Deutsche Bank
Corporate & Investment Bank

Inflation Derivatives
House of the Year
Risk Awards 2011, Risk Magazine

#1 USD Inflation Swaps
#1 USD inflation Options
CPI – The Consumer Price Index
The Consumer Price Indexes (CPI) program produces monthly data on changes in the prices paid by urban consumers for a representative basket of goods and services.

- The index includes owner occupied housing using a rental equivalence approach.
- It is published once per month, usually around the middle of the following month.

Energy is by far the most Volatile component of CPI
(Transportation costs are highly correlated with Energy)

Annual Volatility of CPI Sub-Indices (1994-2012)

Food and Beverage Prices are much less volatile than Energy

Source: Deutsche Bank
CPI History
Inflation is Seasonal

Inflation is generally higher leading into the Summer and lower heading into year-end.

This can be observed by comparing seasonal adjusted CPI (CPI_INDX) with non-seasonal adjusted CPI (CPURNSA).

Source: Bloomberg: CPI INDX <Index> CPURNSA <Index> HS
TIPS Issuance has Increased Significantly

TIPS Outstanding by Issue Year in $mm (as at 16 Jan 2013)

Treasury has committed to support the TIPS market as it provides a diversifying source of funds.

Daily Trading Volume is approximately $11 Billion.

Source: Bloomberg / Deutsche Bank Forecast
US Inflation Derivative Market has been Growing

Interdealer Volumes in $'mm

- Options
- TIPS ASW
- Swaps

A reflection of an increased number of clients participating in the market.

Daily Trading Volume is approximately $1 Billion.

Especially strong growth in Inflation Options.

Deutsche Bank’s currently has 25% market share in US Inflation derivatives (BGC Partners Interdealer Statistics).

Source: BGC Partners
Inflation-linked Products
Inflation Products: TIPS

- TIPS ("Treasury Inflation Protected Securities") are securities issued by the US government that offer investors inflation protection.

- The principal is accredited daily based on the CPI-Urban index and repaid at maturity subject to a minimum of par, providing deflation protection i.e. embedded deflation floor.

- Semi-annual coupons paid on TIPS are based on the inflation-adjusted principal.

**TIPS coupons and principal repayment at maturity**

- Real Coupon
- Inflation
- Notional

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*The TIPS market is the largest inflation-linked market in the world. Regular auctions are conducted in 5y, 10y and 30y TIPS.*
TIPS Issues
Total Market value is approximately $1 Trillion

TIPS Outstanding by Issue in $mm (as at 12 February 2013)

Data Source: Bloomberg
TIPS, Real Rates and Inflation

- TIPS provide exposure to real interest rates rather than inflation

Coupons and Redemption amount grow at the inflation rate. However, these are discounted at the nominal rate to determine the Present Value. Accordingly, the market values of TIPS are a function of both future inflation expectations and nominal rates.

- Breakeven trades can isolate the exposure to expected inflation

\[ \text{TIPS Breakeven} = \text{Long TIPS bond} + \text{Short Treasury of similar maturity} \]
Inflation Swaps

- Inflation swaps offer a mechanism to trade inflation over a given time horizon.
- At maturity, one party pays the cumulative percentage increase in the reference inflation index over the life of the swap in exchange for an annually compounded fixed rate.
- ISDA documentation typically employed.

\[
\frac{CPI(N)}{CPI(0)} - 1 = (1 + \text{fixed})^N - 1
\]
Inflation Products: Inflation Swap Example

- Client asked DB to quote a price to buy a 5-year inflation swap
- Agrees on a fixed rate of 2% (“Swap Breakeven Rate”)
- Client will “break even” if inflation turns out to be 2% per annum over the 5-years; Accordingly, will lose money if inflation is less than 2% and make money if inflation exceeds 2%
- If actual inflation over the 5 years turns out to be 3% per annum, the client be paid the difference between 3% compounded for 5-years and 2% compounded for five years
  → Happy Client

\[
\left(1 + \frac{2\%}{\text{CPI}(0)}\right)^5 - 1
\]
Product: Inflation Swaps

Typically traded in discrete years from 1-year to 30-years

Often traded on a forward basis e.g. 5y5y or 1y9y

The zero-coupon structure makes it possible to match an exact cash flow profile by combining swaps of different maturities

Trading in Core Inflation recently initiated by Deutsche Bank

![Zero Coupon Inflation Swap Levels Graph]
Historical 5Y5Y Inflation Swap Levels

- As historically forward-starting inflation, e.g. 5y5y, has always been within a tight band
- Forward-starting tends to be the easiest way to implement this and has other attractive features e.g. no seasonality, relatively flat carry

Past Performance is no Guarantee of Future Results
Implied Inflation
TIPS vs. Inflation Swaps

Expected Inflation implied by Inflation Swaps is higher than that implied by TIPS Breakevens

For the most part, reflects a supply/demand imbalance

No natural sellers of Inflation swaps

Large seller of TIPS: The US Government

Why is this not arbitrated away?

