option Pricing Relationships
- Binomial Option Pricing Model
- European Option Pricing Model
- Empirical Tests of Currency Option Models

Futures Contracts: Preliminaries

- A futures contract is *like* a forward contract:
  - It specifies that a certain currency will be exchanged for another at a specified time in the future at prices specified today.
- A futures contract is *different from* a forward contract:
  - Futures are standardized contracts trading on organized exchanges with daily resettlement through a clearinghouse.

Futures Contracts: Preliminaries

- Standardizing Features:
  - Contract Size
  - Delivery Month
  - Daily resettlement
- Initial Margin (about 4% of contract value, cash or T-bills held in a street name at your brokers).

Daily Resettlement: An Example

- Suppose you want to speculate on a rise in the $/¥ exchange rate (specifically you think that the dollar will appreciate).

	U.S. $ equivalent		Currency per U.S. $	
	Wed	Tue	Wed	Tue
Japan (yen)	0.007142857	0.007194245	140	139
1-month forward	0.006993007	0.007042254	143	142
3-months forward	0.006666667	0.006711409	150	149
6-months forward	0.00625	0.006289308	160	159

Currently $1 = ¥140. The 3-month forward price is $1=¥150.

Daily Resettlement: An Example

- Currently \$1 = ¥140 and it appears that the dollar is strengthening.
- If you enter into a 3-month futures contract to *sell* ¥ at the rate of \$1 = ¥150 you will make money if the yen depreciates. The contract size is ¥12,500,000
- Your initial margin is 4% of the contract value:

$$\$3{,}333.33 = .04 \times ¥12{,}500{,}000 \times \frac{\$1}{¥150}$$

Daily Resettlement: An Example

If tomorrow, the futures rate closes at $1 = ¥149, then your position's value drops.

Your original agreement was to sell ¥12,500,000 and receive $83,333.33

But now ¥12,500,000 is worth $83,892.62

$$\$83{,}892.62 = ¥12{,}500{,}000 \times \frac{\$1}{¥149}$$

You have lost $559.28 overnight.

Daily Resettlement: An Example

- The \$559.28 comes out of your \$3,333.33 margin account, leaving \$2,774.05
- This is short of the \$3,355.70 required for a new position.

$$\$3{,}355.70 = .04 \times ¥12{,}500{,}000 \times \frac{\$1}{¥149}$$

- Your broker will let you slide until you run through your *maintenance margin*. Then you must post additional funds or your position will be closed out. This is usually done with a *reversing trade*.

Currency Futures Markets

- The Chicago Mercantile Exchange (CME) is by far the largest.
- Others include:
  - The Philadelphia Board of Trade (PBOT)
  - The MidAmerica commodities Exchange
  - The Tokyo International Financial Futures Exchange
  - The London International Financial Futures Exchange

The Chicago Mercantile Exchange

- Expiry cycle: March, June, September, December.
- Delivery date 3rd Wednesday of delivery month.
- Last trading day is the second business day preceding the delivery day.
- CME hours 7:20 a.m. to 2:00 p.m. CST.

CME After Hours

- Extended-hours trading on GLOBEX runs from 2:30 p.m. to 4:00 p.m dinner break and then back at it from 6:00 p.m. to 6:00 a.m. CST.
- Singapore International Monetary Exchange (SIMEX) offer interchangeable contracts.
- There's other markets, but none are close to CME and SIMEX trading volume.

Basic Currency Futures Relationships

- *Open Interest* refers to the number of contracts outstanding for a particular delivery month.
- Open interest is a good proxy for demand for a contract.
- Some refer to open interest as the *depth* of the market. The *breadth* of the market would be how many different contracts (expiry month, currency) are outstanding.

