SOME ASPECTS OF OPTION PRICING

Ph.D. seminar 16-11-2018

SOME ASPECTS OF OPTION PRICING

Idag = August 30, 2010. Photo: Yvonne Asell

-850.000.000 SEK

MARKET MODEL

Work on:
a filtered probability space $(\Omega, \mathcal{F}, \mathbb{F} := \{\mathcal{F}_t\}_{t\geq 0}, P)$, carrying an N-dimensional Brownian motion W. (source of randomness), satisfying the usual conditions.

MARKET MODEL

Work on:
a filtered probability space $(\Omega, \mathcal{F}, \mathbb{F} := \{\mathcal{F}_t\}_{t\geq 0}, P)$, carrying an N-dimensional Brownian motion W. (source of randomness), satisfying the usual conditions.

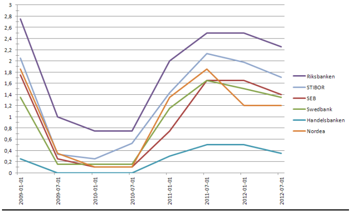
Two types of traded assets on our market:

Risk-free asset (bank account) B

$$dB(t) = r(t)B(t)dt$$

Risky assets (stocks) $S_1, \dots, S_N$

$$dS_i(t) = \mu_i(t, S_i(t))dt + \sigma_i(t, S_i(t))dW(t)$$



Let $T > 0$ and Φ be some $\mathcal{F}_T$-measurable function.

SOME ASPECTS OF OPTION PRICING

MARKET MODEL

<u>Work on:</u>
a filtered probability space $(\Omega, \mathcal{F}, \mathbb{F} := \{\mathcal{F}_t\}_{t\geq 0}, P)$, carrying an N-dimensional Brownian motion W. (source of randomness), satisfying the usual conditions.

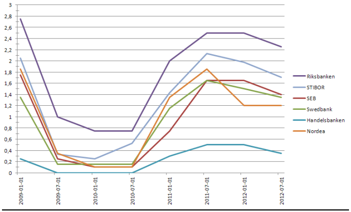
<u>Two types of traded assets on our market:</u>

Risk-free asset (bank account) B

$$dB(t) = r(t)B(t)dt$$

Risky assets (stocks) $S_1, \ldots, S_N$

$$dS_i(t) = \mu_i(t, S_i(t))dt + \sigma_i(t, S_i(t))dW(t)$$



Let $T > 0$ and Φ be some $\mathcal{F}_T$-measurable function.

What is the *fair price* of a T-payoff $\Phi(S(T))$ at time $t < T$?

SIMPLE MARKET MODEL WITH 2 TRADED ASSETS

Bank account with price process

$$dB_t = rB_t dt, \quad r \text{ deterministic constant.}$$

Stock with price process

$$dS_t = \alpha S_t dt + \sigma S_t dW_t, \quad \alpha, \sigma \text{ deterministic constants.}$$

SIMPLE MARKET MODEL WITH 2 TRADED ASSETS

Bank account with price process

$$dB_t = rB_t dt, \quad r \text{ deterministic constant.}$$

Stock with price process

$$dS_t = \alpha S_t dt + \sigma S_t dW_t, \quad \alpha, \sigma \text{ deterministic constants.}$$

What is the fair price (cost) of $\Phi(S(T)) := \max\{S(T) - K, 0\}$ at time $t \leq T$?

SIMPLE MARKET MODEL WITH 2 TRADED ASSETS

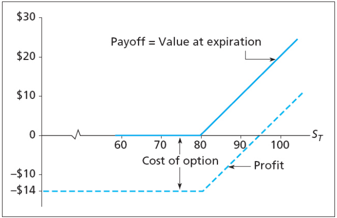
Bank account with price process

$$dB_t = rB_t dt, \quad r \text{ deterministic constant.}$$

Stock with price process

$$dS_t = \alpha S_t dt + \sigma S_t dW_t, \quad \alpha, \sigma \text{ deterministic constants.}$$

What is the fair price (cost) of $\Phi(S(T)) := \max\{S(T) - K, 0\}$ at time $t \leq T$?



