Options (2)

Class 20
Financial Management, 15.414

Today

Options

- Option pricing
- Applications: Currency risk and convertible bonds

Reading

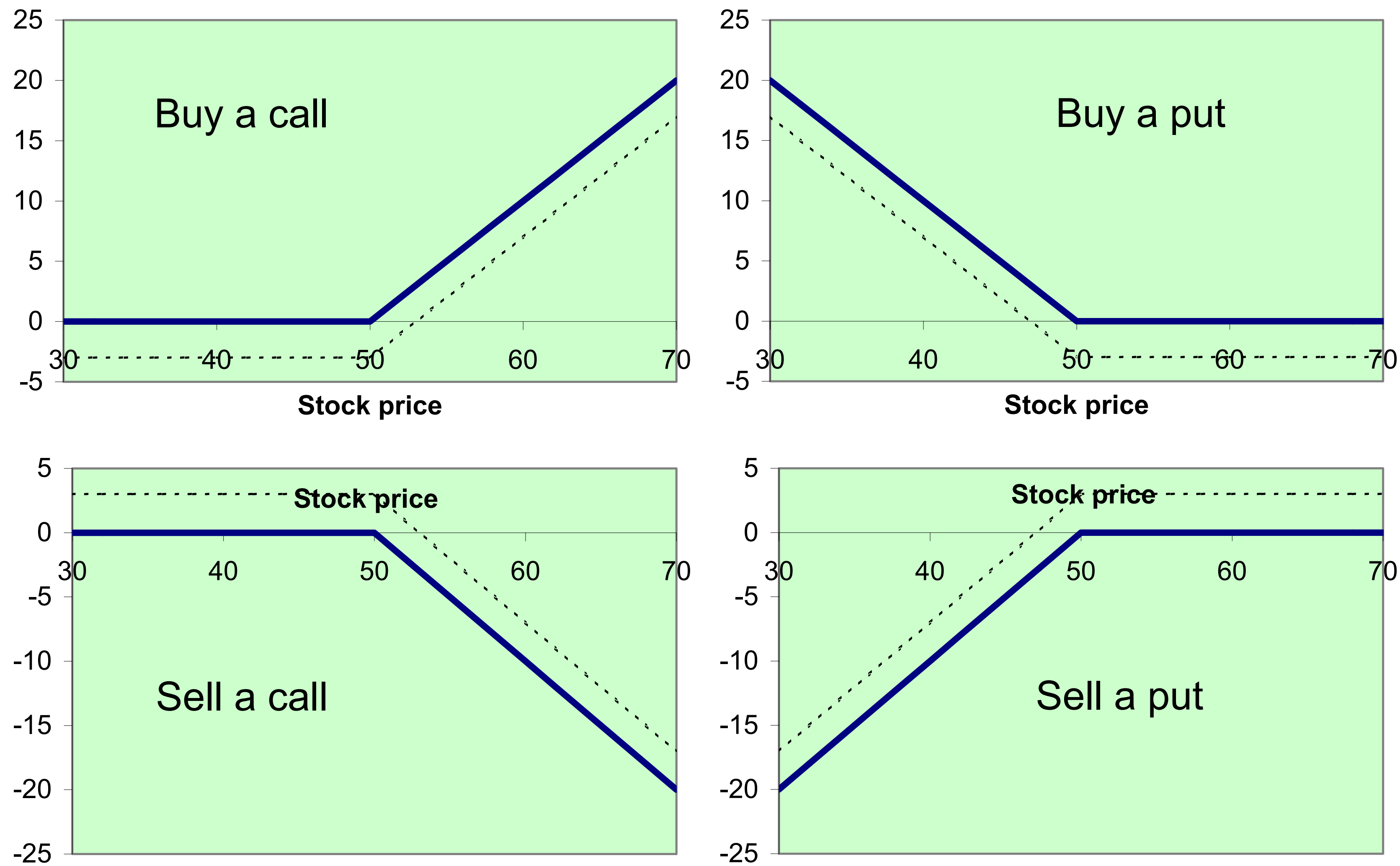
- Brealey and Myers, Chapter 20, 21

Options

Gives the holder the right to either buy (call option) or sell (put option) at a specified price.

- Exercise, or strike, price
- Expiration or maturity date
- American vs. European option
- In-the-money, at-the-money, or out-of-the-money

Option payoffs (strike = $50)



Valuation

Option pricing

How can we estimate the expected cashflows, and what is the appropriate discount rate?

