Ivy DB

File and Data Reference Manual

Version 3.0

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Chapter 1. Introduction

Ivy DB is a comprehensive database of historical price, implied volatility, and sensitivity information for the entire US listed index and equity options markets. The product has been designed to provide data of the highest obtainable quality, suitable for empirical and/or econometric studies of the options markets, development and testing of option trading strategies, and options research support. Ivy DB includes historical data for all US listed equities and market indices and all US listed index and equity options from 1996 till present. Ivy DB data files are updated nightly to reflect new closing prices, dividend payments or other corporate actions, and option contract expirations, new listings, or other changes.

OptionMetrics compiles the Ivy DB data from raw 3:59PM EST price information provided by Spryware, LLC. This raw data is edited and organized to facilitate its use in options market research. Interest rate curves, dividend projections, and option implied volatilities and sensitivities are calculated by OptionMetrics using our proprietary algorithms, which are based on standard market conventions.

Chapter 2. File Formats

The data within Ivy DB is organized in several files:

- Security file (IVYSECUR.yyyymmddD.txt)
- Security_Name file (IVYSECNM.yyyymmddD.txt)
- Exchange file (IVYEXCHG.yyyymmddD.txt)
- Distribution file (IVYDISTR.yyyymmddD.txt)
- Security_Price file (IVYSECPR.yyyymmddD.txt)
- Option_Info file (IVYOPINF.yyymmddD.txt)
- Option_Price file (IVYOPPRC.yyyymmddD.txt)
- Zero_Curve file (IVYZEROC.yyyymmddD.txt)
- Index_Dividend file (IVYIDXDV.yyyymmddD.txt)
- Std_Option_Price file (IVYSTDOP.yyyymmddD.txt)
- Option_Volume file (IVYOPVOL.yyyymmddD.txt)
- Volatility_Surface file (IVYVSURF.yyyymmddD.txt)
- Historical_Volatility file (IVYHVOL.yyyymmddD.txt)
- Open_Interest file (IVYOPTOI.txt)

Files are produced nightly in a tab-delimited format. Security, Security_Name, Exchange, Distribution and Option_Info files contain a full copy of the tables by the same name. Therefore these particular five tables are being truncated during the nightly data load processes.

In the descriptions below, the layout of each file is shown, giving the data type, maximum field length (for character fields) and the field name. All dates are given in YYYYMMDD format. The primary key (unique fields) for each file is shown in **bold**.

Security File

The Security file contains information on all equity and index securities known to Ivy DB.

File layout

Data type	Length	Field Name
integer	-	**Security ID**
char	8	CUSIP
char	6	Ticker
char	4	SIC
char	1	Index Flag
integer	-	Exchange Flags
char	1	Class
char	1	Issue Type **
char	3	Industry Group **

** Columns added in Version 2.5

Field descriptions

Security ID

The Security ID is the unique identifier for this security. Unlike CUSIP numbers and ticker symbols, Security ID's are unique over the security's lifetime and are not recycled. The Security ID is the primary key for all data contained in Ivy DB.

CUSIP

The first 8 digits of the security's current CUSIP number

Ticker

Ticker is the security's current ticker symbol. For stocks with multiple classes, this field contains only the base of the complete ticker. For example, NYSE tickers BKS.A and BKS.B would both contain BKS in the ticker field. Class indicators are stored in the Class field.

SIC

The security's SIC code

Index Flag

This flag indicates whether the security is an index. It is set to '1' if the security is an index and to '0' otherwise.

Exchange Flags

A field indicating the current primary exchange for the security:

`00000` – Currently delisted
`00001` – NYSE/ARCA
`00002` – AMEX
`00004` – NASDAQ National Markets System
`00008` – NASDAQ Small Cap
`00016` – OTC Bulletin Board
`32768` – The security is an index

Class

The class designator, if any, of the security on the effective date

Issue Type

The type of security:
`0` – Common Stock
`A` – Market index
`7` – Mutual or investment trust fund
`F` – ADR/ADS
`%` – Exchange-traded fund
(blank) – Unspecified

Industry Group

IndustryGroup field is a 3-digit classification code for the security in the North American Industry Groups database provided by MorningStar, LLC. The first digit represents the security's macroeconomic sector classification; the second digit represents the security's business segment; and the third digit represents the security's industry group.

A complete listing of the MG Sector Classification Code is given in Appendix A.

Security_Name File

The Security_Name file contains a historical record of changes to the ticker, issuer and issue descriptions, and CUSIP's for a security.

File layout

Data type	Length	Field Name
integer	-	**Security ID**
date	-	**Date**
char	8	CUSIP
char	6	Ticker
char	1	Class
char	28	Issuer Description
char	20	Issue Description
char	4	SIC

Field descriptions

Security ID
The Security ID for the security

Date
The effective date of the change

CUSIP
The first 8 digits of the security's CUSIP as of the effective date

Ticker
The base portion of the security's ticker on the effective date

Class
The class designator, if any, of the security on the effective date

Issuer Description
A description of the issuing company or entity

Issue Description
A description of the particular issue

SIC
The SIC code for the security

Notes

All securities have at least one Security Name record dating from the start of the historical record, containing the security's ticker, CUSIP, and descriptive information as of the starting date of Ivy DB.

Exchange File

The Exchange file contains a historical record of changes to the active exchange for a security, and new listing and delisting information.

