US Fixed Income Strategy
J.P. Morgan Securities Inc.
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Research Note

Agency Callables Primer

- **We provide an introduction to Agency callable bonds**
- **Callables are negatively convex instruments due to the embedded optionality…**
- **… which causes them to outperform duration-matched bullets if rates remain range-bound, but underperform if rates move significantly**
- **We recommend using convexity-weighted excess returns to adjust for varying convexity risk among structures and to assess relative value**
- **We discuss callable structure selection in light of views on rates and implied volatility…**
- **…and introduce 'breakeven-maps' to identify callables with high cushion to changes in implied vol and rates**

Introduction

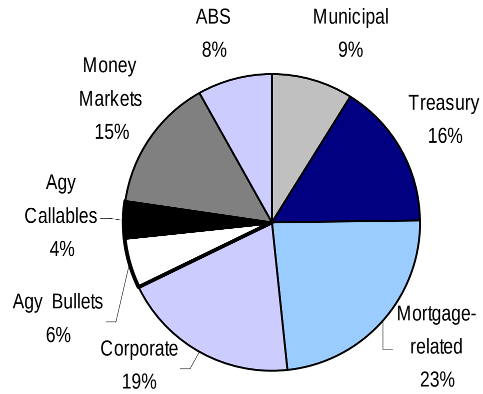
A callable bond is one that may be redeemed by the issuer before its final maturity date – that is, the issuer has the right, but not the obligation, to redeem the bond at one or more points in time before maturity. The redemption may occur on any of the predetermined dates specified in the call schedule, and at a predetermined price, usually par. A long position in the callable bond involves the sale of a call option by the investor to the issuer. Consequently, a callable bond can be thought of as a portfolio comprising a long bullet position and short call option position.

Callable Bond = Bullet Bond – Call Option

Par-priced callable bonds offer higher coupons relative to par-priced, maturity-matched bullets, as investors need to be compensated for selling the embedded option. Indeed, for most investors, the additional yield pick up tends to be the motivation behind choosing callable investment vehicles.

Chart 1: Agencies comprise 10% of the US fixed income universe

Composition of outstanding US bond market debt (%)



Source: JPMorgan, SIFMA

Table 1: Callable debt comprises 50% of long-term debt outstanding

Composition of outstanding Agency debt as of 8/31/2007 ($bn, %)

$bn	FNMA	FHLMC	FHLB	Total	Total
Short-term	169	162	249	580	22%
Long-term	621	629	838	2,088	78%
Total	*790*	*791*	*1087*	*2,668*	100%
Long-term					
Bellwether Bullets	249	240	162	651	31%
MTN Bullets	0	73	240	314	15%
Callable	305	295	436	1,035	50%
Sub Debt	9	6	0	15	1%
Other	58	16	0	74	4%
Total	621	629	838	2,088	100%

* Short-term debt includes discount notes, bills and coupon-bearing paper issued with original maturity of 1-year or less

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Agency callables have the same credit ratings as senior bullet Agency debt; thus, the early redemption feature is the primary source of any differences in risk characteristics between agency callables and senior bullet debt. With Fannie Mae, Freddie Mac, and FHLB all issuing long-term callable bonds, the agency callable market has grown to over $1tn in size and has helped make Agencies the 5th largest segment of the USD fixed income universe (Chart 1).

Of the three major housing related GSEs, FHLB currently has the highest amount of callable debt outstanding (Table 1); however, recent trends show that callable issuance has increased for all three housing-related GSEs relative to the overall issuance (Chart 2). Callable debt currently comprises 50% of long-term debt issued by the three housing-related GSEs. To better understand the drivers behind these trends, we briefly examine the motivations for callable issuance on the part of the various GSEs.

The Federal Home Loan Bank system primarily accesses the capital markets on behalf of its member banks, with any funding advantage being passed on through a combination of advances (by the FHLB to member banks) and dividends paid to members of the system. FHLB issuance can be in either bullet or callable form. The FHLB tends to issue a significant amount of callables because strong investor appetite for these instruments allows the issuer to "monetize" the embedded call by selling it to the street for more than the price demanded by the investors. Put simply, issuers such as the FHLB buy "cheap" calls from investors and sell them to dealers, using the differential to lower their funding costs. It stands to reason that the FHLB, whose core function is to access the capital markets as efficiently as possible, is a large and opportunistic issuer of callables. Looking ahead, we expect FHLB to increase its issuance of callables as they look for opportunities to term out their recent heavy issuance in discount notes. FHLB issued more than $80bn discount notes in August and $61bn in September as its member banks increased their demand for advances from the system as market conditions became relatively illiquid.

