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FINANCIAL ECONOMICS

Peter Ireland

Boston College

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Using Options to Infer Contingent Claims Prices

Notice that call options often have payoff structures that resemble those of contingent claims: making positive payoffs in "good" states and expiring worthless in "bad" states.

Douglas Breeden (US, b.1950) and Robert Litzenberger (US, b.1943) devised a way of using option prices to infer contingent claims prices, allowing for many states of the world.

Douglas Breeden and Robert Litzenberger, "Prices of State-Contingent Claims Implicit in Option Prices," *Journal of Business* Vol.51 (October 1978): pp.621-651.

Using Options to Infer Contingent Claims Prices

Suppose there are N states, corresponding to different levels of the S&P 500, with

$$P^1 < P^2 < \ldots < P^N$$

and

$$P^{i+1} = P^i + \delta$$

with $\delta > 0$.

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For each state i, construct a "butterfly" portfolio of call options:

Buy one calls with strike price P^{i-1}

Write (sell short) two calls with strike price P^{i}

Buy one call with strike price P^{i+1}

If q_o^i is the price of an option with strike price P^i, this portfolio costs

$$q_o^{i-1} + q_o^{i+1} - 2q_o^i$$

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Now let's compute the portfolio's payoffs:

S&P 500	Long $K = P^{i-1}$	Short 2 $K = P^i$	Long $K = P^{i+1}$	Total
$P \leq P^{i-1}$	0	0	0	0
$P = P^i$	$P^i - P^{i-1}$	0	0	δ
$P \geq P^{i+1}$	$P - P^{i-1}$	$-2(P - P^i)$	$P - P^{i+1}$	0

$$
\begin{aligned}
& (P - P^{i-1}) - 2(P - P^i) + (P - P^{i+1}) \\
= \; & 2P^i - P^{i-1} - P^{i+1} \\
= \; & 2P^i - (P^i - \delta) - (P^i + \delta) = 0
\end{aligned}
$$

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$P \leq P^{i-1}$	0	0	0	0
$P = P^{i}$	$P^{i} - P^{i-1}$	0	0	δ
$P \geq P^{i+1}$	$P - P^{i-1}$	$-2(P - P^{i})$	$P - P^{i+1}$	0

Since the portfolio's payoffs replicate those from δ claims for state i, the price q_{cc}^{i} of a contingent claim for state i must satisfy

$$q_{cc}^{i} = (1/\delta)(q_{o}^{i-1} + q_{o}^{i+1} - 2q_{o}^{i})$$

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$$q_{cc}^i = (1/\delta)(q_o^{i-1} + q_o^{i+1} - 2q_o^i)$$

Additional accuracy can be achieved by choosing smaller values of δ, that is, by using a "finer grid" to define the states.

Options trade on the S&P 500 with many strike prices, so data on q_o^i are readily available.

Note that you don't have to actually trade the options to price the contingent claims.