Reading a Futures Quote

	Open	Hi	Lo	Settle	Change	Lifetime High	Lifetime Low	Open Interest
Sept	**.9282**	**.9325**	**.9276**	**.9309**	**+.0027**	**1.2085**	**.8636**	**74,639**

- Sept: Expiry month
- Open: Opening price
- Hi: Highest price that day
- Lo: Lowest price that day
- Settle: Closing price
- Change: Daily Change
- Lifetime High and Lifetime Low: Highest and lowest prices over the lifetime of the contract.
- Open Interest: Number of open contracts

Eurodollar Interest Rate Futures Contracts

- Widely used futures contract for hedging short-term U.S. dollar interest rate risk.
- The underlying asset is a hypothetical $1,000,000 90-day Eurodollar deposit—the contract is *cash settled*.
- Traded on the CME and the Singapore International Monetary Exchange.
- The contract trades in the March, June, September and December cycle.

Reading Eurodollar Futures Quotes

EURODOLLAR (CME)—$1 million; pts of 100%								
	Open	High	Low	Settle	Chg	Yield Settle	Yield Change	Open Interest
July	94.69	94.69	94.68	94.68	-.01	5.32	+.01	47,417

Eurodollar futures prices are stated as an index number of three-month LIBOR calculated as *F* = 100-LIBOR.

The closing price for the July contract is 94.68 thus the implied yield is 5.32 percent = 100 – 98.68

The change was .01 percent of $1 million representing $100 on an annual basis. Since it is a 3-month contract one basis point corresponds to a $25 price change.

Options Contracts: Preliminaries

- An option gives the holder the right, *but not the obligation*, to buy or sell a given quantity of an asset in the future, at prices agreed upon today.
- Calls vs. Puts
  - Call options gives the holder the right, but not the obligation, to buy a given quantity of some asset at some time in the future, at prices agreed upon today.
  - Put options gives the holder the right, but not the obligation, to sell a given quantity of some asset at some time in the future, at prices agreed upon today.

Options Contracts: Preliminaries

- European vs. American options
  - European options can only be exercised on the expiration date.
  - American options can be exercised at any time up to and including the expiration date.
  - Since this option to exercise early generally has value, American options are usually worth more than European options, other things equal.

Options Contracts: Preliminaries

- In-the-money
  - The exercise price is less than the spot price of the underlying asset.
- At-the-money
  - The exercise price is equal to the spot price of the underlying asset.
- Out-of-the-money
  - The exercise price is more than the spot price of the underlying asset.

Options Contracts: Preliminaries

- Intrinsic Value
  - The difference between the exercise price of the option and the spot price of the underlying asset.
- Speculative Value
  - The difference between the option premium and the intrinsic value of the option.

Option Premium	=	Intrinsic Value	+	Speculative Value

Currency Options Markets

- PHLX
- HKFE
- 20-hour trading day.
- OTC volume is much bigger than exchange volume.
- Trading is in seven major currencies plus the euro against the U.S. dollar.

PHLX Currency Option Specifications

Currency	**Contract Size**
Australian dollar	AD50,000
British pound	£31,250
Canadian dollar	CD50,000
Deutsche mark	DM62,500
French franc	FF250,000
Japanese yen	¥6,250,000
Swiss franc	SF62,500
Euro	€62,500

Currency Futures Options

- Are an option on a currency futures contract.
- Exercise of a currency futures option results in a long futures position for the holder of a call or the writer of a put.
- Exercise of a currency futures option results in a short futures position for the seller of a call or the buyer of a put.
- If the futures position is not offset prior to its expiration, foreign currency will change hands.

Basic Option Pricing Relationships at Expiry

- At expiry, an American call option is worth the same as a European option with the same characteristics.
- If the call is in-the-money, it is worth $S_T - E$.
- If the call is out-of-the-money, it is worthless.