File layout

Data Type	Length	Field Name
integer	-	**Security ID**
date	-	**Date**
integer	1	**Sequence Number**
char	1	Status
char	1	Exchange
char	1	Add/Delete (Indicator)
integer	-	Exchange Flags

Field descriptions

Security ID

The Security ID for the security.

Date

The effective date of the exchange change

Sequence Number

A unique integer, starting from 1, to distinguish between multiple exchange changes occurring on the same day.

Status

The change in the status of the security that generated the exchange record:

`$` – Initial entry (start of historical record)
`A` – The security is inactive (no longer being priced)
`C` – The security has been purged due to inactivity
`D` – The security has been delisted
`E` – The security's exchange has changed
`N` – The security has been newly listed (but not yet priced)
`S` – Trading in the security has been suspended
`X` – Security is inactive due to an acquisition or merger
`3` – The security has been reactivated, and this is the first day priced
`4` – The security is new, and this is the first day priced

5 – Matured, called or expired

Exchange

The exchange added or deleted
A – NYSE
B – AMEX
F – NASDAQ National Market System
G – Index
H – NASDAQ Small Cap
O – OTC Bulletin Board
% - Other OTC
? - Exchange not known
D - Chicago Stock Exchange
E - ARCA Stock Exchange
J - Toronto Stock Exchange
K - Montreal Stock Exchange
N - Archipelago/Pacific Exchange (ARCA)
T - Boston Stock Exchange
U - Non-NASDAQ OTC
V - Canadian Venture Exchange (CDNX)
X - OTC Equipment Trust

Add/Delete

* – Exchange was added
(blank) – Exchange was deleted

Exchange Flags

The primary exchange for the issue, after the change:
00000 – Currently delisted
00001 – NYSE/ARCA
00002 – AMEX
00004 – NASDAQ National Markets System
00008 – NASDAQ Small Cap
00016 – OTC Bulletin Board
32768 – The security is an index

Notes

All securities have at least one Exchange record dating from the start of the historical record, with status '$', containing the security's exchange listing information as of the starting date of Ivy DB.

Distribution File

The Distribution file contains information on a security's distributions and splits*.

File layout

Data Type	Length	Field Name
integer	-	**Security ID**
date	-	**Record Date**
integer	-	**Sequence Number**
date	-	Ex Date
real	-	Amount
real	-	Adjustment Factor
date	8	Declare Date
date	8	Payment Date
integer	-	Link Security ID
char	1	Distribution Type
char	1	Frequency
char	3	Currency
char	1	Approximate flag
char	1	Cancel flag
char	1	Liquidation flag

* Do not use the Distribution File for Market Indices

Field descriptions

Security ID

The Security ID for the security

Record Date

The record date for the distribution

Sequence Number

A unique integer, starting from 1, to distinguish between multiple distributions with the same record date

Ex Date

The ex-distribution or ex-dividend date

Amount

The dollar amount of the cash distribution if the distribution was announced; yield if the dividend is projected (The dividend is projected when the Distribution Type is %)

Adjustment Factor

The adjustment to the security's price that is required to compare pre-distribution to post-distribution prices

Declare Date

The declaration date for the distribution (if available)

Payment Date

The payment date for the distribution

Link Security ID

For mergers and acquisitions LinkSecurityID is the Security ID corresponding to the equity of the acquiring company. For spin-offs, it is the Security ID of the spun-off security.

Distribution Type

The type of distribution:
`0` – Unknown or not yet classified
`1` – Regular dividend
`2` – Split
`3` – Stock dividend
`4` – Capital gain distribution
`5` – Special dividend
`6` – Spin-off
`7` – New equity issue (same company)
`8` – Rights offering
`9` – Warrants issue
`%` – Regular dividend projection

Frequency

Payment frequency:
`0` – Dividend omitted
`1` – Annual
`2` – Semiannual
`3` – Quarterly
`4` – Monthly
`5` – Frequency varies
`blank` – Not available

Currency

The ISO code for currency of the cash distribution

Approximate flag

`0` – Amount field is exact
`1` – Amount field is approximate

Cancel flag

`0` – The distribution was or will be made as scheduled

1 – The distribution was cancelled, or a regular payment was omitted

Liquidation Flag

0 – The distribution is a non-liquidating distribution

1 – The distribution is either a partial or total liquidating distribution

Security_Price File

The Security_Price file contains the price history for the security.

File layout

Data Type	Length	Field Name
integer	-	**Security ID**
date	-	**Date**
real	-	Bid/Low
real	-	Ask/High
real	-	Close Price
large integer	-	Volume
real	-	Total Return
real	-	Adjustment Factor
real	-	Open Price
integer	-	Shares Outstanding **
real	-	Adjustment Factor 2 **

** Column added in Version 2.5

Field descriptions

Security ID

The Security ID for the security.

Date

The date for this price record

Bid/Low

If this field is positive, then it is the low price for the security on this date. If it is negative, there was no trading on this date, and the field represents the closing bid price for the security.

Ask/High

If this field is positive, then it is the high price for the security on this date. If it is negative, there was no trading on this date, and the field represents the closing ask price for the security.

Close Price

If this field is positive, then it is the closing price for the security on this date. If it is negative, then it is the average of the closing bid and ask prices for the security on this date. In case there are no valid bid or ask for the day, the record does not appear in the table at all.

Volume

Volume field is set to the sum of volumes on all exchanges where the security traded given day.