Two formulas

- Put-call parity
- Black-Scholes formula*

* Fischer Black and Myron Scholes

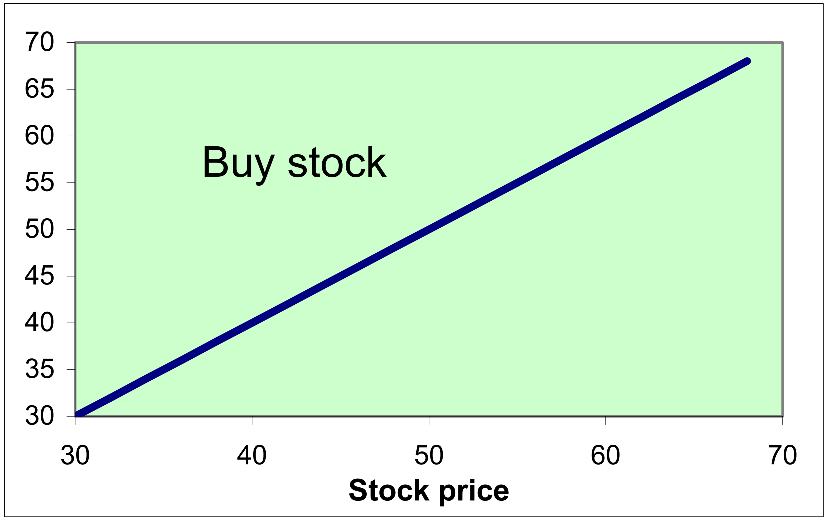
Put-call parity

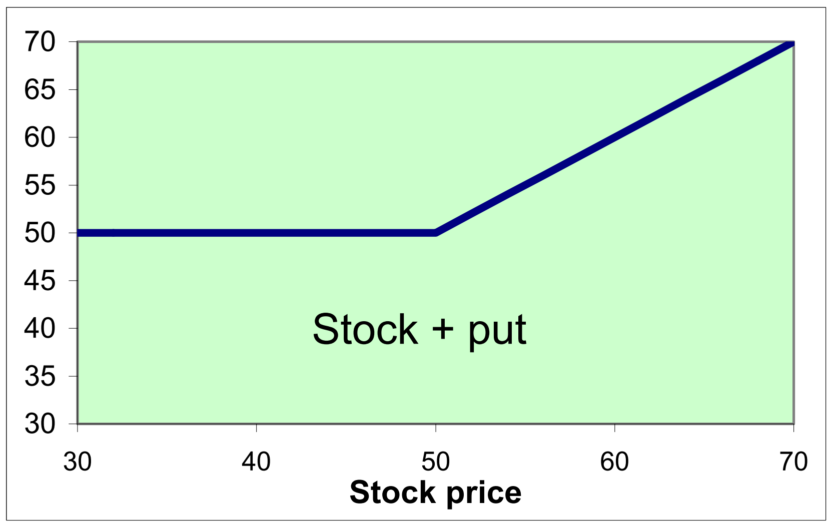
Relation between put and call prices

P + S = C + PV(X)

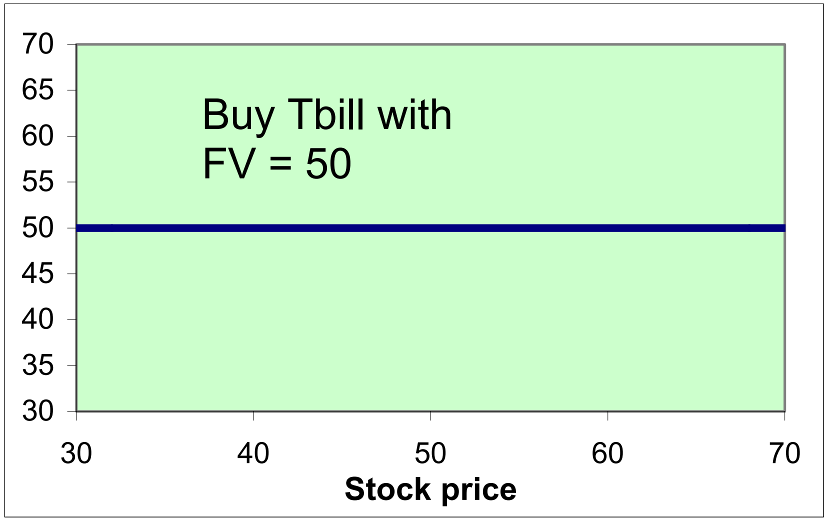
S = stock price
P = put price
C = call price
X = strike price
PV(X) = present value of $X = X / (1+r)^t$
r = riskfree rate

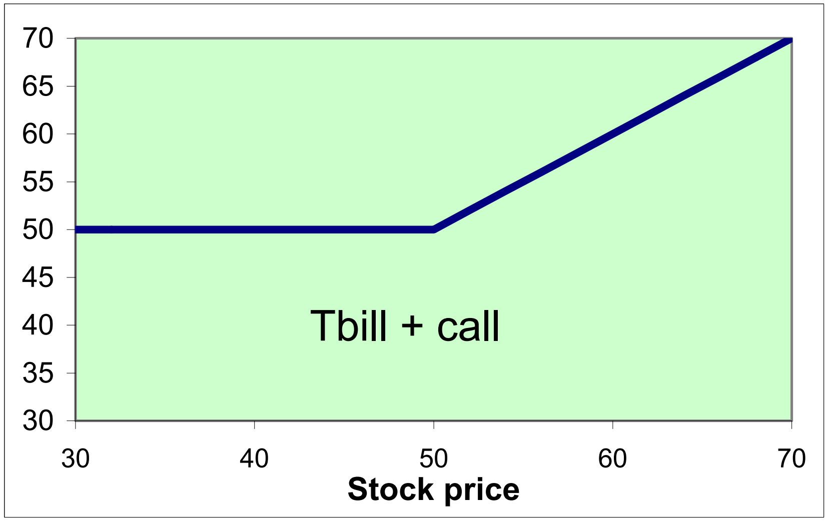
Option strategies: Stock + put





Option strategies: Tbill + call





Example

On Thursday, Cisco call options with a strike price of $20 and an expiration date in October sold for $0.30. The current price of Cisco is $17.83. How much should put options with the same strike price and expiration date sell for?

Put-call parity

P = C + PV(X) – S

C = $0.30, S = $17.83, X = $20.00

r = 1% annually → 0.15% over the life of the option

Put option = 0.30 + 20 / 1.0015 – 17.83 = $2.44

Black-Scholes

Price of a call option

$$C = S \times N(d_1) - X\, e^{-rT} N(d_2)$$

S = stock price

X = strike price

r = riskfree rate (annual, continuously compounded)