1. Limits on balance sheet capacity
2. Mark-to-market risk

TIPS vs. Swap Breakevens

Data Source: Bloomberg LP
TIPS Asset Swap
The National Bureau of Economic Research (NBER)*

“Why Does the Treasury Issue Tips? The Tips–Treasury Bond Puzzle”
Matthias Fleckenstein, Francis A. Longstaff, and Hanno Lustig
NBER Working Paper No. 16358
September 2010


“To the best of our knowledge, the relative mispricing of TIPS and Treasury bonds represents the largest arbitrage ever documented in the financial economics literature. The TIPS–Treasury arbitrage poses a major puzzle to classical asset pricing theory.”

* The NBER is the nation's leading nonprofit economic research organization. Eighteen of the 33 American Nobel Prize Winners in Economics and six of the past Chairmen of the President’s Council of Economic Advisers have been researchers at the NBER. The more than 1,000 professors of economics and business now teaching at colleges and universities in North America who are NBER researchers are the leading scholars in their fields,

http://www.nber.org/info.html
Product: TIPS on Asset Swap
The link between TIPS and Inflation Swaps – no net exposure to inflation

- Obtain duration/yield pickup via a top-credit quality assets (US Sovereign)
- Competing product to Nominal Treasuries, Agencies, …
- E.g. Post as collateral, replace treasury holdings, or hedge duration (with Repo) inexpensively

Fixed TIPS Assets Swap Levels

Source: Deutsche Bank Closing Levels
Product: TIPS on Asset Swap
Floating TIPS Asset Swap

- Earn an carry over repo rates / fed funds
- TIPS are easy to repo as they are US Government Treasuries

Feb '42 offers a much higher spread than Feb '41s as it has a much lower coupon (0.75% vs 2.125%)

Floating TIPS Asset Swap Spreads

Source: Deutsche Bank Closing Levels
Product: TIPS on Asset Swap

Mechanics

- Investor buys a TIPS
- Investor agrees to pay away all the cash-flows (P+I) from the bond
- Investor receives in return Libor + X% until maturity
- Investor receives Par (100) at maturity
Product : TIPS on Asset Swap
Example: How to make almost risk-less money

- Buy $100m Notional of TIPS maturing in January 2014 i.e. $130mm Dirty Price
- Fund the $130mm on overnight repo (current rate 0.06%, say)
- Swap out all the TIPS cash-flows in exchange for 3mL-0.07% coupons + $130mm on Maturity Date (current 3m Libor rate is 0.29%)
- Accordingly, asset swap will pay back the full $130mm on maturity date

- 3m Libor is almost always higher than repo rates (as it should be given it is an uncollateralized rate)
- Accordingly, assuming no change in the spread between Libor and Repo rates, earn carry of 0.29%-0.07% - 0.06% = 0.16% per annum on $130mm
Inflation Products – ETPs, TRS and Notes
Exchange Based Products
DB is an active market maker in Fixed Income ETPs

A large number of ETFs track inflation-linked sovereign bonds
e.g. TIP, WIP, STPZ, IPE, LTPZ, STIP, TIPZ, TDTF, TDTT, ITIP, GTIP, VTIP, etc.
New ETFs: Breakeven: INFL, DEFL, UINF, SINF, RINF, FINF and Active: ILB

First Inflation ETNs were recently listed

- INFL  Powershares DB US Inflation ETN
- DEFL  Powershares DB US Deflation ETN

- Combines Long TIPS with Inverse Treasury position
- Daily liquidity provision at NAV
- Live market making
- Designed such that 1bp change in inflation expectations equates to a 10c change in ETN price
- Different Credit and Tax Treatment compared to ETFs

CME considering launching Futures on CPI and TIPS
Total Return Swaps and Inflation-linked Notes

**Total Return Swaps**
- Allows clients to go long or short cash instruments in an unfunded form
- E.g. 1: Return of the 10+ year TIPS index vs Libor +/- Spread
- E.g. 2: Return of Overall TIPS Breakeven Index vs Libor +/- Spread

**Inflation-linked Notes**
- Creation of a customized note issued by DB or a Third Party
- E.g. 1: Provide coupons of Annual Inflation + 1.50%
- E.g. 2: Provide coupons of 1.5 Leverage x Annual Inflation
Inflation Products – Options
Understanding Inflation Options
Two key concepts

1) Inflation Options are either

   CAPS    i.e. Calls

or

   FLOORS  i.e. Puts (strikes can be negative)

