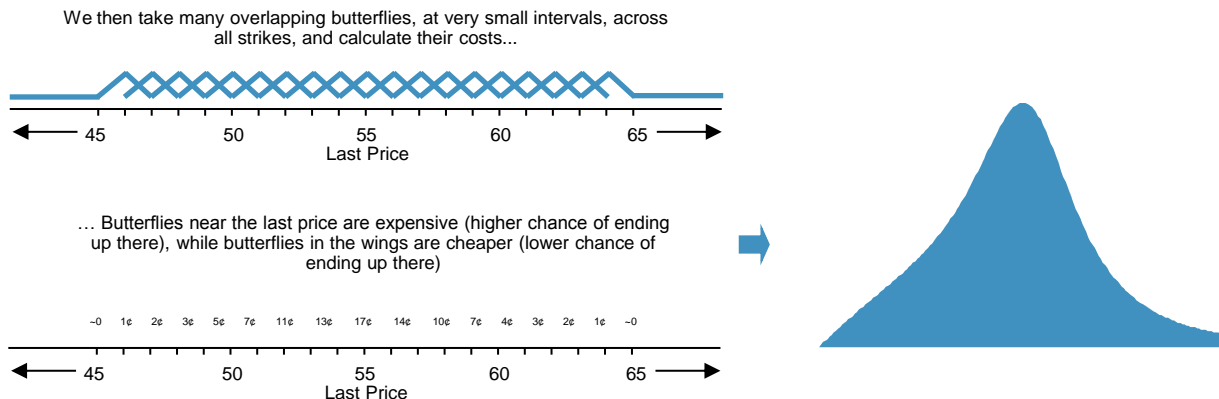# How Options Implied Probabilities Are Calculated

The implied probability distribution is an approximate risk-neutral distribution derived from traded option prices using an interpolated volatility surface. In a risk-neutral world (i.e., where we are not more adverse to losing money than eager to gain it), the fair price for exposure to a given event is the payoff if that event occurs, times the probability of it occurring. Worked in reverse, the probability of an outcome is the cost of exposure to the outcome divided by its payoff.

In the options market, we can buy exposure to a specific range of stock price outcomes with a strategy know as a butterfly spread (long 1 low strike call, short 2 higher strikes calls, and long 1 call at an even higher strike). The probability of the stock ending in that range is then the cost of the butterfly, divided by the payout if the stock is in the range.

Building a Butterfly:

Buy 1 50 call …add 2 short 55 calls …then Buy 1 60 call

Max payoff = $5 at $55

Min payoff = $0 outside of $50 - $60

To find a smooth distribution, we price a series of theoretical call options expiring on a single date at various strikes using an implied volatility surface interpolated from traded option prices, and with these calls price a series of very tight overlapping butterfly spreads. Dividing the costs of these trades by their payoffs, and adjusting for the time value of money, yields the future probability distribution of the stock as priced by the options market.

We then take many overlapping butterflies, at very small intervals, across all strikes, and calculate their costs...

45 50 55 60 65
Last Price

… Butterflies near the last price are expensive (higher chance of ending up there), while butterflies in the wings are cheaper (lower chance of ending up there)

~0 1¢ 2¢ 3¢ 5¢ 7¢ 11¢ 13¢ 17¢ 14¢ 10¢ 7¢ 4¢ 3¢ 2¢ 1¢ ~0

45 50 55 60 65
Last Price

Note, adequate trading volume and liquidity is required to produce a volatility surface and price theoretical options. Therefore, options implied probabilities will not be available for all equities.