T = time-to-maturity of the option, in years

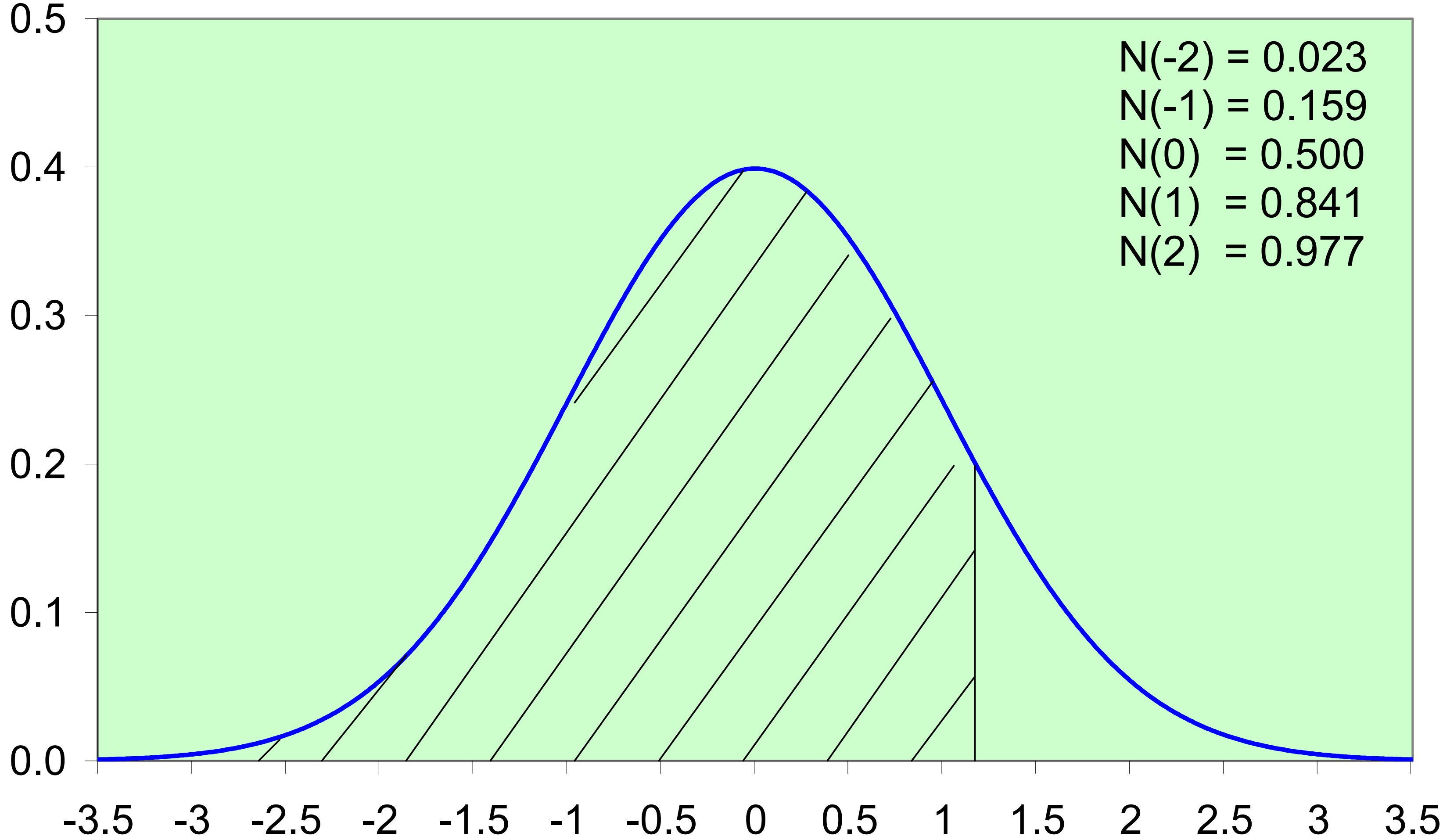
$$d_1 = \frac{\ln(S/X) + (r + \sigma^2/2)\,T}{\sigma\sqrt{T}}$$

$$d_2 = d_1 - \sigma\sqrt{T}$$

$N(\cdot)$ = prob that a standard normal variable is less than d_1 or d_2

σ = annual standard deviation of the stock return

Cumulative Normal Distribution



Example

The CBOE trades Cisco call options. The options have a strike price of $20 and expire in 2 months. If Cisco's stock price is $17.83, how much are the options worth? What happens if the stock goes up to $19.00? 20.00?

Black-Scholes

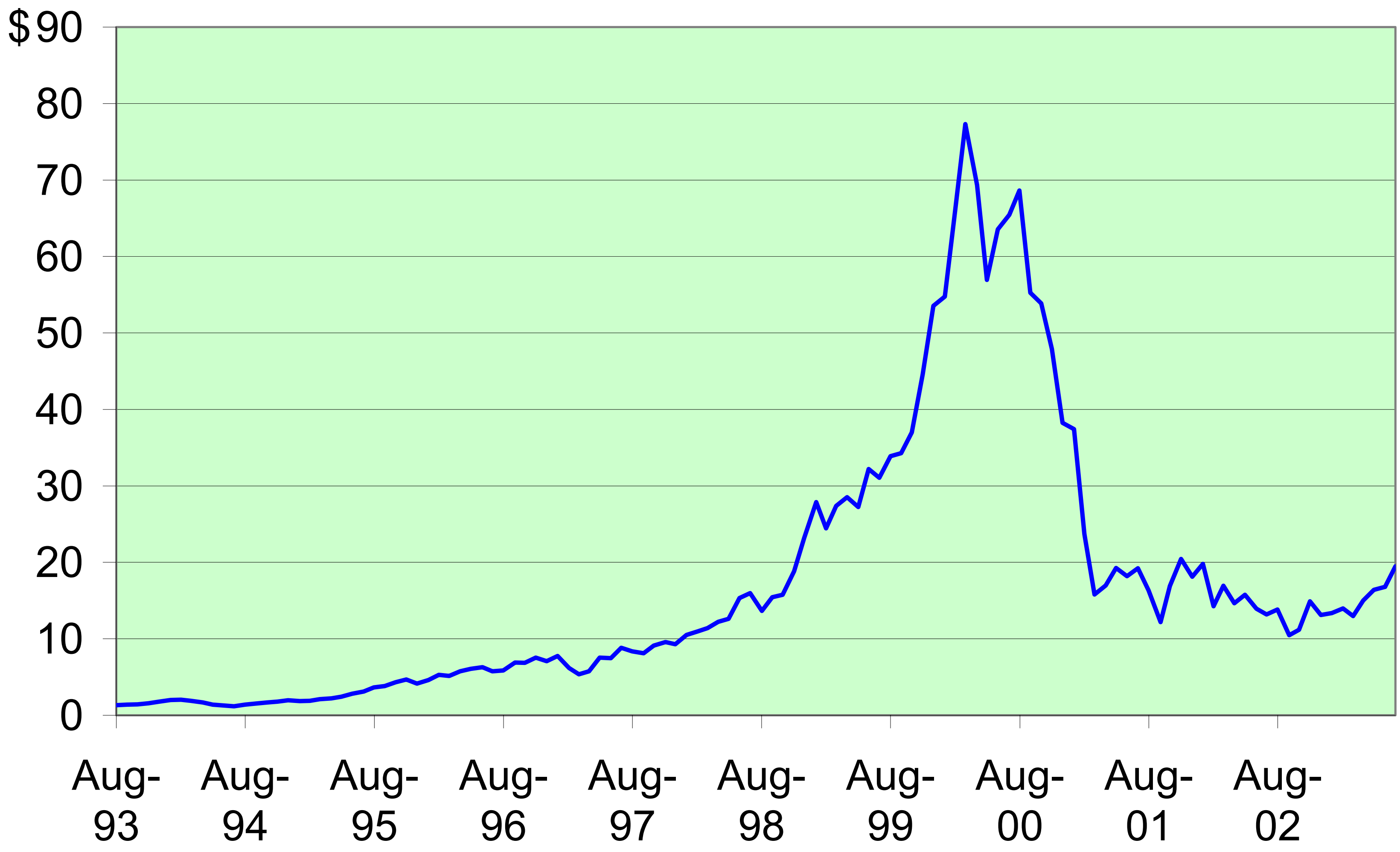
$S = 17.83, \quad X = 20.00, \quad r = 1.00, \quad T = 2/12, \quad \sigma_{2003} = 36.1\%$