$\max\{S(T) - K, 0\}$ is the payoff of a *call option* with maturity T and strike K.

SOME ASPECTS OF OPTION PRICING

From Politics, Aristotele (350 B.C.):

"... and Apollodorus of Lemnos have written about both agriculture and fruit-farming, and similarly others also on other topics, so these subjects may be studied from these authors by anybody concerned to do so; but in addition a collection ought also to be made of the scattered accounts of methods that have brought success in business to certain individuals. All these methods are serviceable for those who value wealth-getting, for example the plan of Thales of Miletus, which is a device for the business of getting wealth, but which, though it is attributed to him because of his wisdom, is really of universal application. Thales, so the story goes, because of his poverty was taunted with the uselessness of philosophy; but from his knowledge of astronomy he had observed while it was still winter that there was going to be a large crop of olives, so he raised a small sum of money and paid round deposits for the whole of the olive-presses in Miletus and Chios, which he hired at a low rent as nobody was running him up; and when the season arrived, there was a sudden demand for a number of presses at the same time, and by letting them out on what terms he liked he realized a large sum of money, so proving that it is easy for philosophers to be rich if they choose, but this is not what they care about."

Options were traded without standards/regulations until the crash of 1929.

CBOE
CHICAGO BOARD OPTIONS EXCHANGE

In 1973 the Chicago Board Options Exchange (CBOE) opened its doors. Call option trading on 16 stocks.

In 1973, Fischer Black and Myron Scholes published *The pricing of options and corporate liabilities*, putting forth a model for calculating the theoretical estimate of an options price over time (Nobel Prize in Economics in 1997).

The Pricing of Options and Corporate Liabilities

Fischer Black
University of Chicago
Myron Scholes
Massachusetts Institute of Technology

If options are correctly priced in the market, it should not be possible to make sure profits by creating portfolios of long and short positions in options and their underlying stocks. Using this principle, a theoretical valuation formula for options is derived. Since almost all corporate liabilities can be viewed as combinations of options, the formula and the analysis that led to it are also applicable to corporate liabilities such as common stock, corporate bonds, and warrants. In particular, the formula can be used to derive the discount that should be applied to a corporate bond because of the possibility of default.

In 1982, 500'000 contracts were traded in one day on CBOE.

In 2014, an average of 16'900'000 contracts were traded per day on CBOE.

AN EXPLICIT PRICE FORMULA

Recall the simple market model, the *Black-Scholes model*. Assume that the price of Φ is a smooth function of time and underlying,

$$\text{Price}(t; \Phi(S(T))) = F(t, S(t)).$$

AN EXPLICIT PRICE FORMULA

Recall the simple market model, the *Black-Scholes model*. Assume that the price of Φ is a smooth function of time and underlying,

$$\mathrm{Price}(t; \Phi(S(T))) = F(t, S(t)).$$

We can *replicate* this price process by buying a certain amount of stocks, and putting a certain amout of money in the bank. This procedure, *hedging*, leads to the Black-Scholes equation:

$$\begin{cases} F_t + rsF_s + \frac{1}{2}s^2\sigma^2 F_{ss} - rF = 0, \\ F(T, s) = \Phi(s). \end{cases} \tag{BS-EQ}$$

AN EXPLICIT PRICE FORMULA

Recall the simple market model, the *Black-Scholes model*. Assume that the price of Φ is a smooth function of time and underlying,

$$\mathrm{Price}(t; \Phi(S(T))) = F(t, S(t)).$$

We can *replicate* this price process by buying a certain amount of stocks, and putting a certain amout of money in the bank. This procedure, *hedging*, leads to the Black-Scholes equation:

$$\begin{cases} F_t + rsF_s + \frac{1}{2}s^2\sigma^2 F_{ss} - rF = 0, \\ F(T, s) = \Phi(s). \end{cases} \tag{BS-EQ}$$