Total Return

The holding period return for this security, from the last good pricing date to this date. The holding period return is calculated as the total price appreciation for the security over the holding period (adjusted for splits and other price factor changes) plus the cash value of any distributions which go ex-dividend during the holding period, divided by the security's last available closing price (or bid-ask midpoint).

Adjustment Factor (Cumulative Adjustment Factor)

This is the cumulative product of all the adjustment factors for this security as of this date. When a security is first listed, its Cumulative Adjustment factor is set to 1.0. For all subsequent dates, the Cumulative Adjustment Factor is the product of all non-zero Adjustment Factors from the Distribution file having ex-date prior or equal to the date of this price. For example, if a security has a 2-for-1 split on day T1 and a 3-for-1 split on day T2, the initial adjustment factor of 1 would become 2 on T1, and 6 on T2. If there is a subsequent 3-for-2 split on day T3, the cumulative adjustment factor would become 9. To calculate an adjusted close price for a security on a given day, multiply the Close Price by the Cumulative Adjustment Factor on that day and divide by the value of the Cumulative Adjustment Factor for this security as of today (i.e., the last date in the Security Price file for this security).

Open Price

The opening price for this security, if available (equal to 0 if there is no opening price).

Shares Outstanding

The total number of a company's publicly traded shares divided by 1000 and lagged by one business day. For ADRs the number represents the total shares outstanding of the foreign security.

Adjustment Factor 2 (Cumulative Total Return Factor)

Similar to the Cumulative Adjustment Factor, but includes the effect of dividends and spin-offs. When a security is first listed, its Cumulative Total Return factor is set to 1.0. To calculate an adjusted close price for a security on a given day including dividends, multiply the Close Price by the Cumulative Total Return Factor on that day and divide

by the value of the Cumulative Total Return Factor for this security as of today (i.e., the last date in the Security Price file for this security).

Option_Info File

The Option_Info file contains information about the options for an underlying security.

File layout

Data Type	Length	Field Name
integer	-	**Security ID**
char	1	Dividend Convention
char	1	Exercise Style
integer	-	AM Settlement Flag **

** Column added in Version 2.5

Field descriptions

Security ID

The Security ID for the underlying security

Dividend Convention

The method of incorporating dividends into the option calculations:
`(blank)` – Discrete dividend payments, constant projected dividend yield
? – Unknown or not yet classified
`I` – Continuous implied dividend yield
`F` – Options on futures

Exercise Style

`A` – American
`E` – European
`?` – Unknown or not yet classified

AM Settlement Flag

`0` – options on the security expire at the market close of the last trading day
`1` –options on the security expire at the market open of the last trading day

In other words, if an option is AM settled, as most cash-settled index option classes are**,** we use one less day than we use for PM-settled options to count days to expiration.

Option_Price File

The Option_Price file contains the historical price, implied volatility, and sensitivity information for the options on an underlying security.

File layout

Data Type	Length	Field Name
integer	-	Security ID
date	-	**Date**
char	21	**Symbol**
char	1	**Symbol Flag**
integer	-	Strike
date	-	Expiration
char	1	Call/Put
real	-	Best Bid
real	-	Best Offer
date	-	Last Trade Date
integer	-	Volume
integer	-	Open Interest
char	1	Special Settlement
real	-	Implied Volatility
real	-	Delta
real	-	Gamma
real	-	Vega
real	-	Theta
integer	-	Option ID
integer	-	Adjustment Factor

Field descriptions

Security ID

The Security ID for the underlying security

Date

The date of this price

Symbol

The option symbol

Symbol Flag

The flag is set to 0 for the old option notation (i.e. root and suffix) and it is set to 1 if the symbol is the new OSI symbol.

Strike

The strike price of the option times 1000.

Expiration

The expiration date of the option

Call/Put

`C` – Call

`P` – Put

Best Bid

The best, or highest, closing bid price across all exchanges on which the option trades for the records dated March 4th 2008 and older. The best, or highest, 15:59 EST bid price across all exchanges on which the option trades for the records dated March 5th 2008 till present.

Best Offer

The best, or lowest, closing ask price across all exchanges on which the option trades for the records dated March 4th 2008 and older. The best, or lowest, 15:59 EST ask price across all exchanges on which the option trades for the records dated March 5th 2008 till present.

Last Trade Date

The date on which the option last traded

Volume

The total volume of option contracts

Open Interest

This is the open interest for the option, i.e. number of contracts outstanding. Open interest is lagged by one-day after November 28th, 2000. Prior to this date, the open interest is **not** lagged. Open Interest file with updated values is posted on the following morning (see Open_Interest file specs).

Special Settlement

`0` – The option has a standard settlement (100 shares of underlying security are to be delivered at exercise; the strike price and premium multipliers are $100 per tick).

`1` – The option has a non-standard settlement. The number of shares to be delivered may be different from 100 (fractional shares); additional securities and/or cash may be required; and the strike price and premium multipliers may be different than $100 per tick.

`E` – The option has a non-standard expiration date. This is usually due to an error in the historical data which has not yet been researched and fixed.

Implied Volatility

This is the calculated implied volatility of the option. Implied volatilities are not calculated for options with non-standard settlement.

Delta

Delta of an option indicates the change in option premium for a $1.00 change in underlying price.

Gamma

The gamma of an option indicates the absolute change in Delta for a $1.00 change in underlying price.

Vega (Kappa)

The vega/kappa of an option indicates the change in option premium, in cents, for one percentage point change in volatility.