$$C_{aT} = C_{eT} = Max[S_T - E, 0]$$

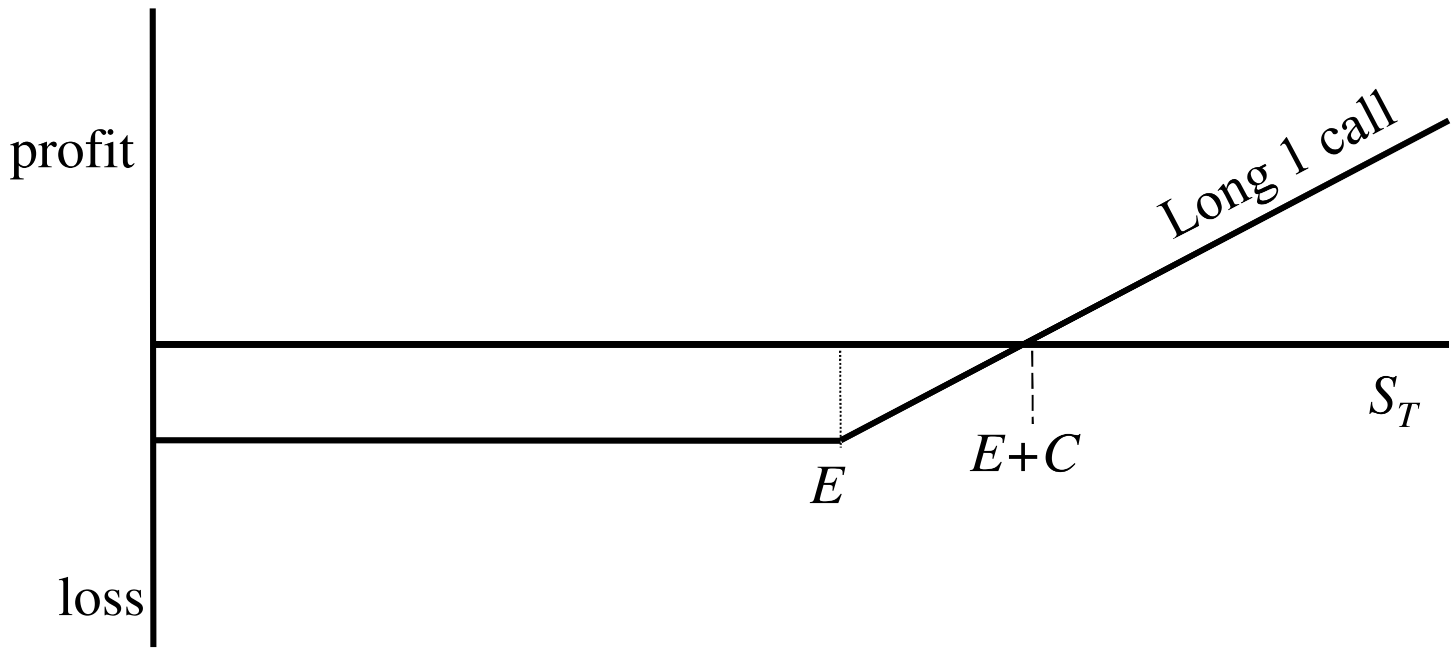
Basic Option Pricing Relationships at Expiry

- At expiry, an American put option is worth the same as a European option with the same characteristics.
- If the put is in-the-money, it is worth $E - S_T$.
- If the put is out-of-the-money, it is worthless.