Fannie Mae and Freddie Mac have other motivations to issue callables as well – typically, these GSEs carry significant amounts of negatively convex assets (MBS) on their balance sheets. Thus, issuing negatively convex liabilities (i.e., callable bonds) is another way for them to better manage balance sheet risks, in addition to buying swaptions. Thus, for these GSEs, callable issuance depends on funding advantage as well as convexity needs stemming from their MBS portfolios. Additionally, FNMA and FHLMC themselves have preferred to issue more callables due to the different accounting rules applied to callable debt

Chart 2: Issuance of Agency callables has outpaced that of bullets…

Total FNMA, FHLB, and FHLMC long-term callable and bullet debt outstanding ($bn)

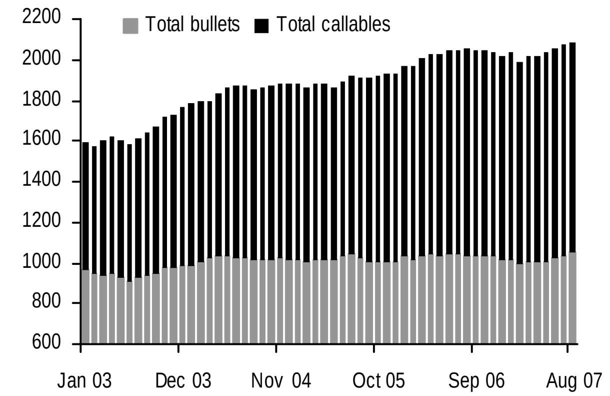
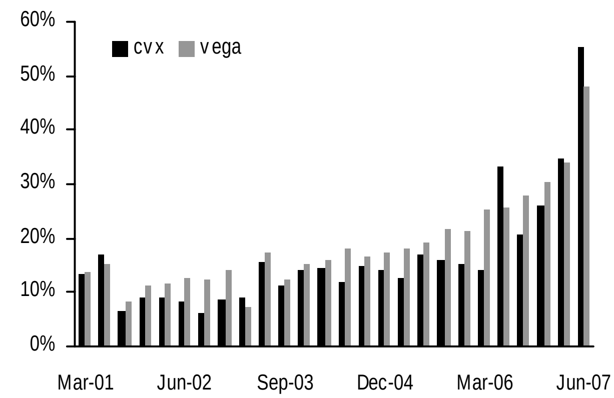


Chart 3: …as the Agencies' have increasingly used callables to internally hedge negative convexity and vega of their portfolios

Estimated fraction of the dollar convexity and the dollar vega risk of FNMA and FHLMC MBS portfolios that is hedged through callable liabilities



Source: JPMorgan

and derivatives. Indeed, we find that callables now offset a greater proportion of convexity and vega risk of the agencies' portfolios (Chart 3), as the agencies have issued a greater amount of callables. Looking ahead, we expect issuance in callables to remain high as callable redemptions have increased recently; furthermore, callable issuance is also likely to increase if the Agencies' portfolio constraints are eased in early 2008, as indicated recently by their regulator.

Market terminology

The GSEs offer a wide array of callable structures that vary in maturities, call frequency, and lockouts. Table 2

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illustrates the typical notation used to describe callable characteristics, which we discuss below:

- **Lockout** (or call protection): refers to the period between the issue date and the first exercise date during which the issuer may not exercise the option.

- **Call frequency:** refers to the frequency of call dates on which the issuer can redeem the bond. Callable structures incorporate one of three different option types: American, Bermudan, or European. The American option gives the issuer the ability to call the bond any time after the lockout date. It provides the greatest flexibility in timing the call decision and imparts the greatest call risk to the investor, since each day after the initial lockout represents a potential call date. Bermudan options give the issuer the ability to call the note at several points in time, but not continuously; examples include monthly, quarterly, or semi-annually. The most typical Bermudan structure allows the issuer to call the bond on any coupon date after the initial lockout. Finally, European options may be called only once during the life of the bond, on the call date.

As noted earlier, Agency callables offer a yield pick relative to bullets, since an investor of a callable bond is short the embedded option and should be compensated for taking the additional risk. The yield pick varies with final maturity, lockout, and call frequency, and depends on several factors including the level of yields, slope of the yield curve and levels of implied volatility. Table 3 shows the current yield pick for select par priced callables versus duration-, maturity-, and lockout-matched bullets. Note that the yield pick-up increases with greater option frequency, ceteris paribus. For example, Table 3 shows that a 5nc1 (SA) picks excess yield of 9bp relative to a similar-structure European callable since the investor needs to be compensated for taking on even greater call risk.