Theta

The theta of an option indicates the change in option premium as time passes, in terms of dollars per year.

Option ID

Option ID is a unique integer identifier for the option contract. This identifier can be used to track specific option contracts over time.

Adjustment Factor

This is the cumulative product of all the adjustment factors for this option as of this date. When an option is first listed, its adjustment factor is set to 1. For all subsequent dates, the Adjustment Factor is the product of all non-zero Adjustment Factors from the Distribution file having ex-date prior or equal to the date of this price which result in an adjustment in the number of option contracts held.

Zero_Curve File

The Zero_Curve file contains the current zero-coupon interest rate curve used by Ivy DB.

File layout

Datatype	Length	Field Name
date	-	**Date**
integer	-	**Days**
real	-	Rate

Field descriptions

Date

The date of this zero curve

Days

The number of days to maturity

Rate

The continuously-compounded zero-coupon interest rate

Index_Dividend file

The Index_Dividend file contains the current dividend yield used for implied volatility calculations on index options.

File layout

Data Type	Length	Field Name
integer	-	**Security ID**
date	-	**Date**
real	-	Rate

Field descriptions

Security ID

The Security ID of the underlying index

Date

The date of this dividend yield

Rate

The annualized dividend yield

Std_Option_Price file

The Std_Option_Price file contains information on "standardized" (interpolated) options. Currently, this file contains information on at-the-money-forward options with expirations of 30, 60, 91, 182, 365, 547 and 730 calendar days. A standardized option is only included if there exists enough option price data on that date to accurately interpolate the required values.

File layout

Data Type	Length	Field Name
integer	-	**Security ID**
date	-	**Date**
integer	-	**Days**
real	-	Forward Price
real	-	Strike
char	1	**Call/Put**
real	-	Premium
real	-	Implied Volatility
real	-	Delta
real	-	Gamma
real	-	Theta
real	-	Vega

Field descriptions

Security ID

The Security ID for the underlying security

Date

The date of this option price

Days

The number of days to expiration

Forward Price

This is the price of a single share of the underlying security on the expiration date of the option. The forward security price is calculated based on the last closing security price, plus the interest, less projected dividends.

Strike

The strike price of the standardized option set to be equal to the forward price.

Call/Put

C – Call

`P` – Put

Premium

The premium for the option is interpolated from Volatility_Surface file.

Implied Volatility

The implied volatility of the standardized option is derived by linear interpolation from the Volatility_Surface file.

Delta

Delta has units $/$.

Gamma

Gamma has units $/($^2).

Theta

Theta of the option is annualized.

Vega/Kappa

Vega/kappa of the option has the units of $/volatility. This can, also, be read as cents/%.

Option_Volume file

The Option_Volume file contains daily total contract volume information for each underlying security. Volume is aggregated by calls, puts, and total.

File layout

Data Type	Length	Field Name
integer	-	**Security ID**
date	-	**Date**
char	1	**Call/Put**
integer	-	Volume
integer	-	Open Interest**

** Column added in Version 2.5

Field descriptions

Security ID

The Security ID for the underlying security

Date

The date of this option volume record

Call/Put

`C` – Call
`P` – Put
`(blank)` – Total

Volume

The total contract volume for (call, put, all) options for the underlying security on the specified date.

Open Interest

The total contract open interest for (call, put, all) options for the underlying security on the specified date.

Volatility_Surface file

The Volatility_Surface file contains the interpolated volatility surface for each security on each day, using a methodology based on a kernel smoothing algorithm. This file contains information on standardized options, both calls and puts, with expirations of 30, 60, 91, 122, 152, 182, 273, 365, 547, and 730 calendar days, at deltas of 0.20, 0.25, 0.30, 0.35, 0.40, 0.45, 0.50, 0.55, 0.60, 0.65, 0.70, 0.75, and 0.80 (negative deltas for puts). A standardized option is only included if there exists enough option price data on that date to accurately interpolate the required values.

File layout

Data Type	Length	Field Name
integer	-	**Security ID**
date	-	**Date**
integer	-	**Days**
integer	-	**Delta**
char	1	Call/Put
real	-	Implied Volatility
real	-	Implied Strike **
real	-	Implied Premium **
real	-	Dispersion **

** Column(s) added in Version 2.5

Field descriptions

Security ID

The Security ID for the underlying security

Date

The date of this option volume

Days

The number of days to expiration

Delta

Delta of the option

Call/Put

`C` – Call
`P` – Put

Implied Volatility

The calculated interpolated implied volatility of the option

Implied Strike

The strike price corresponding to this delta

Implied Premium

The premium of a theoretical option with this delta and implied volatility

Dispersion

Dispersion is a measure of the accuracy of the implied volatility calculation, roughly corresponding to a weighted standard deviation. A larger dispersion indicates a less accurate smoothed implied volatility. Dispersion is only calculated if there are at least two contracts with non-negative implied volatility in OPTION_PRICE for the day for the underlying security. Otherwise dispersion is set to -99.99.

$$Dispersion = \sqrt{\frac{\sum_i V_i \sigma_i^2 \Phi(x_{ij} y_{ij} z_{ij})}{\sum_i V_i \sigma_i \Phi(x_{ij} y_{ij} z_{ij})} - \hat{\sigma}_j^2}$$ *

* Please refer to page 34.