$$P_{aT} = P_{eT} = Max[E - S_T, 0]$$

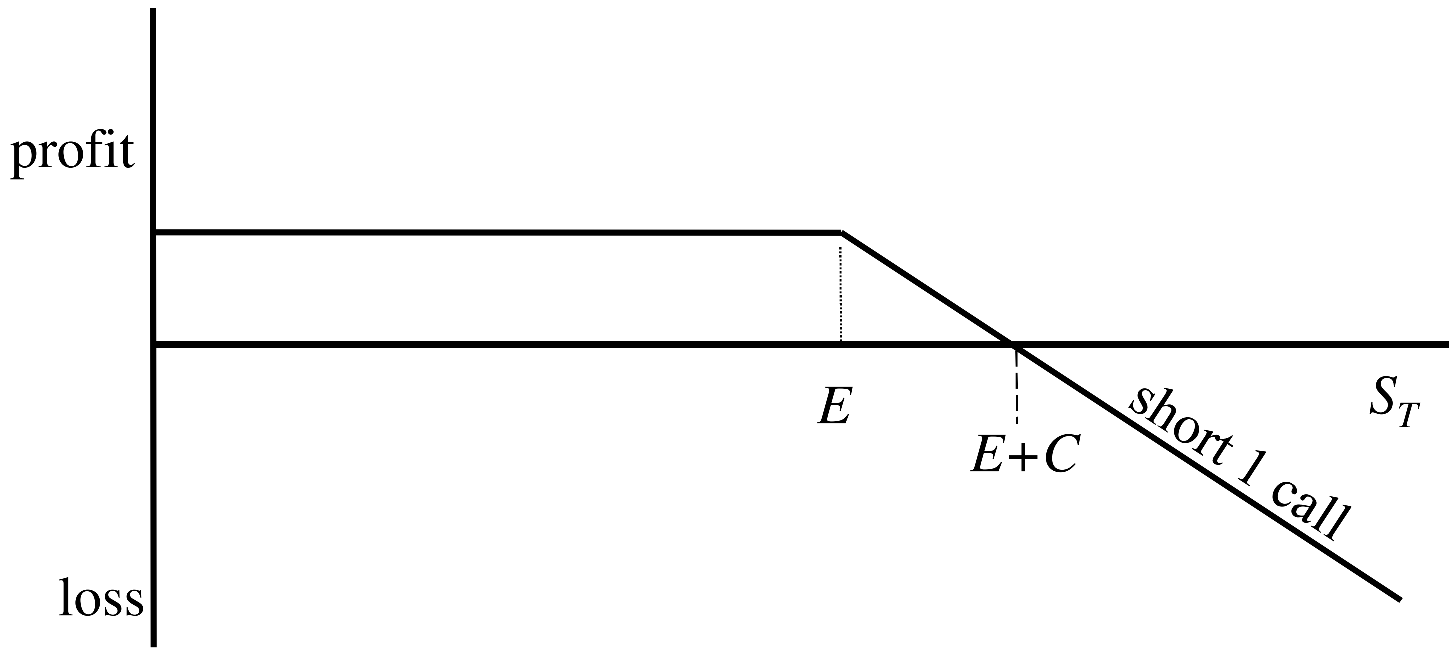
Basic Option Profit Profiles

$$C_{aT} = C_{eT} = Max[S_T - E, 0]$$



Basic Option Profit Profiles

$$C_{aT} = C_{eT} = Max[S_T - E, 0]$$