2) Inflation Options are either

   YEAR-on-YEAR (YoY) References Annual Inflation

or

   ZERO COUPON (ZC) References CPI (cumulative inflation)
Year on Year Inflation Options
Regular payments based on annual Levels of Inflation

■ Payout based on difference between YoY Inflation and Strike each year

Year-on-year options generally have annual pay dates, but more frequent payouts are possible

Often these options are embedded in inflation-linked notes

E.g. $100mm 3%-strike five-year cap starting in 2004 would have paid out $0.4mm at the end of 2005 and $1.1mm at the end of 2007 with no other payments

YOY Inflation by Calendar Year

2005 2006 2007 2008 2009
3.4 2 4.1 0.1 2.7

Deutsche Bank
**Zero Coupon Options**
Payment on maturity based on cumulative inflation and compounded strike

- Single payment at maturity based on cumulative inflation from inception

There is particularly good liquidity in 0% options since they are similar to the redemption options embedded in TIPS.

E.g. $100mm 0% strike two-year floor with a starting reference of July 2008 will pay out $0.89mm (-0.445% per annum deflation) in October 2010 (3-month lag).
Understanding Inflation Options: Inflation Volatility
Market vs Economist Expectations

Negative skew in the options market. Economic theory suggests prices are sticky downwards i.e. market implied probability of deflation is too high.

Implied Volatility is too high relative to economist expectations.

‘Fat tailed’ distribution means wings have too much value.
Building a CPI Curve
Building the CPI Curve
Process

- Given market quotes for the zero coupon inflation-swap rates or TIPS breakevens it is possible to build a forward CPI curve.

- Constructing a complete forward curve involves:
  
  (a) extracting future fixings from quoted ZCIS rates

  (b) interpolating the available points to obtain the inflation trend

  (c) adding the CPI seasonality

1. For the quoted tenors the future fixings can be obtained using:

   \[ \text{Implied Ref CPI}_{t+\text{tenor}} = \text{Ref CPI}_t \times (1+ \text{ZCIS rate})^{\text{tenor}} \]

2. Interpolation between quoted ZCIS rates can be linear, cubic, which may lead to a smoother forward curve, or other depending on the data.

3. To obtain the monthly CPI projections seasonality needs to be taken into account (next slide).
Building the CPI Curve
Example

**Construction of the forward CPI curve**

<table>
<thead>
<tr>
<th>CPI Index</th>
<th>Projected value from ZCIS</th>
<th>Monthly seasonality</th>
<th>Removing the seasonal component</th>
<th>Trend CPI by linear interpolation</th>
<th>Incorporating seasonal component</th>
<th>Full CPI curve</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sep-09</td>
<td>109.8420</td>
<td>0.08%</td>
<td>$=109.8420 / \exp(0.08%) =$ 109.7541</td>
<td>109.7541</td>
<td>$=109.754 \times \exp(0.08%) =$ 109.8420</td>
<td></td>
</tr>
<tr>
<td>Oct-09</td>
<td>109.9722</td>
<td>0.02%</td>
<td></td>
<td>109.9722</td>
<td>$=109.972 \times \exp(0.02%) =$ 109.9942</td>
<td></td>
</tr>
<tr>
<td>Nov-09</td>
<td>110.1902</td>
<td>-0.19%</td>
<td></td>
<td>110.1902</td>
<td>$=110.190 \times \exp(-0.19%) =$ 109.9810</td>
<td></td>
</tr>
<tr>
<td>Dec-09</td>
<td>110.4083</td>
<td>0.17%</td>
<td></td>
<td>110.4083</td>
<td>$=110.408 \times \exp(0.17%) =$ 110.5963</td>
<td></td>
</tr>
<tr>
<td>Jan-10</td>
<td>110.6263</td>
<td>-0.46%</td>
<td></td>
<td>110.6263</td>
<td>$=110.626 \times \exp(-0.46%) =$ 110.1175</td>
<td></td>
</tr>
<tr>
<td>Feb-10</td>
<td>110.8444</td>
<td>0.14%</td>
<td></td>
<td>110.8444</td>
<td>$=110.844 \times \exp(0.14%) =$ 111.0002</td>
<td></td>
</tr>
<tr>
<td>Mar-10</td>
<td>111.0624</td>
<td>0.35%</td>
<td></td>
<td>111.0624</td>
<td>$=111.062 \times \exp(0.35%) =$ 111.4523</td>
<td></td>
</tr>
<tr>
<td>Apr-10</td>
<td>111.2805</td>
<td>0.23%</td>
<td></td>
<td>111.2805</td>
<td>$=111.280 \times \exp(0.23%) =$ 111.5363</td>
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</tr>
<tr>
<td>May-10</td>
<td>111.4985</td>
<td>0.05%</td>
<td></td>
<td>111.4985</td>
<td>$=111.499 \times \exp(0.05%) =$ 111.5541</td>
<td></td>
</tr>
<tr>
<td>Jun-10</td>
<td>111.7166</td>
<td>-0.08%</td>
<td></td>
<td>111.7166</td>
<td>$=111.717 \times \exp(-0.08%) =$ 111.6275</td>
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<tr>
<td>Jul-10</td>
<td>111.9346</td>
<td>-0.29%</td>
<td></td>
<td>111.9346</td>
<td>$=111.935 \times \exp(-0.29%) =$ 111.6108</td>
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</tr>
<tr>
<td>Aug-10</td>
<td>112.1527</td>
<td>-0.02%</td>
<td></td>
<td>112.1527</td>
<td>$=112.153 \times \exp(-0.02%) =$ 112.1302</td>
<td></td>
</tr>
<tr>
<td>Sep-10</td>
<td>112.4607</td>
<td>0.08%</td>
<td>$=112.4607 / \exp(0.08%) =$ 112.3707</td>
<td>112.3707</td>
<td>$=112.371 \times \exp(0.08%) =$ 112.4607</td>
<td></td>
</tr>
</tbody>
</table>