$$d_1 = \frac{\ln(S/X) + (r + \sigma^2/2)\,T}{\sigma\sqrt{T}} = -0.694$$

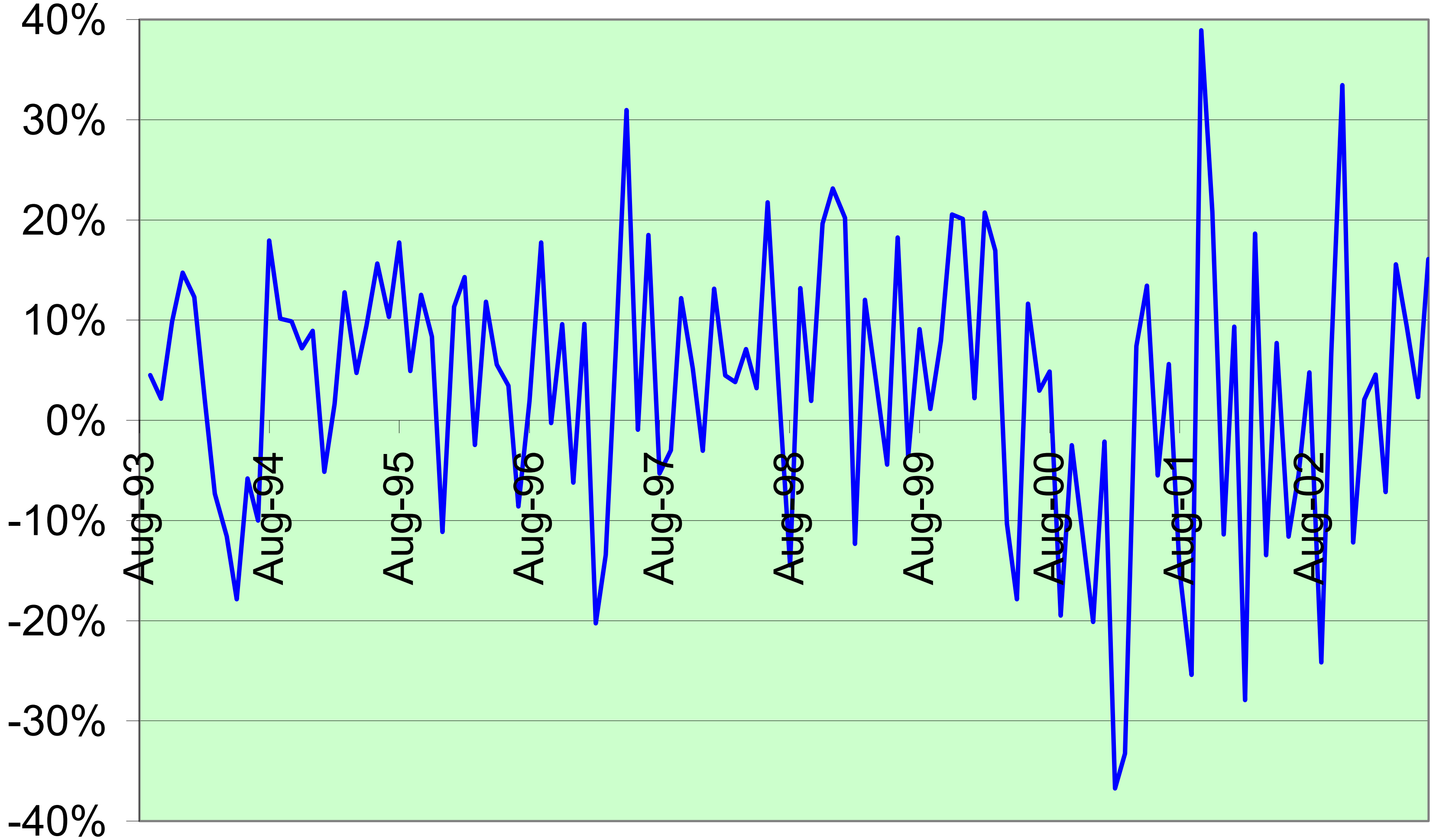
$$d_2 = d_1 - \sigma\sqrt{T} = -0.842$$

Call price $= S \times N(d_1) - X\,e^{-rT}\,N(d_2) =$ **$0.35**

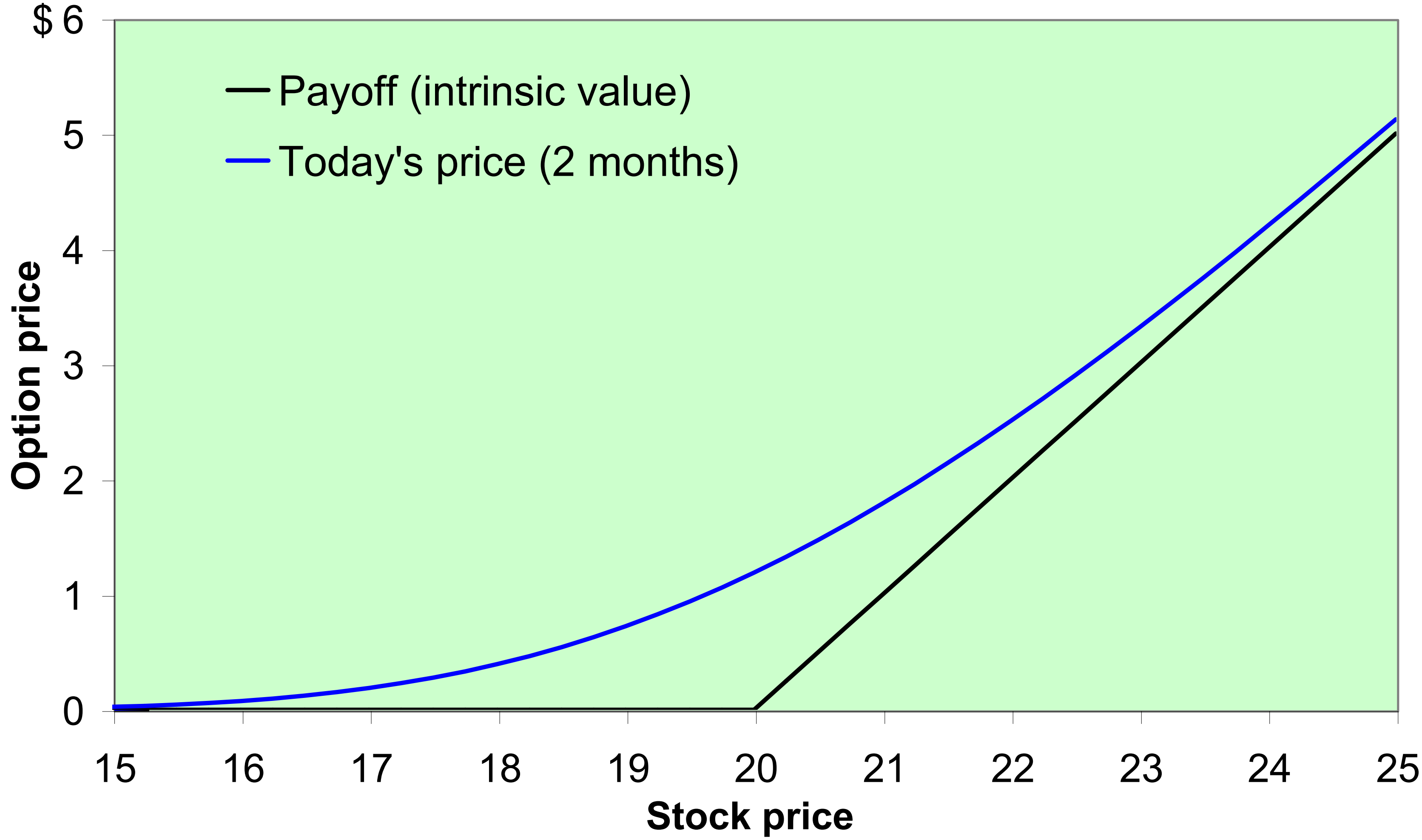
Cisco stock price, 1993 – 2003