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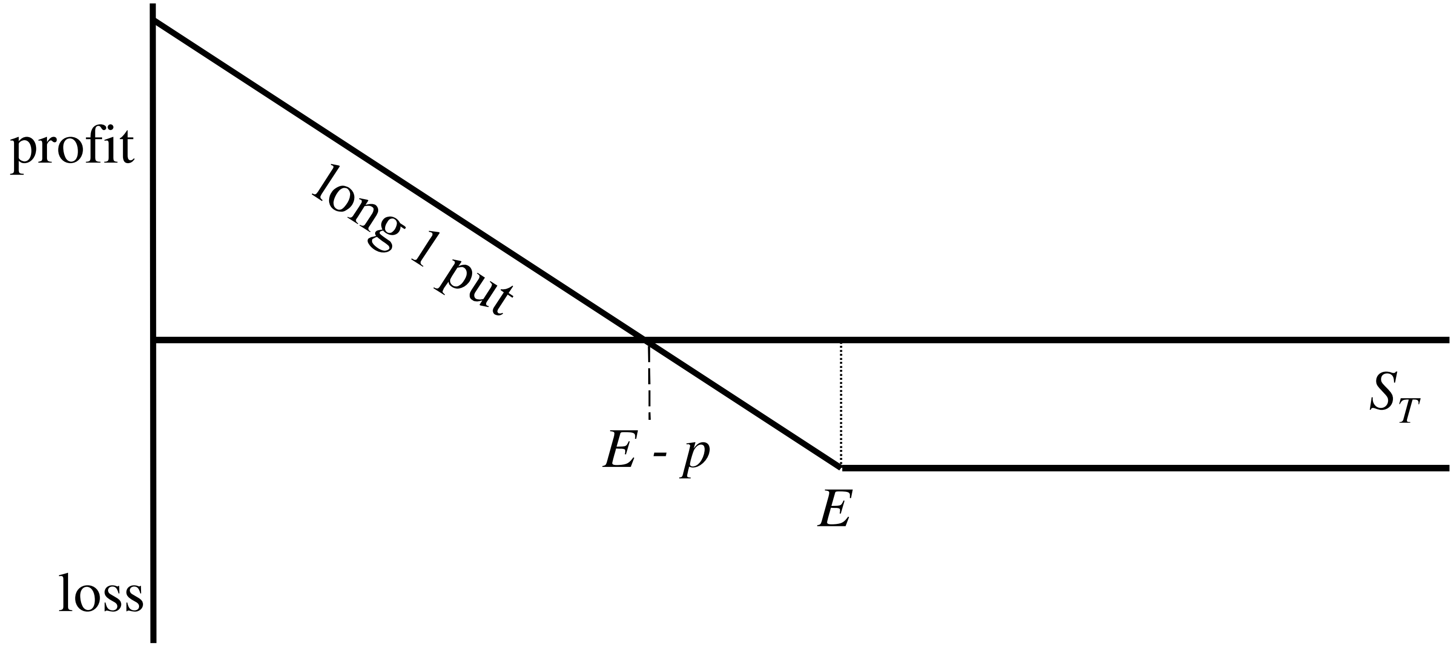

Basic Option Profit Profiles

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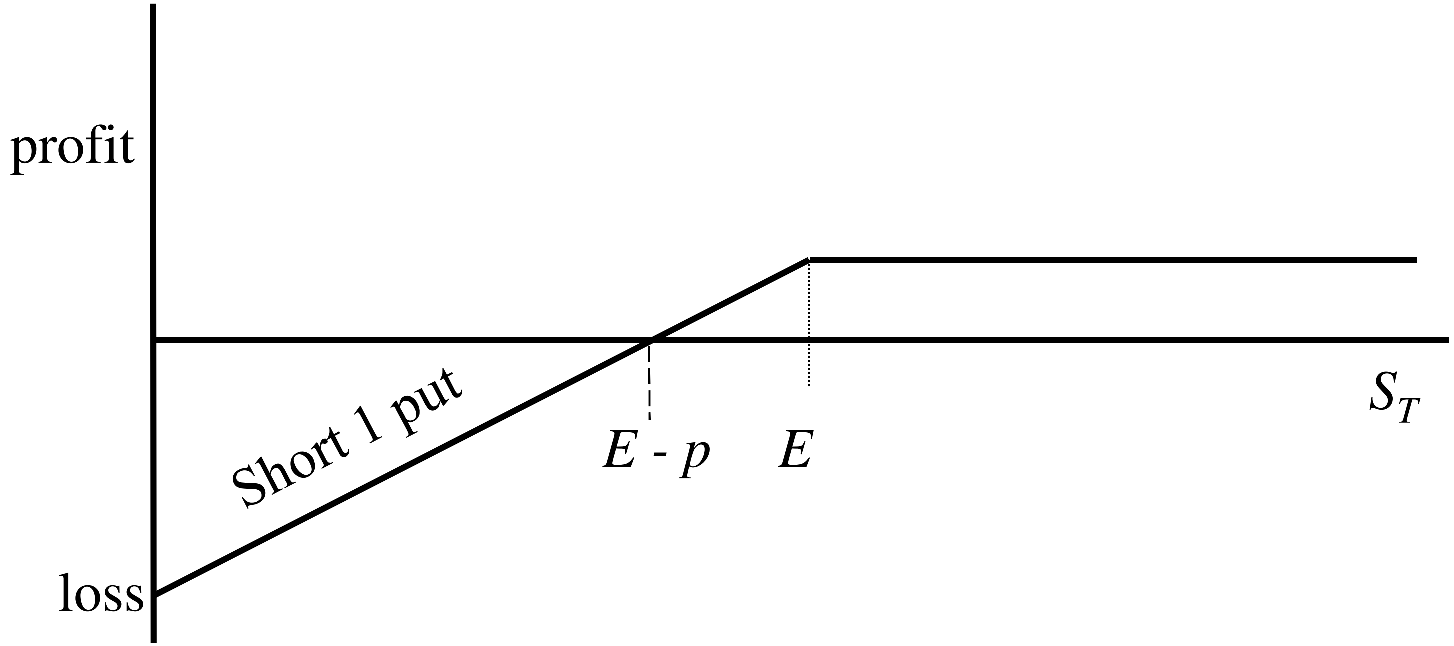