![Graph showing CPI curve and projected trend](image-url)
CPI Volatility Models
Jarrow and Yildirim (2003)*

**Foreign Currency Analogy**

- The “Real” is a “foreign currency” pegged to the value of a basket of goods and services
- Real Rates are the interest rates in the “foreign currency”
- CPI Index is the exchange rate between USD and the “Real” Currency

**Three-Factor HJM Model (Nominal Rates, Real Rates and Inflation Index)**

- Nominal Forward Rates: \( df_n(t,T) = \alpha_n(t,T)dt + \sigma_n(t,T)dW_n(t) \)
- Real Forward Rates: \( df_r(t,T) = \alpha_r(t,T)dt + \sigma_r(t,T)dW_r(t) \)
- Inflation Index: \( \frac{dI(t)}{I(t)} = \mu_I(t)dt + \sigma_I(t)dW_I(t) \)

**In Practice**

- Adjusted to incorporate Stochastic Volatility
- Calibrate volatility assumptions as well as correlations between factors
- Used to value Exotic (Path-dependent) Payoff Structures

Black-Scholes Type Models

Option Pricing Models

- **Black’s Model**: Treat Inflation Index as Log-normally Distributed
- **Bachelier Model**: Treat Inflation Rate as Normally Distributed
- **Shifted Log-normal Model**: Inflation Rate cannot go below -100%

In Practice

- Intraday calculations for vanilla Inflation Options
  e.g. TIPS Redemption Floors
- Different volatilities by Term and Strike based on calibrations to market trading levels
SABR Model

Incorporates Stochastic Volatility.  **SABR: Stochastic Alpha Beta Rho**

Allows better fitting of Volatility Skews/Smiles

**Process:**

\[
\begin{align*}
\text{d}F_t &= \sigma_tF_t^{\beta} \text{d}W_t, \\
\text{d}\sigma_t &= \alpha\sigma_tdZ_t;
\end{align*}
\]

- **Alpha** is the (log-normal) volatility of volatility - influences the Volatility Smile
- **Beta** is the sensitivity of the change in forward to the level of the forward – influences the Volatility Skew (e.g. normal vs. log-normal)
- **Rho** is the correlation between the two processes i.e. the correlation between change in Forward Level and change in Volatility – also influences the Volatility Skew

Generally, **Beta** is fixed based on historical experience, and **Rho** is calibrated

**In Practice**

- Pricing of all vanilla inflation options, including daily mark-to-market of vanilla option books
- Much quicker and more stable than JY Monte Carlo Model, but cannot value exotics

Inflation Market

Summary

Products

- **TIPS**
  - Treasuries whose principal adjusts in-line with CPI
- **TIPS Asset-Swap**
  - Obtain a yield pickup over treasuries / repo rates
- **Inflation Swaps**
  - Hedge or take a view on inflation
- **ETFs / ETNs**
  - Trade in a similar way to Equities
- **Total Return Swaps**
  - Unfunded exposure to TIPS or TIPS Breakevens
- **Inflation-linked Notes**
  - Customized inflation-linked cash flows
- **Inflation Options**
  - Capped or floored exposure to inflation

Models

- **Jarrow - Yildirim**
  - Exotic inflation options
- **BS-Type**
  - Intraday calculations
- **SABR**
  - Vanilla inflation option

Structural Imbalances in the Inflation Market

- Inflation Swaps imply higher CPI levels than TIPS
- Very front-end of the inflation curve tends to be cheap
- Implied volatility significantly exceeds realized volatility
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