Yield and spread measures

Market convention is to look at the Yield to Worst (YTW) for callables, which is the minimum of the Yield to Maturity (YTM) and Yield to Call (YTC). The YTC is the yield that would be realized assuming that the bond is redeemed on the call date, while the YTM is calculated assuming that bond is held till maturity. Table 4 illustrates the three measures for par, premium, and discount callables; note that all the structures shown are callable at par. For the par-priced callable, the YTM, YTC, and YTW are equal. However, **for the callable priced at a**

Table 2: Notation in Agency callables

Structure		Description
5nc1 (1x)	A European callable with: - 5-year final maturity - 1-year lockout	The issuer may call the bond only once after 1-year
5nc1 (Q)	A bond callable quarterly with: - 5-year final maturity - 1-year lockout (SA) used for bonds callable semi-annually	The issuer may call the bond at quarterly intervals after 1-year
5nc1 (Cont.)	An American callable with: - 5-year final maturity - 1-year lockout	The issuer may call the bond at any time after 1-year

Table 3: Callables offer a yield pick relative to the bullet curve

Par callable structures versus bullets (bp), as of 10/2/2007

Structure	Yield	Duration	Convexity	Yield pick to bullets (bp)		
				Duration-matched	Maturity-matched	Lockout-matched
3nc1 (1x)	4.98	1.56	-0.57	55	52	50
5nc1 (1x)	5.25	2.02	-1.08	84	60	77
7nc1 (1x)	5.44	2.38	-1.54	102	61	96
5nc1 (SA)	5.34	2.1	-0.97	93	69	86

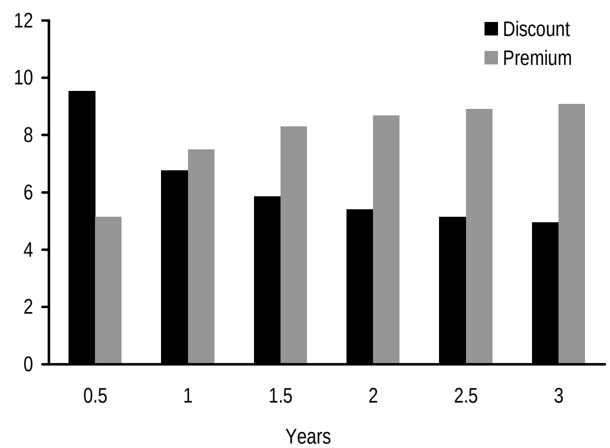
Table 4: Yield measures for callables

YTM, YTC, and YTW illustrated for par, discount, and premium 5nc1 (1x) callable at par

	Par	Discount	Premium
Coupon	6%	5%	7%
Price	100.00	97.62	101.34
Duration	1.91	3.47	1.01
YTC	6%	7.64%	5.53%
YTM	6%	5.56%	6.68%
YTW	6%	5.56%	5.53%

Chart 4: The yield-to-worst for a discount callable is the yield-to-maturity, and for a premium is the yield to the first call date*

Yields expected to be realized to different call dates for a discount and premium 3nc6mo (SA)



* For a callable bond with fixed rate coupon callable at the same call price across call dates

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premium, the YTC is lower than the YTM and therefore the YTW equals the YTC. This is because the yield earned on the note will be lower if the principal is redeemed at par on the call date, which occurs before the maturity date. On the other hand, **for a discount callable, the YTW equals the YTM**, since the yield earned on the bond will be lower if the principal redemption is delayed until maturity. Consequently, the YTW for a discount callable that is callable at the same price on all exercise dates is always the YTM, while the YTW for premium callables is the YTC to the first date (Chart 4)

It should be noted, however, that these yield measures are somewhat simplistic as they assume that the bond will be held to the date till which the YTW has been calculated and do not take in to account reinvestment risk or that the projected cash flows of the bond may change as rates change.

To account for these deficiencies, callable bonds are often analyzed in an Option Adjusted Spread (OAS) framework. The OAS is intended to be a metric that measures value relative to a benchmark curve (in recognition of the fact that cash flows occur at various points in time) while also accounting for the embedded optionality. Roughly speaking, for European options, the OAS may be thought of as the constant spread that must be added to benchmark forward rates so that the sum of discounted cash flows, assuming the bond survives to maturity, (discounted using OAS-adjusted forwards) equals the market price of the bond plus the value of the call option. (Of course, the call option must then be valued using an option pricing model). A more detailed illustration is included in the appendix.