American Option Pricing Relationships

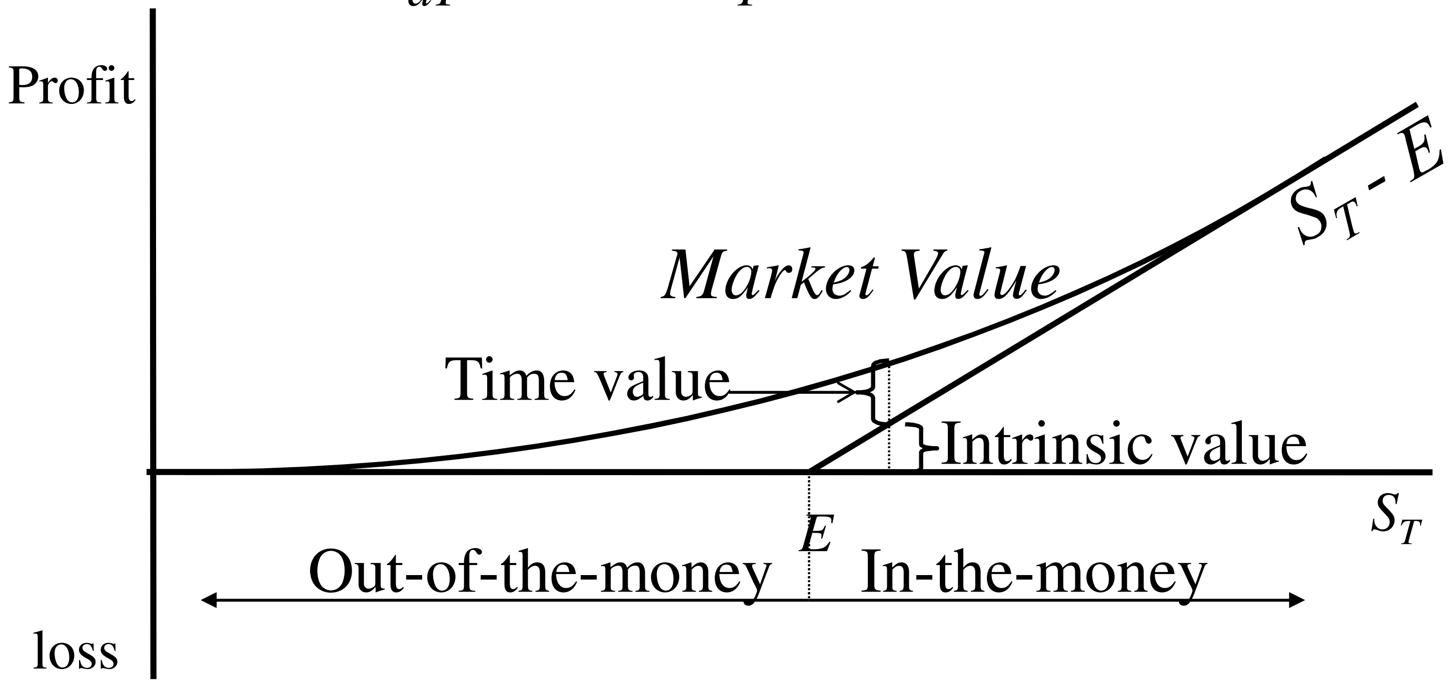
- With an American option, you can do everything that you can do with a European option—this option to exercise early has value.