** Historical_Volatility file

** Table added in Version 2.5

The Historical_Volatility file contains the realized volatility for each optionable security on each day. Realized volatility is calculated over date ranges of 10, 14, 30, 60, 91, 122, 152, 182, 273, 365, 547, and 730 calendar days, using a simple standard deviation calculation on the logarithm of the close-to-close daily total return.

File layout

Data Type	Length	Field Name
integer	-	**Security ID**
date	-	**Date**
integer	-	**Days**
float	-	Volatility

Field descriptions

Security ID

The Security ID for the underlying security

Date

The date of this realized volatility calculation

Days

The number of days included in the calculation

Volatility

The calculated realized volatility

** Open_Interest file

** Table added in Version 2.5
** Data is not provided on the DVDs.

The Open_Interest file contains the previous day's open interest information for each option and updates the value in the Open Interest filed of the Optione_Price file. This file is provided each morning by 9:00 a.m.

File layout

Data Type	Length	Field Name
integer	-	Security ID
date	-	**Date**
char	21	**Symbol**
char	1	**Symbol Flag**
integer	-	Open Interest

Field descriptions

Security ID
The Security ID for the underlying security

Date
The date for the morning it was created.

Symbol
The option symbol

Symbol Flag
The flag is set to 0 for the old option notation (i.e. root and suffix) and it is set to 1 if the symbol is the new OSI symbol.

Open Interest
The open interest for the option

Chapter 3. Calculations

The implied volatilities and option sensitivities contained in Ivy DB are calculated in accordance with standard conventions used by participants in the equity and index option markets.

Interest Rates

Each of the option pricing models used by Ivy DB requires a continuously-compounded interest rate as input. This interest rate is calculated from a collection of continuously-compounded zero-coupon interest rates at various maturities, collectively referred to as the *zero curve.* The zero curve used by the Ivy DB option models is derived from ICE IBA LIBOR rates and settlement prices of CME Eurodollar futures.

For a given option, the appropriate interest rate input corresponds to the zero-coupon rate that has a maturity equal to the option's expiration, and is obtained by linearly interpolating between the two closest zero-coupon rates on the zero curve.

The zero curve is calculated as follows:

Step 1. The IBA LIBOR rates for maturities of 1 week and 1-12 months are converted to discount factors using the formula:

$$DF = (1 + r \times d / 360)^{-1}$$

where r is the IBA LIBOR rate and d is the actual number of days to maturity.

Step 2. The LIBOR discount factors are converted to continuous LIBOR zero rates using the Actual/365 day-count convention:

$$L = -365/d \times \ln(DF)$$

where L is the continuously-compounded LIBOR zero rate.

Step 3. The zero rate on the nearest futures contract date (greater than one week) is obtained by linear interpolation between the two closest LIBOR zero rates computed in Step 2.

Step 4. Each subsequent zero rate is computing by treating the Eurodollar strip implied future rate as a forward rate:

$$F_i = 100 - P_i$$

$$DF_i = DF_{i-1} / [\ 1 + (F_{i-1} / 100) \times (\ n / 360\ )\ ]$$

where P_i is the Eurodollar settlement price and F_i is the implied Eurodollar future rate for futures settlement date i, DF_i is the discount factor to futures date i, and n is the number of days between futures settlement date i–1 and futures settlement date i. This step is repeated to generate discount factors out to ten years.

Step 5. Each of the calculated discount factors is converted into a zero rate by using the formula from Step 2.

There is currently no convexity adjustment applied to the computed zero-coupon rates.

Dividends

When the underlying equity or index pays dividends, each of the option pricing models requires an estimate of the dividends to be paid up until the option's expiration. The methodology used by Ivy DB for dividend payments depends on the type of the underlying security.

The Ivy DB option pricing methodology for equity options assumes that the security's current dividend yield (defined as the most recently announced dividend payment divided by the most recent closing price for the security) remains constant over the remaining term of the option. This "constant dividend yield" assumption is consistent with most dividend-based equity pricing models (such as the Gordon growth model) under the additional assumptions of constant average security return and a constant earnings growth rate.

Even though the dividend yield is constant, Ivy DB assumes that the security pays dividends at specific pre-determined times, namely on the security's regularly scheduled ex-dividend date. In the case of dividends that have already been declared, the ex-dividend dates are known. For dividend payments that are as yet unannounced, Ivy DB uses a proprietary extrapolation algorithm to create a set of projected ex-dividend dates according to the security's usual dividend payment frequency. These projections are listed in the distribution file as Distribution Type = '%', and extend out to five years. Because the actual cash dividend to be received on the ex-dividend date is a function of the security price on that date, and is computed internally by the option pricing models, the Amount field for the projected dates is set equal to dividend yield.

For dividend-paying indices, Ivy DB assumes that the security pays dividends continuously, according to a continuously-compounded dividend yield. A put-call parity relationship is assumed, and the implied index dividend is calculated from the following linear regression model:

$$C - P = b_0 + b_1 S + b_2 ST + b_3 K + b_4 KT + b_5 D_{BA}$$

In this model, C – P is difference between the price of a call option and the price of a put option with the same expiration and strike. When calculating this difference, the bid price of the call is used with the offer price of the put, and vice versa. D_{BA} is a dummy

variable set equal to 1 if the call option's bid price is used. S is the underlying security's (index's) closing price, K is the strike price of the call and put options, and T is the time to expiration in years. The regression is calculated using three months of option data across all strikes and expirations with an exception of contracts expiring in less than 15 days, for a single underlying. According to the principle of put-call parity, the dividend yield on the underlying index will be approximately equal to the negative of the estimated parameter b_2.