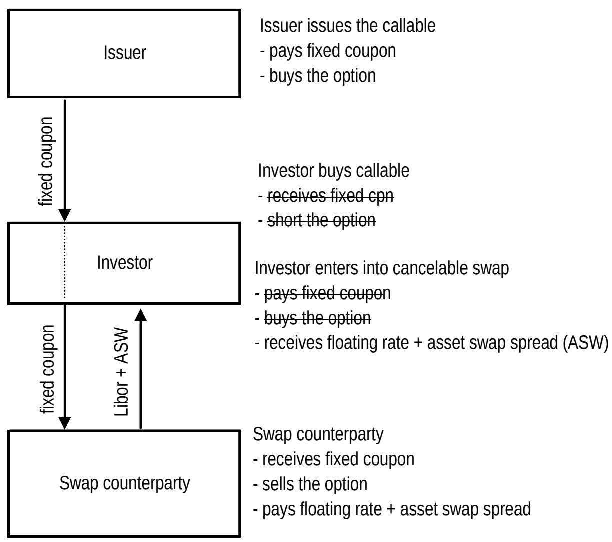
The OAS may be computed to various curves such as the swap curve, Treasury curve, or the Agency curve, and is mainly determined by the credit and liquidity of the bond, as well as supply/demand factors. The OAS calculated relative to the issuer-specific curve may be used as a measure of liquidity, while that calculated relative to the Treasury or the Swap curve may be used as a combined measure of credit, liquidity and technicals.

Market convention is to typically compute the OAS of American and Bermudan callables to the Treasury or Swap curve, and to compute the OAS for European Agency callables relative to the designated yield curve specified per the Securities Industry and Financial Markets Association(SIFMA, formerly BMA) guidelines. The SIFMA guidelines recommend using the Black'76 formula for swaptions and using skew-adjusted swaption volatility as an input. The OAS calculated using the SIFMA guidelines is known as the AOAS (see appendix for details).

Table 5: Market convention to quote Agency callables using Bloomberg

Bloomberg Screen	AOAS	OAS1
Type of structure:	European (AOAS used for quotation)	Bermudan/ Cont. ($price used for quotation)
Curves used:	FNMA (I252) FHLMC (I267) FHLB (I267) The Libor curve (S23) may also be used	The Treasury curve (I111)
Volatility assumption:	Skew-adjusted swaption vol	Constant vol of 14%
Option pricing model:	Black Swaption model	Lognormal (Bloomberg Default)

Chart 5: Asset swapping callables



Bloomberg screens used for pricing callables are AOAS and OAS1.

- **AOAS:** Most European callables now price off the AOAS page, which uses the guidelines developed by the SIFMA. The AOAS screen uses the issuer-specific yield curve, when available, and uses the skew-adjusted vol specific to the structure. European callables are quoted on an AOAS basis, i.e. the OAS is quoted and the price may then be backed out by using the default settings on the AOAS page in Bloomberg.

- **OAS1:** Multi-Euro callables use the OAS1 screen on Bloomberg, which allows customization of inputs and models. For trading purposes, multi-Euro callables are quoted on a dollar price basis. Market participants often use a constant vol assumption of 14% and the Treasury curve while viewing the OAS1 screen on Bloomberg.

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While the SIFMA has issued standard guidelines for trading European Agency callables, there are no standardized guidelines for quoting/ trading multi-Euro callables. **For a more detailed discussion on OAS and the SIFMA guidelines, please refer to the appendices of this publication.** The market conventions for the purpose of quoting callables are summarized in the Table 5.

Asset-swapping callables

Although not identical, a callable bond's OAS to the swap curve is very similar to a more directly tradable spread – the asset-swap-spread for the callable. As discussed earlier, an investor who owns a callable bond is long the bond (i.e. receives fixed coupon) and short the option. An investor may hedge out the volatility and interest rate risk on the callable by entering into a cancelable swap, which involves swapping the fixed-rate coupon receipts for a floating rate (plus a spread), and simultaneously buying the embedded option in the options market (Chart 5). This is one way of monetizing the credit spread while stripping out the interest rate and volatility risk, and enables investors to benefit from differences in pricing of callable and bullet bonds. The Agencies themselves asset swap a significant portion of their callable debt (by receiving a fixed rate cash flow and selling the embedded option) to synthetically create floating rate debt, as this enables them to take advantage of any mispricing in the embedded option or pricing differences between callables and bullets, thereby resulting in reduced borrowing costs.

Risk characteristics of callables

While callables offer yield pick to bullets and may be used to enhance returns, their performance differs from bullets. Unlike with bullets, changes in the level of rates results in callable durations changing, which impacts returns. Additionally, changes in implied volatility also impacts callable returns by impacting the value of the embedded option. Sensitivity to changes in rates and implied volatility are discussed below.