$$C_{aT} \geq C_{eT} = Max[S_T - E, 0]$$

$$P_{aT} \geq P_{eT} = Max[E - S_T, 0]$$

Market Value, Time Value and Intrinsic Value for an American Call

$$C_{aT} \geq Max[S_T - E, 0]$$



European Option Pricing Relationships

Consider two investments

1. Buy a call option on the British pound futures contract. The cash flow today is $-C_e$
2. Replicate the upside payoff of the call by
   1. Borrowing the present value of the exercise price of the call in the U.S. at $i_\$$ The cash flow today is

      $$E/(1+i_\$)$$

   2. Lending the present value of S_T at $i_£$ The cash flow is

      $$-S_T/(1+i_£)$$

European Option Pricing Relationships

When the option is in-the-money both strategies have the same payoff.

When the option is out-of-the-money it has a higher payoff the borrowing and lending strategy.

Thus:

$$C_e \geq \max\left[\frac{S_T}{(1+i_£)} - \frac{E}{(1+i_\$)}, 0\right]$$

European Option Pricing Relationships

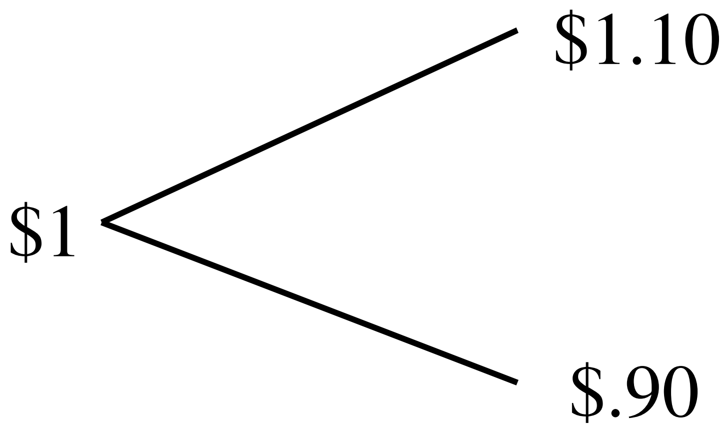
Using a similar portfolio to replicate the upside potential of a put, we can show that:

$$P_e \geq \max\left[\frac{E}{(1+i_\$)} - \frac{S_T}{(1+i_£)}, 0\right]$$

Binomial Option Pricing Model

- Imagine a simple world where the dollar-euro exchange rate is $S_0(\$/€) = \$1$ today and in the next year, $S_1(\$/€)$ is either \$1.1 or \$.90.

$S_0(\$/€)$	$S_1(\$/€)$



Binomial Option Pricing Model

- A call option on the euro with exercise price S_0($/€) = $1 will have the following payoffs.

S_0($/€)	S_1($/€)	C_1($/€)
	$1.10	$.10
$1		
	$.90	$0

Binomial Option Pricing Model

- We can replicate the payoffs of the call option. With a levered position in the euro.

S_0($/€)	S_1($/€)	C_1($/€)
	$1.10	$.10
$1		
	$.90	$0

Binomial Option Pricing Model

Borrow the present value of $.90 today and buy € 1.
Your net payoff in one period is either $.2 or $0.

S_0($/€)	S_1($/€)	debt	portfolio	C_1($/€)
	$1.10	-$.90	$.20	$.10
$1				
	$.90	-$.90	$.00	$0

Binomial Option Pricing Model

- The portfolio has twice the option's payoff so the portfolio is worth twice the call option value.