This put-call parity relationship only holds exactly for European options. There are only a few index options which trade according to American exercise: The AMEX Computer Technology Index; the Amex Oil Index; the CBOE Internet Index; the PHLX Semiconductor Index, the PHLX Gold Index; and the CBOE S&P 100 Index. For the S&P 100 index, we assume that the dividend yield is equal to that computed for the S&P 500 index. For the other American-exercise indices, we use the results of the dividend regression unmodified. While this may induce a slight bias into the calculations, we expect the overall effect on the computed implied volatilities to be minimal.

European Options

Most index options have a European-style exercise feature, and can be priced according to the Black-Scholes model:

$$C = Se^{-qT} N(d_1) - Ke^{-rT} N(d_2)$$
$$P = Ke^{-rT} N(-d_2) - Se^{-qT} N(-d_1)$$

where

$$d_1 = [\ \ln(S/K) + (r - q + \tfrac{1}{2}\sigma^2)\ T\ ] / \sigma\sqrt{T}\ ,$$
$$d_2 = d_1 - \sigma\sqrt{T}\ ,$$

C is the price of a call option, P is the price of a put option, S is the current underlying security price, K is the strike price of the option, T is the time in years remaining to option expiration, r is the continuously-compounded interest rate, q is the continuously-compounded annualized dividend yield, and σ is the implied volatility.

For calculating implied volatilities and associated option sensitivities, the theoretical option price is set equal to the midpoint of the best closing bid price and best closing offer price for the option. The Black-Scholes formula is then inverted using a numerical search technique to calculate the implied volatility for the option.

American Options

Options that have an American-style exercise feature are priced using a proprietary pricing algorithm that is based on the industry-standard Cox-Ross-Rubinstein (CRR)

binomial tree model. This model can accommodate underlying securities with either discrete dividend payments or a continuous dividend yield.

In the framework of the CRR model, the time between now and option expiration is divided into *N* sub-periods. Over the course of each sub-period, the security price is assumed to move either "up" or "down". The size of the security price move is determined by the implied volatility and the size of the sub-period. Specifically, the security price at the end of sub-period *i* is given by one of the following:

$$S_{i+1}^{up} = S_i u \equiv S_i \exp\left(\sigma\sqrt{h}\right)$$

$$S_{i+1}^{down} = S_i d \equiv S_i \exp\left(-\sigma\sqrt{h}\right)$$

where $h \equiv T/N$ is the size of the sub-period, and S_i is the security price at the beginning of the sub-period.

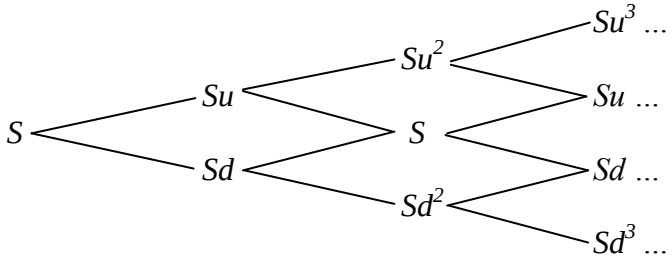
The price of a call option at the beginning of each sub-period is dependent on its price at the end of the sub-period, and is given by:

$$C_i = \max\left\{ \begin{array}{c} \left[pC_{i+1}^{up} + (1-p)C_{i+1}^{down} \right] / R \\ S_i - K \end{array} \right\} \quad (1)$$

and likewise for a put option. Here, *r* is the interest rate, *q* is the continuous dividend yield (if the security is an index), $R \equiv exp([r\text{-}q]h)$, and C_{i+1}^{up} and C_{i+1}^{down} are the price of the option at the end of the sub-period, depending on whether the security price moves "up" or "down". The "risk-neutral" probability *p* is given by:

$$p = \frac{R-d}{u-d}$$

To use the CRR approach to value an option, we start at the current security price *S* and build a "tree" of all the possible security prices at the end of each sub-period, under the assumption that the security price can move only either up or down:



The tree is constructed out to time *T* (option expiration).

Next the option is priced at expiration by setting the option expiration value equal to the exercise value: C = max(S−K,0) and P = max(K−S,0). The option price at the beginning of each sub-period is determined by the option prices at the end of the sub-period, using the formula above. Working backwards, the calculated price of the option at time i=0 is the theoretical model price.

To compute the implied volatility of an option given its price, the model is run iteratively with new values of σ until the model price of the option converges to its market price, defined as the midpoint of the option's best closing bid and best closing offer prices. At this point, the final value of σ is the option's implied volatility.

The CRR model is adapted to securities that pay discrete dividends as follows: When calculating the price of the option from equation (1), the security price S_i used in the equation is set equal to the original tree price S_i^0 *minus* the sum of all dividend payments received between the start of the tree and time i. Under the constant dividend yield assumption, this means that the security price S_i used in equation (1) should be set equal to $S_i^0(1-n\delta)$, where S_i^0 is the original tree price, δ is the dividend yield, and n is the number of dividend payments received up to time i. All other calculations are the same.

The CRR model usually requires a very large number of sub-periods to achieve good results (typically, N > 1000), and this often results in a large computational requirement. The Ivy DB proprietary pricing algorithm uses advanced techniques to achieve convergence in a fraction of the processing time required by the standard CRR model.