For $\Phi(s) = \max\{s - K, 0\}$, (BS-EQ) has the explicit solution $F(t, S(t)) =$

$$C_{BS}(t, S(t); \sigma, r, T, K) = S(t)\mathcal{N}(d_1) - e^{-r(T-t)}K\mathcal{N}(d_2),$$

$$d_1 := \frac{1}{\sigma\sqrt{T-t}}\Big(\ln(S(t)/K) + (r + \sigma^2/2)(T-t)\Big),$$

$$d_2 := d_1 - \sigma\sqrt{T-t}.$$

$$\mathcal{N}(x) := \frac{1}{\sqrt{2\pi}}\int_{-\infty}^{x} \exp\left(-\frac{1}{2}\theta^2\right) d\theta.$$


"All the News That's Fit to Print"

The New York Times

Late Edition

VOL. CXXXVII . . . No. 47,298 NEW YORK, TUESDAY, OCTOBER 20, 1987 30 CENTS

STOCKS PLUNGE 508 POINTS, A DROP OF 22.6%;
604 MILLION VOLUME NEARLY DOUBLES RECORD

U.S. Ships Shell Iran Installation In Gulf Reprisal

Offshore Target Termed a Base for Gunboats

By STEVEN V. ROBERTS

A Huge Blow to the Five-Year Bull Market

Dow's Record Fall

WORLDWIDE IMPACT

Frenzied Trading Raises Fears of Recession — Tape 2 Hours Late

By LAWRENCE J. DE MARIA

Does 1987 Equal 1929?

By ERIC GELMAN


THE TIMES

TUESDAY OCTOBER 20 1987

Dow Jones crashes 508 points: City wipes £50bn off shares

Wall Street's blackest hours

By Kenneth Fleet

Yuppies aghast at end of boom

BP shares below offer price

Monday October 19, 1987, NYSE falls $> 20\%$ in one day.

"What we did is rely on experience. And all science is based on experience. And if you're not willing to draw any conclusions from experience, you might as well sit on your hands and do nothing." - Trader

IMPLIED VOLATILITY

Observed call option market prices C_i on underlying $S(t)$, with parameters (r, T_i, K_i), $i = 1, \ldots, N$. Volatility σ not observable.

Black-Scholes implied volatility σ_{BS} solves the implicit equation

$$C_i = C_{BS}(t, S(t); \sigma_{BS}, r, T_i, K_i).$$

Laughter in the Dark - The Problem of the Volatility Smile, Emanuel Derman May 26, 2003

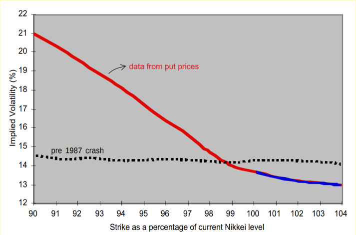
IMPLIED VOLATILITY

Observed call option market prices C_i on underlying $S(t)$, with parameters (r, T_i, K_i), $i = 1, \ldots, N$. Volatility σ not observable.

Black-Scholes implied volatility σ_{BS} solves the implicit equation

$$C_i = C_{BS}(t, S(t); \sigma_{BS}, r, T_i, K_i).$$

FIGURE 1. A typical implied volatility smile for the three-month options on the Nikkei index in late 1994. The dotted line shows the lack of skew that was common prior to the 1987 crash.



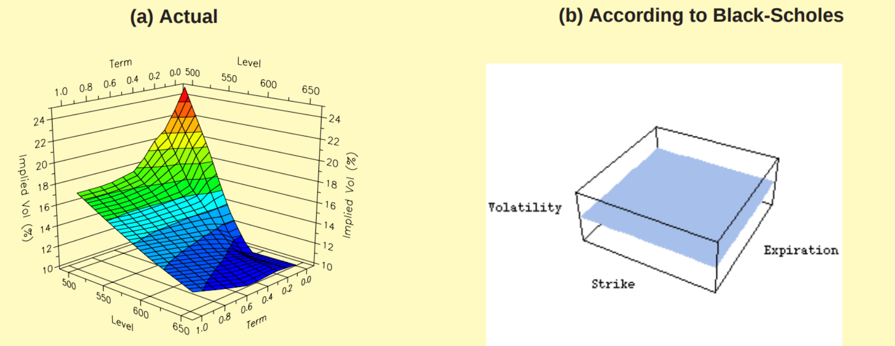
σ_{BS} was not (T_i, K_i)-dependent pre-1987!