Sensitivity to changes in rates – Duration and Convexity

a. Duration

Duration is a first order measure of the bonds' price sensitivity to changes in interest rates; it is the approximate percentage change in price of the bond due to a 1% change in yields. In the case of bonds with embedded optionality, the duration measure must take into account that the future cash flows of the bond may change due to a change in

Chart 6: Duration may be measured relative to parallel shifts in the entire curve, or relative to a single point on the yield curve

Option adjusted duration for a parallel rate shift in the yield curve versus partial durations to specific points on the yield curve for a 5nc1 (1x), as of 10/2/2007

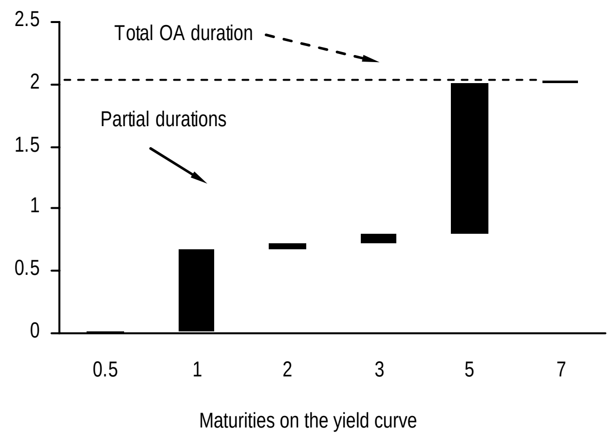
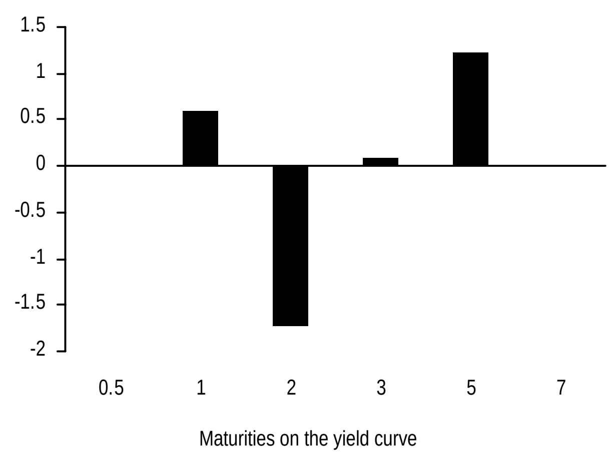


Chart 7: Using a callable to substitute a similar duration bullet shifts partial duration exposure to its lockout and maturity

Partial duration of 5nc1 (1x) minus that of forward duration matched bullet, as of 10/2/2007



interest rates. The measure of duration that takes this into account is referred to as the option adjusted duration.

The duration of a callable may be calculated to measure sensitivity to parallel shifts in the yield curve, or to measure sensitivity to specific maturity points on the yield curve (i.e. partial durations). Chart 6 shows the partial durations for a 5nc1 (1x) for various sectors on the yield curve versus its option adjusted duration calculated for a parallel rate shift in the entire yield curve. The chart shows the duration of the callable for a parallel rate shift is 2.02, i.e. the value of the callable changes by approximately 20bp for a 10bp shift in rates. However, the partial duration profile suggests that this European callable is

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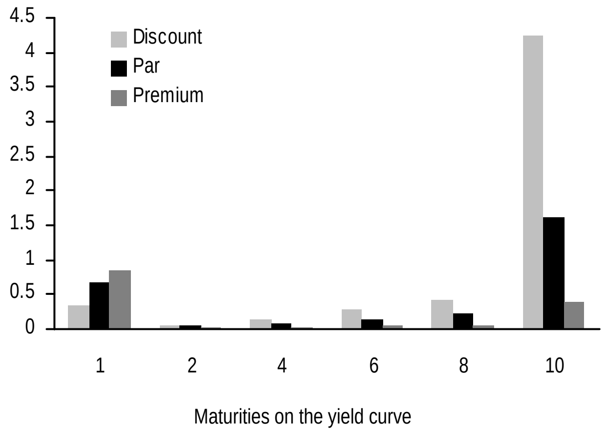
Chart 8: The partial duration profile of a callable depends on its moneyness

Partial duration profile of par, premium* and discount 10nc1 (1x) callable



*Premium coupon = Par coupon + 100bp
Discount coupon = Par coupon - 100bp

most sensitive to changes in 1- and 5-year rates, i.e. to the points on the yield curve corresponding to its lockout and final maturity. This callable may be thought of as a 1s/5s barbell.

Notably, **substituting a callable with a similar duration bullet has the impact of changing the partial duration profile while keeping the overall duration constant**. A European callable, in particular, has maximum sensitivity to points on the yield curve corresponding to its lockout and final maturity, while a bullet has maximum sensitivity to the point corresponding to its maturity. Chart 7 shows that using a 5nc1 (1x) to substitute a similar duration bullet has the impact of shifting the exposure from the 2-year sector, where most of the sensitivity of the bullet is concentrated, to the 1- and 5-year sectors. Consequently, bullet/ callable trades offer a way to do butterfly trades on a cash neutral basis and enable shifting exposure away from parts of the yield curve that have undesirable characteristics.