Standardized Option Prices

The standardized option prices and implied volatilities in the Std_Option_Price file are calculated using linear interpolation from the Volatility Surface file. First the forward price of the underlying security is calculated using the zero curve and the projected distributions. Next, the volatility surface points are linearly interpolated to the forward price and the target expiration, to generate an at-the-money-forward implied volatility.

Volatility Surface

The standardized option implied volatilities in the Volatility_Surface file are calculated using a kernel smoothing technique. The data is first organized by the log of days to expiration and by "call-equivalent delta" (delta for a call, one plus delta for a put). A kernel smoother is then used to generate a smoothed volatility value at each of the specified interpolation grid points.

At each grid point j on the volatility surface, the smoothed volatility $\hat{\sigma}_i$ is calculated as a weighted sum of option implied volatilities:

$$\hat{\sigma}_j = \frac{\sum_i V_i \sigma_i \Phi\left(x_{ij}, y_{ij}, z_{ij}\right)}{\sum_i V_i \Phi\left(x_{ij}, y_{ij}, z_{ij}\right)}$$

where i is indexed over all the options for that day, V_i is the vega of the option, σ_i is the implied volatility, and $\Phi(.)$ is the kernel function:

$$\Phi\left(x, y, z\right) = \frac{1}{\sqrt{2\pi}} e^{-\left[\left(x^2/2h_1\right)+\left(y^2/2h_2\right)+\left(z^2/2h_3\right)\right]}$$

The parameters to the kernel function, x_{ij}, y_{ij}, and z_{ij} are measures of the "distance" between the option and the target grid point:

$$x_{ij} = \log\left(T_i / T_j\right)$$
$$y_{ij} = \Delta_i - \Delta_j$$
$$z_{ij} = I_{\{CP_i = CP_j\}}$$

where T_i (T_j) is the number of days to expiration of the option (grid point); Δ_i (Δ_j) is the "call-equivalent delta" of the option (grid point); CP_i (CP_j) is the call/put identifier of the option (grid point); and I{.} is an indicator function (=0 if the call/put identifiers are equal, or 1 if they are different).

The kernel "bandwidth" parameters were chosen empirically, and are set as h_1=0.05, h_2=0.005, and h_3=0.001.

Option and Underlying Price

The option price used in implied volatility calculation is an average between max Bid and min Ask. These are selected across all exchanges the contract is traded on. Option prices used in implied volatility calculations up to March 4, 2008 are end of day prices. Starting from March 5, 2008 we have been capturing best bid and best offer as close to 4 o'clock as possible in an attempt to better synchronize the option price with the underlying close. Currently all option quotes, except for VIX option prices, are captured at 15:59 EST. The underlying price used is the official (composite) close. In VIX implied volatility calculations end of day option prices continue to be used along with futures settlement prices as the underlying prices.

Missing Values

There are several situations where the implied volatilities cannot be calculated for the OPTION_PRICE, STD_OPTION_PRICE, and VOLATILITY_SURFACE tables. These reasons change based on the method of calculation used and as a result differ by table. These reasons are detailed below and are organized by tables.

For the OPTION_PRICE table the implied volatility will be set to -99.99 if any of the following conditions holds:

1. The option is a "special settlement" (Special Settlement Flag = 1)
2. The midpoint of the bid/ask price is below intrinsic value
3. The vega of the option is below 0.5
4. The implied volatility calculation fails to converge
5. The underlying price is not available

For the STD_OPTION_PRICE and VOLATILITY_SURFACE tables the implied volatility will be set to –99.99 if any of the follow conditions hold:

1. An insufficient number of option data points are available to perform the interpolation.

Chapter 4. Appendices

Appendix A: Industry Group Codes

Code	Description
1	Basic Materials
11	Chemicals
110	Chemicals - Major Diversified
111	Synthetics
112	Agricultural Chemicals
113	Specialty Chemicals
12	Energy
120	Major Integrated Oil & Gas
121	Independent Oil & Gas
122	Oil & Gas Refining & Marketing
123	Oil & Gas Drilling and Exploration
124	Oil & Gas Equipment & Services
125	Oil & Gas Pipelines
13	Metals & Mining
130	Steel & Iron
131	Copper
132	Aluminum
133	Industrial Metals & Minerals
134	Gold
135	Silver
136	Nonmetallic Mineral Mining
2	Conglomerates
21	Conglomerates
210	Conglomerates
3	Consumer Goods
31	Consumer Durables
310	Appliances
311	Home Furnishings & Fixtures
312	Housewares & Accessories
313	Business Equipment
314	Electronic Equipment
315	Toys & Games
316	Sporting Goods
317	Recreational Goods, Other
318	Photographic Equipment & Supplies
32	Consumer Non-Durables
320	Textile - Apparel Clothing

321	Textile - Apparel Footwear & Accessories
322	Rubber & Plastics
323	Personal Products
324	Paper & Paper Products
325	Packaging & Containers
326	Cleaning Products
327	Office Supplies
33	Automotive
330	Auto Manufacturers - Major
331	Trucks & Other Vehicles
332	Recreational Vehicles
333	Auto Parts
34	Food & Beverage
340	Food - Major Diversified
341	Farm Products
342	Processed & Packaged Goods
343	Meat Products
344	Dairy Products
345	Confectioners
346	Beverages - Brewers
347	Beverages - Wineries & Distillers
348	Beverages - Soft Drinks
35	Tobacco
350	Cigarettes
351	Tobacco Products, Other
4	Financial
41	Banking
410	Money Center Banks
411	Regional - Northeast Banks
412	Regional - Mid-Atlantic Banks
413	Regional - Southeast Banks
414	Regional - Midwest Banks
415	Regional - Southwest Banks
416	Regional - Pacific Banks
417	Foreign Money Center Banks
418	Foreign Regional Banks
419	Savings & Loans
42	Financial Services
420	Investment Brokerage - National
421	Investment Brokerage - Regional
422	Asset Management
423	Diversified Investments
424	Credit Services
425	Closed-End Fund - Debt