Laughter in the Dark - The Problem of the Volatility Smile, Emanuel Derman May 26, 2003

IMPLIED VOLATILITY

"is the wrong number to put in the wrong formula to get the right price" - Rebonato

FIGURE 2. The implied volatility surface for S&P 500 options



Post 1987, jump-type events (long-run risk) are included in the valuation of options, yielding a skewed volatility surface.

PARAMETRIZATION OF THE BS-IV SURFACE

Misspriced options introduce *arbitrage possibilities* on the market.

Some lingo from financial mathematics

Portfolio: $(h_B, h_1, \dots, h_N)$ units of $(B, S_1, \dots, S_N)$, with value process

$$V^h(t) = h_B(t)B(t) + \sum_{i=1}^{N} h_i(t)S_i(t), \quad t \geq 0.$$

Self-financing portfolio: no cash infusions, all gains are reinvested, i.e.

$$dV^h(t) = h_B(t)dB(t) + \sum_{i=1}^{N} h_i(t)dS_i(t).$$

Arbitrage possibility: the existence of a self-financing portfolio h such that

$$V^h(0) = 0, \quad P(V^h(T) \geq 0) = 1, \quad P(V^h(T) > 0) > 0.$$

Equivalent martingale measure (EMM): a measure, equivalent to the *real-world measure* P, under which all *normalized price processes* on the market are *local martingales*.

Theorem (Folk theorem)

The model is arbitrage free essentially if and only if there an EMM Q.

I: Existence of an EMM Q implies absence of arbitrage.
EMM propertyof Q yields

$$dB(t) = 0, \quad dS_i(t) = S_i(t)\sigma_i(t)dW^Q(t), \quad i = 1, \dots, N. \tag{1}$$

Assume some self-financing proces h is bounded and satisfies

$$P(V(T;h) \geq 0) = 1, \quad P(V(T;h) > 0) > 0. \tag{2}$$

Want to show that $V(0;h) > 0$. Since $Q \sim P$,

$$Q(V(T;h) \geq 0) = 1, \quad Q(V(T;h) > 0) > 0. \tag{3}$$

Since h is self-financing,

$$dV(t;h) = \sum_{i=1}^{N} h_i(t)S_i(t)\sigma_i(t)dW^Q(t) \Rightarrow V(\cdot;h) \text{ is a } Q\text{-martingale!} \tag{4}$$

So $V(0;h) = E^Q[V(T;h)] > 0$, proving non-existence of a bounded arbitrage portfolio.

Theorem (Folk theorem)

The model is arbitrage free essentially if and only if there exists a (local) martingale measure Q.

II: Absence of arbitrage implies existence of an EMM Q.
$\mathcal{K}_0 :=$ set of claims reachable by a self-financed portfolio at zero initial cost.

$$\begin{aligned} \mathcal{K} &:= \mathcal{K}_0 \cap L^\infty(\Omega, \mathcal{F}_T, P), \\ L^\infty_+ &:= \text{nonnegative random variables in } L^\infty(\Omega, \mathcal{F}_T, P), \\ \mathcal{C} &:= \mathcal{K} - L^\infty_+. \end{aligned} \tag{5}$$

$\mathcal{C} =$ set of all claims dominated by the bounded claims in $\mathcal{K}_0$. Hence $\mathcal{C}$ can be reached by self-financing portfolio with zero initial cost if you also allow yourself to throw away money.

Theorem (Folk theorem)

The model is arbitrage free essentially if and only if there exists a (local) martingale measure Q.

II: Absence of arbitrage implies existence of an EMM Q.
$\mathcal{K}_0 :=$ set of claims reachable by a self-financed portfolio at zero initial cost.

$$\begin{aligned} \mathcal{K} &:= \mathcal{K}_0 \cap L^\infty(\Omega, \mathcal{F}_T, P), \\ L^\infty_+ &:= \text{nonnegative random variables in } L^\infty(\Omega, \mathcal{F}_T, P), \\ \mathcal{C} &:= \mathcal{K} - L^\infty_+. \end{aligned} \tag{5}$$

$\mathcal{C}$ = set of all claims dominated by the bounded claims in $\mathcal{K}_0$. Hence $\mathcal{C}$ can be reached by self-financing portfolio with zero initial cost if you also allow yourself to throw away money.