Cisco returns, 1993 – 2003



Cisco option prices



Option pricing

Factors affecting option prices

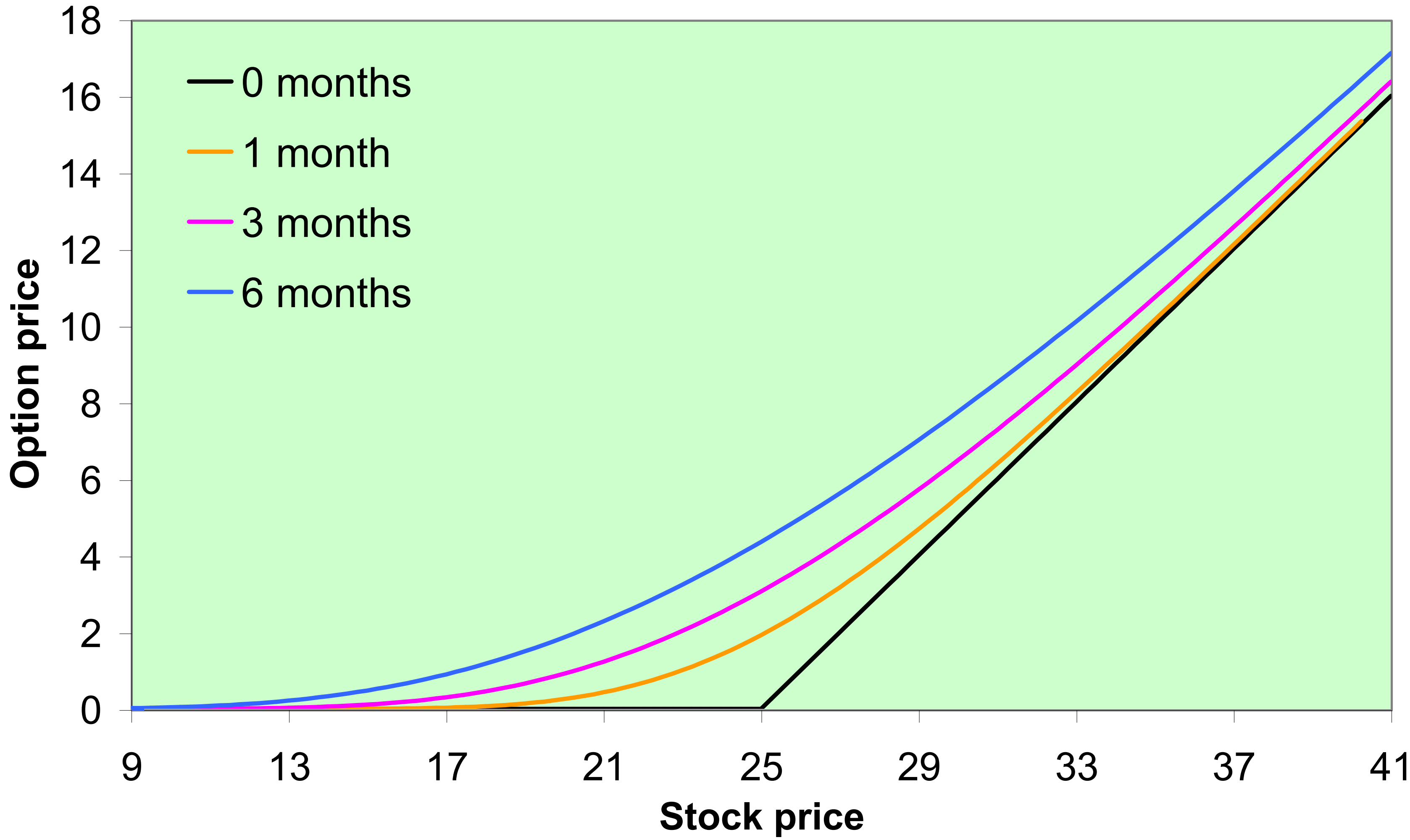
	Call option	Put option
Stock price (S)	+	–
Exercise price (X)	–	+
Time-to-maturity (T)	+	+
Stock volatility (σ)	+	+
Interest rate (r)	+	–
Dividends (D)	–	+