426	Closed-End Fund - Equity
427	Closed-End Fund - Foreign
43	Insurance
430	Life Insurance
431	Accident & Health Insurance
432	Property & Casualty Insurance
433	Surety & Title Insurance
434	Insurance Brokers
44	Real Estate
440	REIT - Diversified
441	REIT - Office
442	REIT - Healthcare Facilities
443	REIT - Hotel/Motel
444	REIT - Industrial
445	REIT - Residential
446	REIT - Retail
447	Mortgage Investment
448	Property Management
449	Real Estate Development
5	Healthcare
51	Drugs
510	Drug Manufacturers - Major
511	Drug Manufacturers - Other
512	Drugs - Generic
513	Drug Delivery
514	Drug Related Products
515	Biotechnology
516	Diagnostic Substances
52	Health Services
520	Medical Instruments & Supplies
521	Medical Appliances & Equipment
522	Health Care Plans
523	Long-Term Care Facilities
524	Hospitals
525	Medical Laboratories & Research
526	Home Health Care
527	Medical Practitioners
528	Specialized Health Services
6	Industrial Goods
61	Aerospace/Defense
610	Aerospace/Defense - Major Diversified
611	Aerospace/Defense - Products & Services
62	Industrial
620	Farm & Construction Machinery

621	Industrial Equipment & Components
622	Diversified Machinery
623	Pollution and Treatment Controls
624	Machine Tools & Accessories
625	Small Tools & Accessories
626	Metals Fabrication
627	Industrial Electrical Equipment
628	Textile Manufacturing
63	Materials & Construction
630	Residential Construction
631	Manufactured Housing
632	Lumber, Wood Production
633	Cement
634	General Building Materials
635	Heavy Construction
636	General Contractors
637	Waste Management
7	Services
71	Leisure
710	Lodging
711	Resorts & Casinos
712	Restaurants
713	Specialty Eateries
714	Gaming Activities
715	Sporting Activities
716	General Entertainment
72	Media
720	Advertising Agencies
721	Marketing Services
722	Entertainment - Diversified
723	Broadcasting - TV
724	Broadcasting - Radio
725	CATV Systems
726	Movie Production, Theaters
727	Publishing - Newspapers
728	Publishing - Periodicals
729	Publishing - Books
73	Retail
730	Apparel Stores
731	Department Stores
732	Discount, Variety Stores
733	Drug Stores
734	Grocery Stores
735	Electronics Stores
736	Home Improvement Stores

737	Home Furnishing Stores
738	Auto Parts Stores
739	Catalog & Mail Order Houses
74	Specialty Retail
740	Sporting Goods Stores
741	Toy & Hobby Stores
742	Jewelry Stores
743	Music & Video Stores
744	Auto Dealerships
745	Specialty Retail, Other
75	Wholesale
750	Auto Parts Wholesale
751	Building Materials Wholesale
752	Industrial Equipment Wholesale
753	Electronics Wholesale
754	Medical Equipment Wholesale
755	Computers Wholesale
756	Drugs Wholesale
757	Food Wholesale
758	Basic Materials Wholesale
759	Wholesale, Other
76	Diversified Services
760	Business Services
761	Rental & Leasing Services
762	Personal Services
763	Consumer Services
764	Staffing & Outsourcing Services
765	Security & Protection Services
766	Education & Training Services
767	Technical Services
768	Research Services
769	Management Services
77	Transportation
770	Major Airlines
771	Regional Airlines
772	Air Services, Other
773	Air Delivery & Freight Services
774	Trucking
775	Shipping
776	Railroads
8	Technology
81	Computer Hardware
810	Diversified Computer Systems
811	Personal Computers
812	Computer Based Systems

813	Data Storage Devices
814	Networking & Communication Devices
815	Computer Peripherals
82	Computer Software & Services
820	Multimedia & Graphics Software
821	Application Software
822	Technical & System Software
823	Security Software & Services
824	Information Technology Services
825	Healthcare Information Services
826	Business Software & Services
827	Information & Delivery Services
83	Electronics
830	Semiconductor - Broad Line
831	Semiconductor - Memory Chips
832	Semiconductor - Specialized
833	Semiconductor - Integrated Circuits
834	Semiconductor Equipment & Materials
835	Printed Circuit Boards
836	Diversified Electronics
837	Scientific & Technical Instruments
84	Telecommunications
840	Wireless Communications
841	Communication Equipment
842	Processing Systems & Products
843	Long Distance Carriers
844	Telecom Services - Domestic
845	Telecom Services - Foreign
846	Diversified Communication Services
85	Internet
850	Internet Service Providers
851	Internet Information Providers
852	Internet Software & Services
9	Utilities
91	Utilities
910	Foreign Utilities
911	Electric Utilities
912	Gas Utilities
913	Diversified Utilities
914	Water Utilities