No arbitrage:

$$\mathcal{C} \cap L^\infty_+ = \{0\}. \tag{6}$$

$\mathcal{C}$ and L^∞_+ convex sets in $L^\infty(\Omega, \mathcal{F}_T, P)$ with one point in common...separation by variable in L^1 available? This would be a candidate measure, since the Radon-Nikodym derivative L (taking P to Q) should be in $L^1(\Omega, \mathcal{F}_T, P)$.

Definition (NFLVR)

No Arbitrage (NA) if $\mathcal{C} \cap L_+^\infty = \{0\}$.
No Free Lunch with Vanishing Risk (NFLVR) if $\bar{\mathcal{C}} \cap L_+^\infty = \{0\}$.

Put the weak*-topology, generated by $L^1(\Omega, \mathcal{F}_T, P)$, on $L^\infty(\Omega, \mathcal{F}_T, P)$. Then the dual of $L^\infty(\Omega, \mathcal{F}_T, P)$ is $L^1(\Omega, \mathcal{F}_T, P)$.

Definition (NFLVR)

No Arbitrage (NA) if $\mathcal{C} \cap L^\infty_+ = \{0\}$.
No Free Lunch with Vanishing Risk (NFLVR) if $\bar{\mathcal{C}} \cap L^\infty_+ = \{0\}$.

Put the weak*-topology, generated by $L^1(\Omega, \mathcal{F}_T, P)$, on $L^\infty(\Omega, \mathcal{F}_T, P)$. Then the dual of $L^\infty(\Omega, \mathcal{F}_T, P)$ is $L^1(\Omega, \mathcal{F}_T, P)$.

Theorem (Kreps-Yan Separation Theorem)

If $\mathcal{C}$ is weak*-closed, and if $\mathcal{C} \cap L^\infty_+ = \{0\}$, then there exists a random variable $L \in L^1(\Omega, \mathcal{F}_T, P)$ such that L is P-a.s. strictly positive and $E^P[L \cdot X] \leq 0$ for all $X \in \mathcal{C}$.

Weak*-closedness of $\mathcal{C}$ is granted by (NFLVR) whenever all price processes are uniformly bounded!

Note that L can be used to define a new measure Q by $dQ := L dP$ on $\mathcal{F}_T$.

Theorem 1.1 (Main theorem) *Let S be a bounded real valued semi-martingale. There is an equivalent martingale measure $\mathbf{Q}$ for S if and only if S satisfies* (NFLVR).

Proof. We proceed on a well known path (Delbaen (1992), Mc Beth (1992), Schachermayer (1992), Stricker (1990), Lakner (1992), Kreps (1978)). Since S satisfies (NA) we have $C \cap L^\infty_+ = \{0\}$. Because C is weak* closed in L^∞ we know that there is an equivalent probability measure $\mathbf{Q}$ such that $\mathbf{E}_\mathbf{Q}[f] \leqq 0$ for each f in C. This is precisely the Kreps-Yan separation theorem, for a proof of which we refer to Schachermayer (1993, Theorem 3.1). For each $s < t$, $B \in \mathscr{F}_s$, $\alpha \in \mathbf{R}$ we have $\alpha(S_t - S_s)\mathbf{1}_B \in C$ (S is bounded!). Therefore $\mathbf{E}_\mathbf{Q}[(S_t - S_s)\mathbf{1}_B] = 0$ and $\mathbf{Q}$ is a martingale measure for S.

Delbaen, F. and Schachermayer, W., 1994. A general version of the fundamental theorem of asset pricing. Mathematische annalen, 300(1), pp.463-520.

Theorem 1.1 (Main theorem) *Let S be a bounded real valued semi-martingale. There is an equivalent martingale measure $\mathbf{Q}$ for S if and only if S satisfies* (NFLVR).