It is useful to analyze the partial duration profile of a callable since it sheds light on the curve exposure implied in the long callable position. Moreover, this **partial duration profile changes with the moneyness of the callable**. Chart 8 shows that the partial duration profile for a par priced 10nc1 versus that of a similar structure premium callable (which has a coupon 100bp above the par coupon) and a similar structure discount callable (which has a coupon 100bp below the par coupon). While the par-priced callable has relatively balanced exposure to its lockout and maturity (i.e. 1- and 10-year sectors), the discount callable has relatively greater exposure to its final maturity and the premium callable has relatively greater

Chart 9: The partial duration of European callables is lumpier than that of Multi-European callables

Partial duration of par 10nc1 (1x) versus par 10nc1 (Cont.), as of 10/2/2007

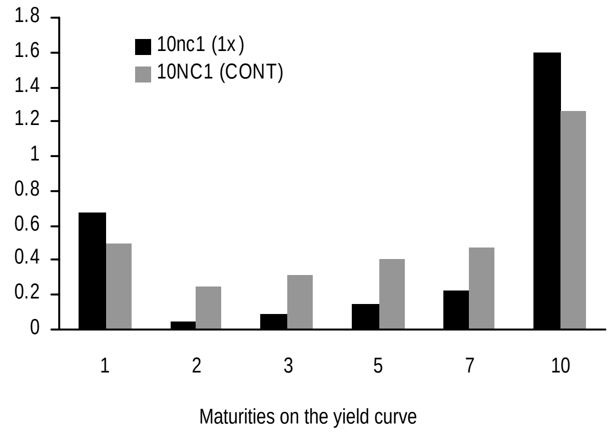


Chart 10: The duration of a callable extends in a sell-off and shortens in a rally…

OA duration of a 5nc1 (1x) and a duration-matched bullet for instantaneous parallel interest rate shifts (years)

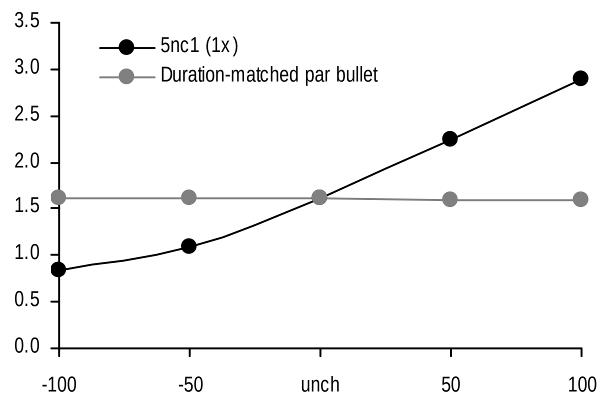
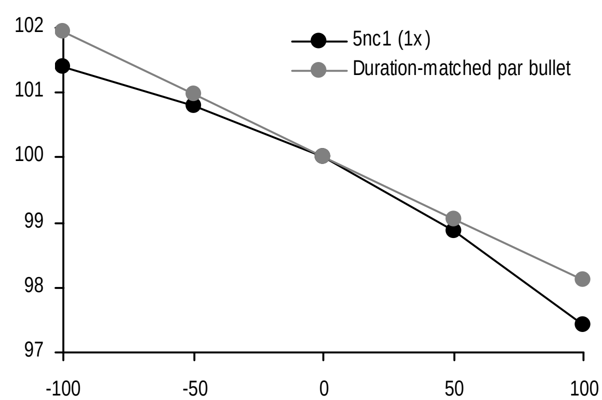


Chart 11: …and impacts its price behavior

Price of a par 5nc1 (1x) and a par duration-matched bullet over instantaneous parallel interest rate shifts



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exposure to its lockout. Hence, outright long positions in each of these callables would imply different curve positions, even if the dollar-duration in each security was kept equal. Another implication of this is that the **curve exposure in a callable portfolio can change with rate shifts**.

Notably, **the partial durations of European callables are lumpier than that of multi-European callables**, i.e. European callables have greater sensitivity to its lockout and maturity but lower sensitivity to the interim maturities when compared to similar multi-Euro structures (reflecting the limited call opportunities in the former). Chart 9 illustrates this by comparing the partial duration profiles of a par-priced European and multi-European 10nc1 to various maturities on the curve.

b. Negative convexity

Convexity is a measure of the change in duration due to a change in interest rates. It is a second order measure of the bonds' price sensitivity to changes in interest rates. Chart 10 illustrates the duration of a 5nc1 over a range of parallel moves in interest rates. It shows that as interest rates fall, the duration of the callable contracts since the issuer of the callable has a greater incentive to call the bond (as they can reissue debt at lower rates). Conversely, if the interest rates rise, the duration of the callable extends since the incentive to the issuer to call the bond declines. This behavior of durations in different interest rate scenarios is a result of the call option embedded in the bond and illustrates the negative convexity of callables (on the other hand, bullets are slightly positively convex)**.**

The changing duration of the callable drives its price behavior in different interest rate scenarios, making it a source of risk to callable performance. The implication of Chart 10 is that **the callable becomes less interest-rate-sensitive in a rally, thereby limiting its price appreciation, and more interest-rate-sensitive in a sell-off, exaggerating the price decline.** Chart 11 illustrates this price behavior for a 5nc1 versus that of similar-duration bullet over a range of interest rate scenarios.

