

# A quick note on implied volatility

## Applied Stochastic Processes (FIN 514)

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2017-18, Module 1 (Fall)

- The Black-Scholes-Merton (BSM), Bachelier (normal) models are seldom used to *predict* the option price. The option prices are determined from the supply and demand of market.
- However, the pricing models are still important because they provide a consistent measure to intuitively understand the prices of the options with different strikes, time to maturity, etc.
- *Implied volatility (IV)* is the value of the volatility in pricing model which returns (or solve) the price of an option given (i.e., from market):

$$C(K, S_0, \sigma, T_e) = \text{Price}$$

- How can you compare the two prices?

$$C(K = 105, S_0 = 100, T_e = 1) = 5.9 \quad P(K = 98, S_0 = 100, T_e = 1) = 8.7$$

The implied volatility is same as 20%.

# General rule

- Option prices (both call and put) increase as the volatility increases:  $C(K, S_0, \sigma, T_e)$  is monotonically increasing function.
- Option value = Time value + Intrinsic Value
  - Intrinsic value: the value you get by exercising option now. ( $> 0$ )
  - Time value: the extra value from the change of the underlying price until the expiry. ( $> 0$ )
- The intrinsic value can be understood as the option value with  $\sigma = 0$ ,  $C(K, S_0, \sigma = 0, T_e)$ , hence the minimum value.
- The call option value as  $\sigma \rightarrow \infty$ :
  - BSM model ( $S_T \geq 0$ ):  $S_0$ . The underlying stock is always worth more than any call option with  $K > 0$ .
  - Normal model ( $S_T$  can be negative):  $\infty$ . Call option can protect the (infinite) loss.

# IV computation

- The computation of IV depends on numerical root-solving method. [Demo]
  - Newton method: using vega,

$$\sigma^{(k+1)} = \sigma^{(k)} - \frac{C(\sigma^{(k)}, \dots) - \text{Price}}{V(\sigma^{(k)})}, \quad V(\sigma) = \frac{\partial C(\sigma, \dots)}{\partial \sigma}$$

- Brent's method: [Demo]
- BSM model:
  - Jackel (2015): Machine epsilon error within two step iterations. ([partial final project](#))
- Normal model:
  - Choi et al (2007): Polynomial approximation with error ( $< 10^{-9}$ )