Proof. We proceed on a well known path (Delbaen (1992), Mc Beth (1992), Schachermayer (1992), Stricker (1990), Lakner (1992), Kreps (1978)). Since S satisfies (NA) we have $C \cap L^{\infty}_{+} = \{0\}$. Because C is weak* closed in L^{∞} we know that there is an equivalent probability measure $\mathbf{Q}$ such that $\mathbf{E}_{\mathbf{Q}}[f] \leqq 0$ for each f in C. This is precisely the Kreps-Yan separation theorem, for a proof of which we refer to Schachermayer (1993, Theorem 3.1). For each $s < t$, $B \in \mathscr{F}_s$, $\alpha \in \mathbf{R}$ we have $\alpha(S_t - S_s)\mathbf{1}_B \in C$ (S is bounded!). Therefore $\mathbf{E}_{\mathbf{Q}}[(S_t - S_s)\mathbf{1}_B] = 0$ and $\mathbf{Q}$ is a martingale measure for S.

This result opens up the world of risk-neutral valuation!

Theorem

The price at time $t \in [0, T]$ of a claim $\mathcal{X}$ with maturity T satisfies

$$\frac{Price(t;\mathcal{X})}{B(t)} = E^{Q}\left[\frac{\mathcal{X}}{B(T)} \mid \mathcal{F}_t\right] \tag{7}$$

Delbaen, F. and Schachermayer, W., 1994. A general version of the fundamental theorem of asset pricing. Mathematische annalen, 300(1), pp.463-520.

PARAMETRIZATION OF THE BS-IV SURFACE

For a call option in the Black-Scholes model,

$$\begin{aligned} C(t,s;\sigma,r,T,K) &= e^{-r(T-t)}E^{Q}\left[\max\{S(T)-K,0\} \mid \mathcal{F}_t\right] \\ &= e^{-r(T-t)}\int_{\mathbb{R}} max\{s-K,0\}q_t(ds) \end{aligned} \tag{8}$$

Differentiation yields $\partial_{KK}C(t,s;\sigma,r,T,K)=q_t(S(t))$.

Convexity of C in K is necessary for no arbitrage!

PARAMETRIZATION OF THE BS-IV SURFACE

For a call option in the Black-Scholes model,

$$\begin{aligned} C(t, s; \sigma, r, T, K) &= e^{-r(T-t)} E^{Q}\left[\max\{S(T) - K, 0\} \mid \mathcal{F}_t\right] \\ &= e^{-r(T-t)} \int_{\mathbb{R}} max\{s - K, 0\} q_t(ds) \end{aligned} \tag{8}$$

Differentiation yields $\partial_{KK} C(t, s; \sigma, r, T, K) = q_t(S(t))$.

Convexity of C in K is necessary for no arbitrage!

Example (SSVI parameterization)

Let $\tau = T - t$ and $w(\tau, x) = \tau\sigma^2(S_\tau/K)$ and

$$w^{\mathrm{SSVI}}(\tau, x) = \frac{\theta_\tau}{2}\left(1 + \rho\phi(\theta_\tau)x + \sqrt{(\phi(\theta_\tau)x + \rho)^2 + (1 - \rho^2)}\right). \tag{9}$$

This *implied total variance* surface yields call option prices free of arbitrage if

$$\begin{aligned} &\theta_\tau\phi(\theta_\tau)(1 + |\rho|) < 4, \qquad \theta_\tau\phi(\theta_\tau)^2(1 + |\rho|) \le 4, \\ &\partial_\tau\theta_\tau \ge 0, \qquad 0 \le \partial_{\theta_\tau}\left(\theta_\tau\phi(\theta_\tau)\right) \le \frac{1}{\rho^2}\left(1 + \sqrt{1 - \rho^2}\right)\phi(\theta_\tau) \end{aligned}$$

SOME ASPECTS OF OPTION PRICING

BS-IV AS MARKET EXPECTATION OF FUTURE RISK

The Implied Volatility Surface **31**

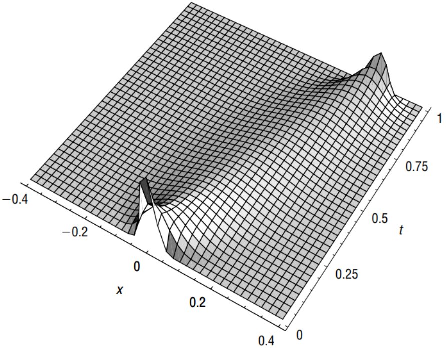


FIGURE 3.1 Graph of the pdf of x_t conditional on $x_T = \log(K)$ for a 1-year European option, strike 1.3 with current stock price = 1 and 20% volatility.