Notably, **a callable with greater call frequency is often less negatively convex than a similar-structure callable with a lower call frequency.** For example, as shown in Table 3, a 5nc1 (SA) has less negative convexity (of -0.97) than a 5nc1 (1x) (of -1.08). This is because the duration of the European callable is more discrete than that of a multi-Euro callable (i.e. a 5nc1 (1x) can either be 1-year bullet or a 5-year bullet, versus a 5nc1 (SA) which may be called on any ½ yearly intervals between 1- and 5-years); therefore the former extends/ contracts at a faster pace in a sell-off/ rally. However, it should be noted that even though a

Chart 12: Callables become more negatively convex when the embedded option gets closer to being at-the-money

OA convexity of callables for instantaneous parallel interest rate shifts (bp); assumes constant Libor OAS, as of 10/2/2007

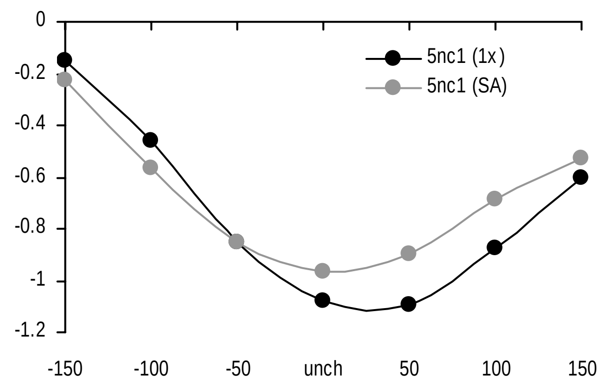

Table 6: Callables with longer lockouts and maturities are more sensitive to changes in implied volatility

Implied yield volatility sensitivity by callable (measured by yield vol vega), versus impact on callable returns due to an instantaneous 1% point decrease in yield vol, as of 10/2/2007

Structure	Vega	Swaption Implied Yield Vol	Return impact of 1% decrease in implied vol (bp)	Return impact adjusted for duration
2NC1 (1X)	-0.02	22.8	1.6	1.3
3NC1 (1X)	-0.03	22.1	3.1	2.0
5NC1 (1X)	-0.06	20.4	6.3	3.1
7NC1 (1X)	-0.08	19.1	7.8	3.3
10NC1 (1X)	-0.13	17.7	12.5	4.5
10NC2 (1X)	-0.17	17.5	17.2	4.0
10NC3 (1X)	-0.19	17.1	18.8	3.7
5NC1 (SA)	-0.08	20.4	7.8	3.7

multi-Euro callable is typically less negatively convex than a similar structure European callable, it is more sensitive to changes in implied volatility than a European callable.

The convexity of callables also changes as interest rates change, and becomes more negative as the embedded option gets closer to being at-the-money (ATM). Chart 12 shows that the convexity of par-priced callables becomes most negative if interest rates increase modestly. This is not surprising since options embedded in callables currently priced at par are in-the-money at the time of issue, given the current term structure of interest rates. Additionally, also note that Chart 12 shows that the multi-Euro callable is less negatively convex than the European structure except when rates move significantly, such as when rates rally by more than 50bp.

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Sensitivity to changes in implied volatility – Vega

A long position in a callable bond involves being short the embedded option, which results in a short position in implied volatility. Consequently, **increases in implied volatility have a negative impact on the performance of the callable bond**. The sensitivity of callables due to a change in implied volatility differs by structure and may be approximated by vega, which measures the change in the bond price due to a 1% point change in percentage yield volatility. Callables with higher vega experience a greater impact on excess returns if implied volatility changes**.** Table 6 compares the vega of several callable structures and shows that:

1. **Structures with longer lockouts and maturities typically are more sensitive to volatility**. For example, a 10nc2 (1x) has a vega of -0.17 while a 5nc1 (1x) has a lower vega of -0.06.

2. **Callables with greater optionality have greater sensitivity to volatility**. For example, a 5nc1 (1x) has a vega of -0.06 while a 5nc1 (SA) has a relatively higher vega of -0.08.

Callables with higher vega experience a greater impact on excess returns if volatility changes (Table 6). **The implication is that if implied volatility is expected to decline, then callables with higher vega should be preferred to those with lower vega.** It also follows that if implied vol is expected to increase, then callable with lower vega should be preferred to those with higher vega.