Example 2

Call option with X = $25, r = 3%

Time to expire	Stock price	Std. deviation	Call option
T = 0.25	$18	30%	$0.02
	25	30	1.58
	32	30	7.26
	18	50	0.25
	25	50	2.57
	32	50	7.75
T = 0.50	18	30	0.14
	25	30	2.29
	32	30	7.68
	18	50	0.76
	25	50	3.67
	32	50	8.68

Option pricing



Using Black-Scholes

Applications

- Hedging currency risk
- Pricing convertible debt

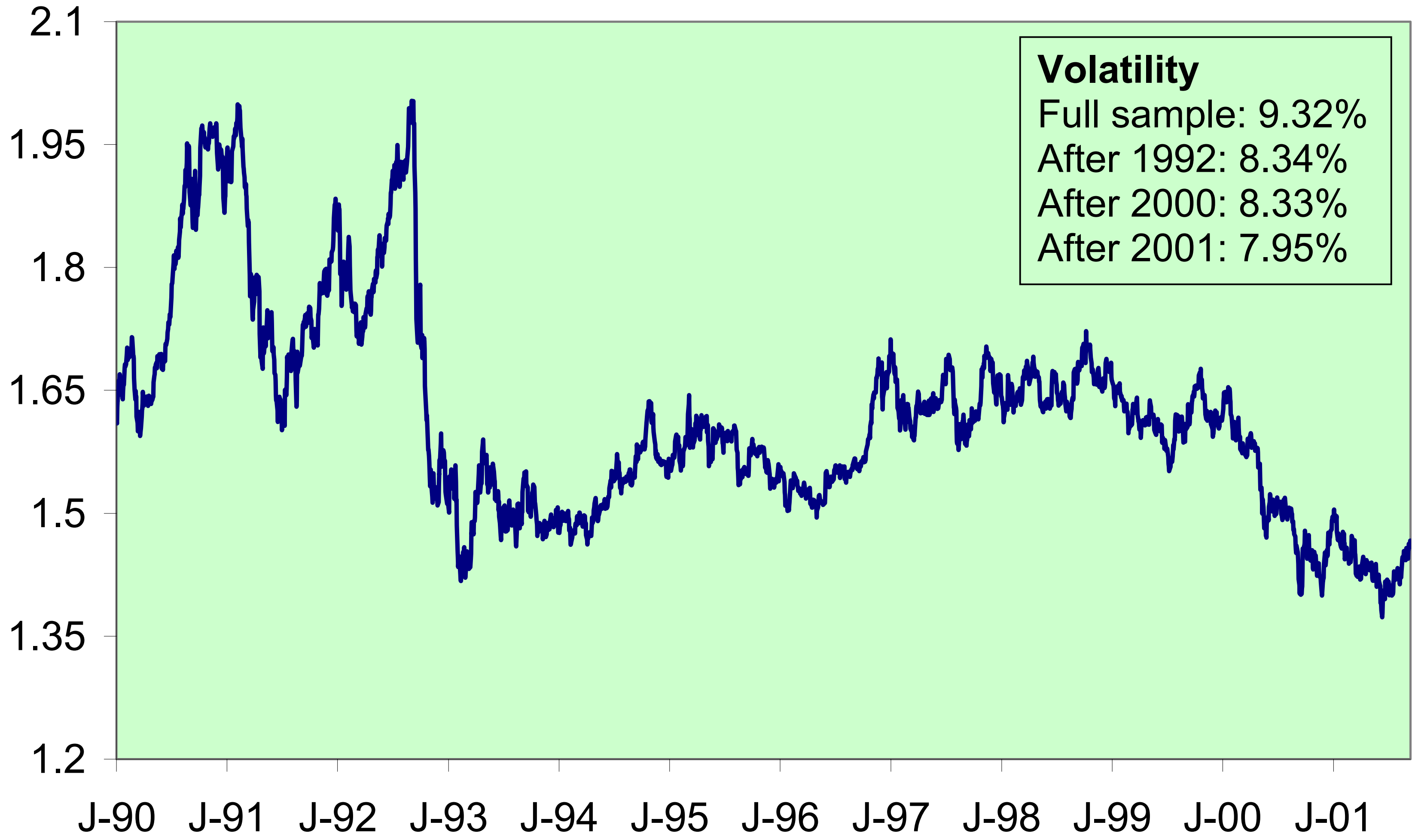
Currency risk

Your company, headquartered in the U.S., supplies auto parts to Jaguar PLC in Britain. You have just signed a contract worth £18.2 million to deliver parts next year. Payment is certain and occurs at the end of the year.