In words, equation (3.11) says that the Black-Scholes implied variance of an option with strike K is given approximately by the integral from valuation date ($t = 0$) to the expiration date ($t = T$) of the local variances along the path $\tilde{x}_t$ that maximizes the Brownian Bridge density $q\,(x_t, t; x_T, T)$.

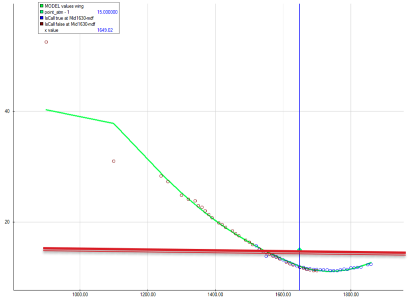
Gatheral, J., 2011. The volatility surface: a practitioner's guide (Vol. 357). John Wiley & Sons.

BS-IV AS MARKET EXPECTATION OF FUTURE RISK

Prior to August 2010, HQ Bank used the following idea in trading:

Expected future risk $\approx$ historical risk (*)

Historical volatility flat line vs market



If we believe in (*), then some options are misspriced on the market.

BS-IV AS MARKET EXPECTATION OF FUTURE RISK

frank ADVOKATBYRÅ

HQ AB sakframställan

Del 6 – Bristerna i Bankens värderingsmetod

1

Värdering i finansiell rapportering

- Enligt Tradinginstruktionen skulle framräknat teoretiskt värde för optionerna ligga till grund för bokföring och resultatberäkning
- Det teoretiska värdet beräknades i ORC
- I slutet av varje månad fördes Tradings värderingar i ORC in i huvudboken
  - Det var alltså Tradings värdering av Tradingportföljen den sista dagen i varje kvartal och år som flöt in i den finansiella rapporteringen (notera dock årsredovisningarna 2007)
  - HQ AB och Banken gjorde inga reserveringar utan den teoretiska värderingen resultatfördes

→ Tradings värderingsmetod var inte förenlig med IAS 39 (marknadens prisbild, aktiv marknad, transaktionspriset, observerbara belägg, kalibrering, smile/skew)

19

Who decides what the correct price is after an option has been bought?

What is a "Day 1"-result?

Acceptable to have different price methods and hence profit/loss statements for traders, risk, accounting, board, public?

frank
ADVOKATBYRÅ

-850.000.000 SEK

AFTERMATH

Finansinspektionen immediately withdraws HQ Bank's bank permit.

HQ Bank is liquidated and sold to Carnegie. HQ AB widthrawn from Nasdaq OMX, but still traded on Aktietorget (smaller Stockholm based exchange).

HQ AB's only area of activity is from this point on to press changes on past employees.

Old board in court 2016 against Swedish Economic Crime Authority. Charges on accounting fraud and illegal valuation methods of the trading portfolio. Owners acquitted.

Owners board before court again 2017 against the new owners of HQ AB, who claimed damages of 4 billion SEK (incl. interest). Owners acquitted, new owners had to liquidate HQ AB to pay 262 million SEK of legal expenses.

Case appealed to highest Swedish court July 2018. "Högsta domstolen" closed the case.

- 2011: "Den stora bankhärvan : finansparet Hagströmers och Qvibergs uppgång och fall".
- 2017: "HQ Gate". Author and journalist Jenny Hedelin quit working, after 13 years, at Dagens Industri due to things she wrote in the book.

SUMMARY

Theoretical pricing of options

- Black-Scholes model
- Risk-neutral valuation

Market model calibration

- Challanges with IV parametrization

Implementation of option trading strategies

- Long-term risk
- Data based strategies

THANK YOU!