S_0($/€)	S_1($/€)	debt	portfolio	C_1($/€)
	$1.10	-$.90	$.20	$.10
$1				
	$.90	-$.90	$.00	$0

Binomial Option Pricing Model

The portfolio value today is today's value of one euro less the present value of a $.90 debt:

$$\$1-\frac{\$.90}{(1+i_{\$})}$$

$S_0(\$/€)$	$S_1(\$/€)$	debt	portfolio	$C_1(\$/€)$
$1	$1.10	-$.90	$.20	$.10
	$.90	-$.90	$.00	$0

Binomial Option Pricing Model

We can value the option as half of the value of the portfolio:

$$C_0 = \frac{1}{2}\left(\$1 - \frac{\$.90}{(1+i_\$)}\right)$$

S_0($/€)	S_1($/€)	debt	portfolio	C_1($/€)
	$1.10	-$.90	$.20	$.10
$1				
	$.90	-$.90	$.00	$0

Binomial Option Pricing Model

- The most important lesson from the binomial option pricing model is:

<u>the replicating portfolio intuition.</u>

- Many derivative securities can be valued by valuing portfolios of primitive securities when those portfolios have the same payoffs as the derivative securities.

European Option Pricing Formula

- We can use the replicating portfolio intuition developed in the binomial option pricing formula to generate a faster-to-use model that addresses a much more realistic world.

European Option Pricing Formula

The model is $C_0 = [F \times N(d_1) - E \times N(d_2)]e^{-r_\$ T}$

Where

C_0 = the value of a European option at time $t = 0$

$$F = S_t e^{(r_\$ - r_£)T}$$

$r_\$$ = the interest rate available in the U.S.

$r_£$ = the interest rate available in the foreign country—in this case the U.K.

$$d_1 = \frac{\ln(F/E) + .5\sigma^2 T}{\sigma\sqrt{T}}, \quad d_2 = d_1 - \sigma\sqrt{T}$$

European Option Pricing Formula

Find the value of a six-month call option on the British pound with an exercise price of $1.50 = £1

The current value of a pound is $1.60

The interest rate available in the U.S. is $r_{\$} = 5\%$.

The interest rate in the U.K. is $r_{£} = 7\%$.

The option maturity is 6 months (half of a year).

The volatility of the $/£ exchange rate is 30% p.a.

Before we start, note that the intrinsic value of the option is $.10—our answer must be at least that.

European Option Pricing Formula

Let's try our hand at using the model. If you have a calculator handy, follow along.

First calculate

$$F = S_t e^{(r_\$ - r_£)T} = 1.50e^{(.05-.07)0.50} = 1.485075$$

Then, calculate d_1 and d_2

$$d_1 = \frac{\ln(F/E) + .5\sigma^2 T}{\sigma\sqrt{T}} = \frac{\ln(1.485075/1.50) + .5(0.4)^2 .5}{.4\sqrt{.5}} = 0.106066$$

$$d_2 = d_1 - \sigma\sqrt{T} = 0.106066 - .4\sqrt{.5} = -0.176878$$

European Option Pricing Formula

$$F = 1.485075$$

$$d_1 = 0.106066$$

$$d_2 = -0.176878$$

$$N(d_1) = N(0.106066) = .5422$$

$$N(d_2) = N(-0.1768) = 0.4298$$

$$C_0 = [F \times N(d_1) - E \times N(d_2)]e^{-r_\$ T}$$

$$C_0 = [1.485075 \times .5422 - 1.50 \times .4298]e^{-.05*.5} = \$0.157$$

Option Value Determinants

		Call	Put
1.	Exchange rate	+	–
2.	Exercise price	–	+
3.	Interest rate in U.S.	+	–
4.	Interest rate in other country	+	–
5.	Variability in exchange rate	+	+
6.	Expiration date	+	+

The value of a call option C_0 must fall within

$$\max (S_0 - E, 0) \leq C_0 \leq S_0.$$

The precise position will depend on the above factors.

Empirical Tests

The European option pricing model works fairly well in pricing American currency options.

It works best for out-of-the-money and at-the-money options.

When options are in-the-money, the European option pricing model tends to underprice American options.

End Chapter Nine