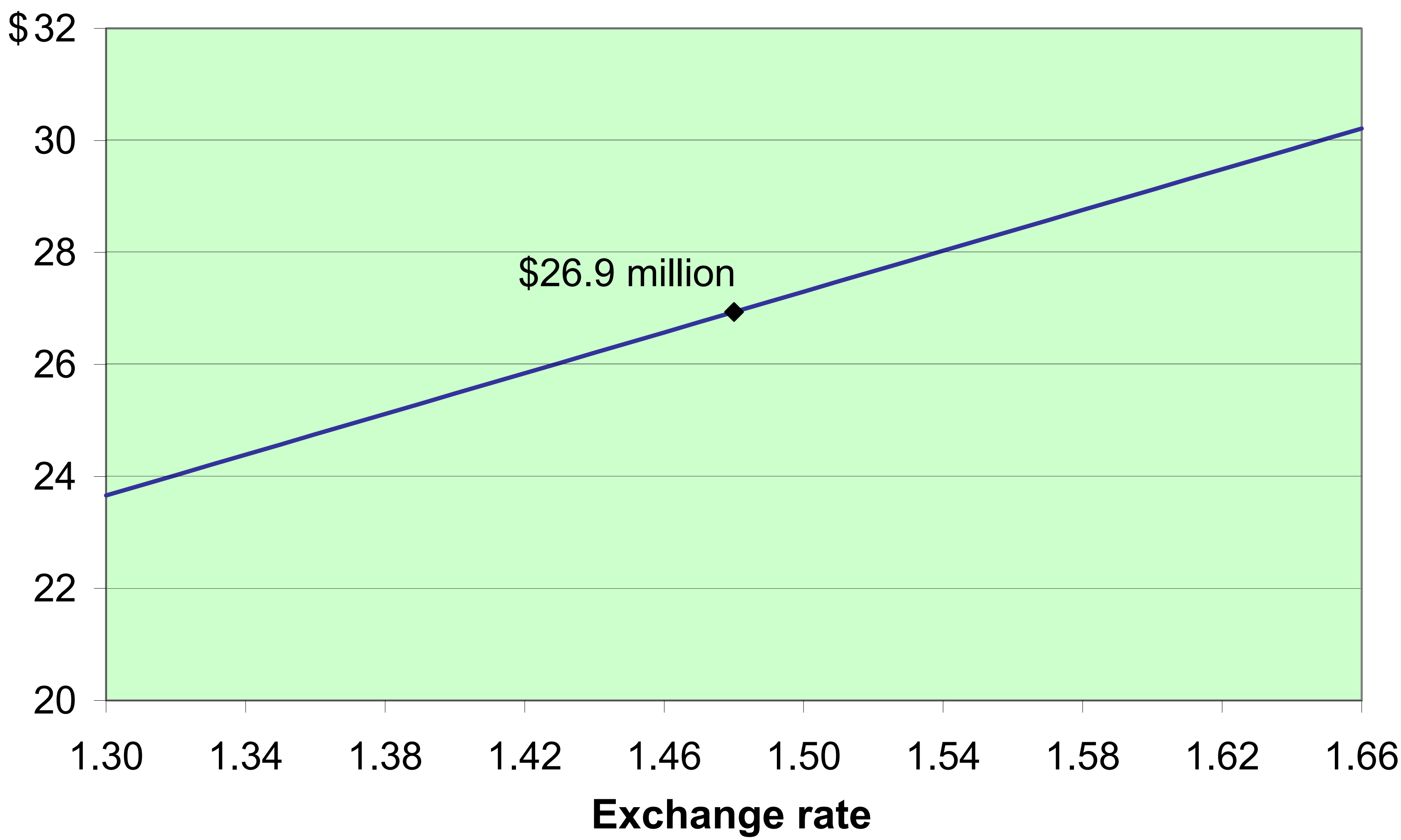
The $ / £ exchange rate is currently $s_{\$/£} = 1.4794$.

How do fluctuations in exchange rates affect $ revenues? How can you hedge this risk?

$s_{\$/£}$, Jan 1990 – Sept 2001



\$ revenues as a function of $s_{\$/£}$



Currency risk

Forwards

1-year forward exchange rate = 1.4513

Lock in revenues of 18.2 × 1.4513 = $26.4 million

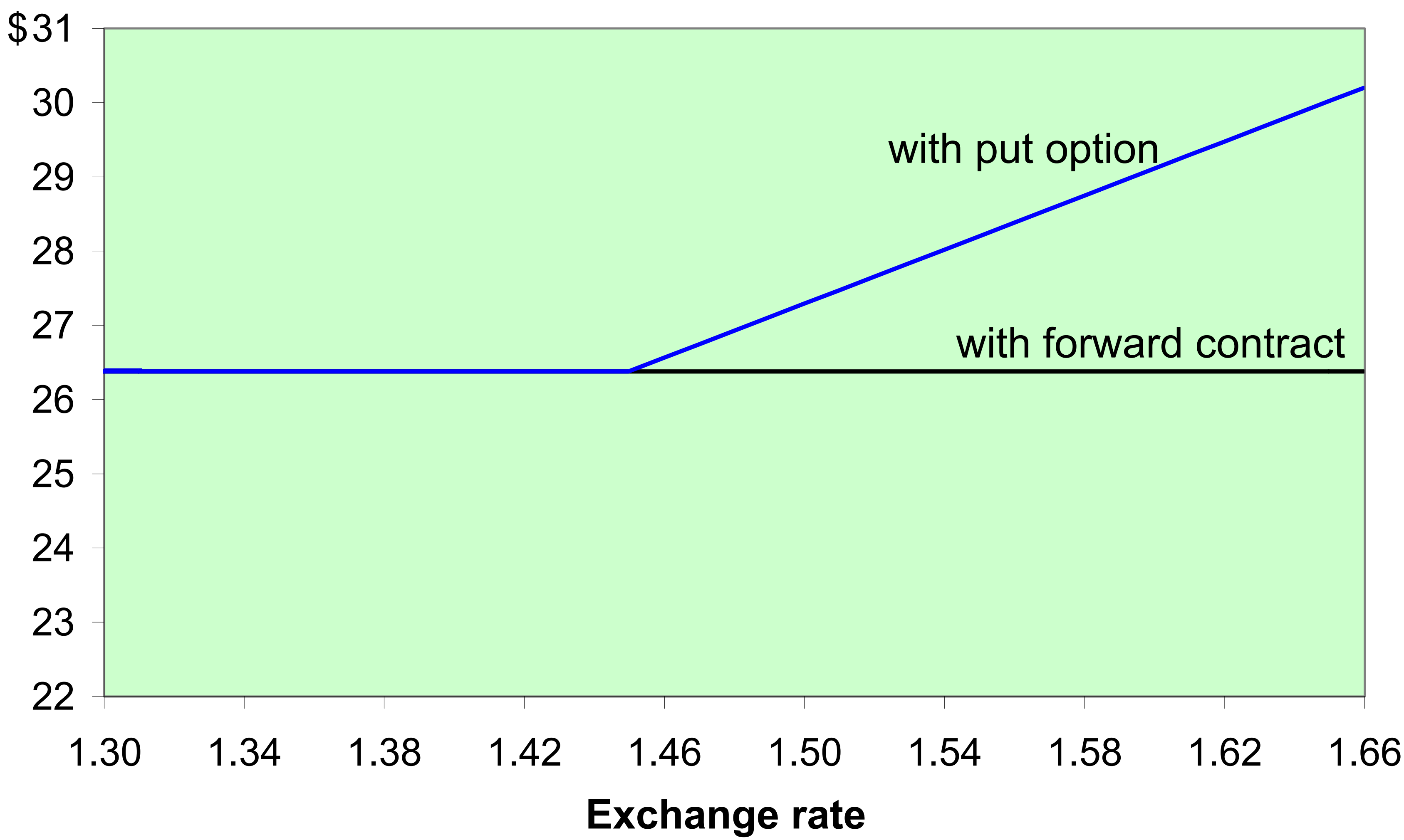
Put options*

S = 1.4794, σ = 8.3%, T = 1, r = -1.8%*

Strike price	Min. revenue	Option price	Total cost (×18.2 M)
1.35	$24.6 M	$0.012	$221,859
1.40	$25.5 M	$0.026	$470,112
1.45	$26.4 M	$0.047	$862,771

*Black-Scholes is only an approximation for currencies; $r = r_{UK} - r_{US}$

\$ revenues as a function of $s_{\$/£}$



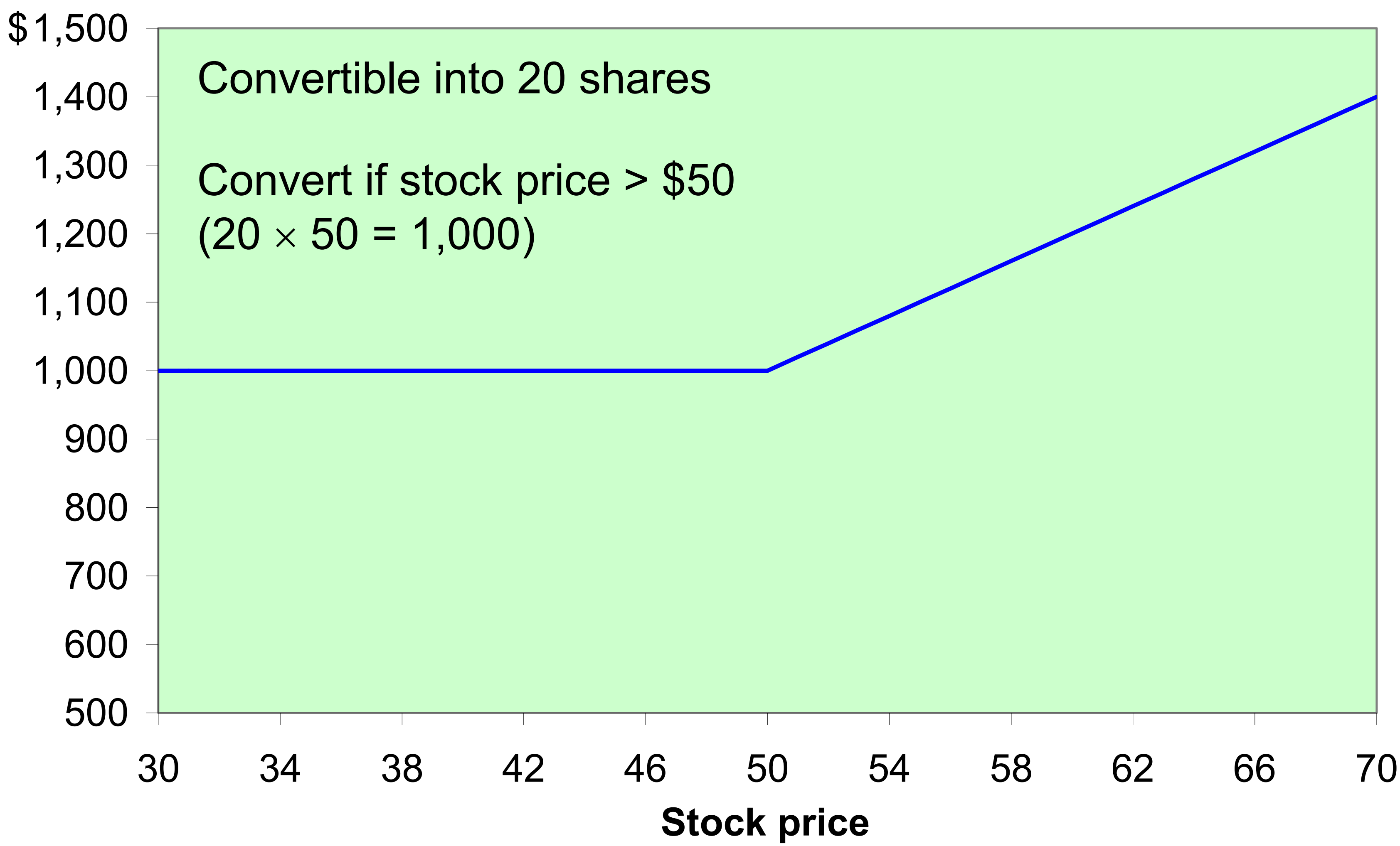
Convertible bonds

Your firm is thinking about issuing 10-year convertible bonds. In the past, the firm has issued straight (non-convertible) debt, which currently has a yield of 8.2%.

The new bonds have a face value of $1,000 and will be convertible into 20 shares of stocks. How much are the bonds worth if they pay the same interest rate as straight debt?

Today's stock price is $32. The firm does not pay dividends, and you estimate that the standard deviation of returns is 35% annually. Long-term interest rates are 6%.

Payoff of convertible bonds



Convertible bonds

Suppose the bonds have a coupon rate of 8.2%. How much would they be worth?

Cashflows*

Year	1	2	3	4	…	10
Cash	\$82	\$82	\$82	\$82		\$1,082

Value if straight debt: \$1,000

Value if convertible debt: \$1,000 + value of call option

* Annual payments, for simplicity

Convertible bonds

Call option

X = \$50, S = \$32, σ = 35%, r = 6%, T = 10

Black-Scholes value = \$10.31

Convertible bond

Option value per bond = 20 $\times$ 10.31 = \$206.2

Total bond value = 1,000 + 206.2 = \$1,206.2

Yield = 5.47%*

*Yield = IRR ignoring option value