Not only do multi-Euro callables have higher vegas than similar structure European callables, but their partial vega profiles differ as well. The vega exposure of European callables is primarily concentrated on implied volatility of its relevant forward structure. For example, a 10nc1 (1x) has the greatest sensitivity to changes in 1yx9y implied vol. On the other hand, multi-European callables are sensitive to changes in a greater area of the implied vol surface (rather than a specific point). Chart 13 shows the partial vegas of the a 10nc1 (SA) and 10nc1 (Euro) for various option expirations. As shown in the chart, the European callable has the greatest sensitivity to implied volatility with 1-year expiries while the sensitivity of semi-annual callable is spread out across expiries.

As with convexity, the vega of callables does not remain constant and changes as interest rates change. Chart 14 shows the vega for par priced 5nc1 (1x) and 5nc1 (Cont.)

Chart 13: The partial vega profile of European callables is lumpier than that of multi-Euro callables
Partial yield vol vegas to various option expirations by callable (*-100) , as of 10/2/2007

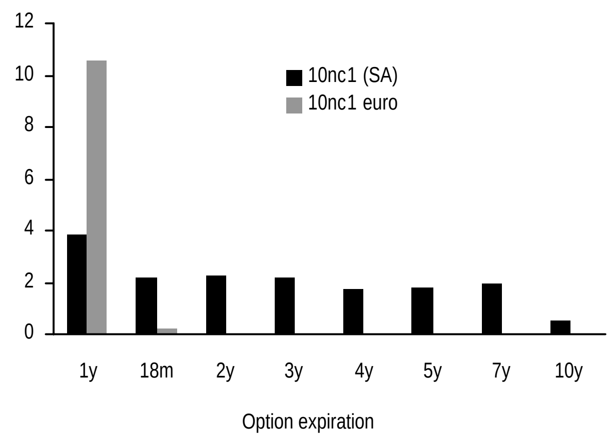
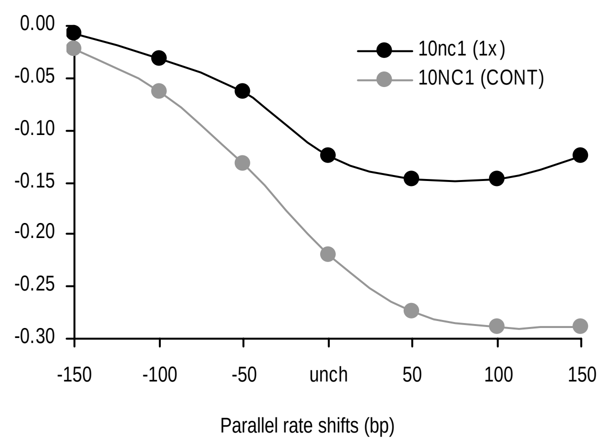


Chart 14: The vega of par priced callables increases in magnitude when the embedded option gets closer to being at the money
Yield vol vega for par 10nc1 (1x) and (Cont.) for parallel instantaneous interest rate shifts, as of 10/2/2007



and shows that the vega of these structures initially increases in magnitude as rates increase, i.e. as the embedded options get closer to being at-the-money. However, the sensitivity to volatility declines as rates continue to rise further as the option moves away from being at-the money. Also note that the continuous callable has vega of greater magnitude than that of the European callable in all interest rate scenarios.

In addition to the overall vega, the partial vega profile of a callable also changes as interest rates change. Interestingly, the partial vega profile for a Bermudan callable shifts differently from that of a European callable as interest rates change. Chart 15 shows the partial vegas of a 10nc1 (SA)

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minus that of 10nc1 (1x) for three rate scenarios. The notionals of the callables are weighted such that the total dollar vega risk is equivalent in each structure in the unchanged rate scenario.

Chart 15 shows that overweighting a bermudan callable versus a similar-structure, vega-equivalent amount of European callable has the impact of reducing vega exposure to the lockout term of the callable and increasing vega exposure to subsequent call dates (since the European vega is concentrated primarily in lockout expiries; see Chart 13). As rates increase, the bermudan vega exposure shifts to longer expiries, since the duration of the callable lengthens and the optimal call date extends (this also implies that the bermudan vega exposure shifts to shorter tails as rates rise). Conversely, as rates fall, the bermudan vega exposure shifts to shorter expiries (Chart 15), since the duration of the callable shortens and the optimal call date contracts.

Callables yield a positive spread to similar-duration and -maturity bullets; however, total return performance is also driven by convexity and vega risks, and can lead to outperformance or underperformance versus bullets. Specifically, the performance of callables relative to bullets depends on several variables, such as changes in the level of rates, slope of the curve, and implied volatility. Therefore, expectations of these variables should be applied for selective inclusion of callables in the portfolio since inclusion merely on the basis of excess yield pick may lead to underperformance. In the following sections we analyze the impact of changes in rates and volatility on callable performance.

Callable performance in different rate environments

We measure callable performance in a total return framework. The returns of a callable depend on various factors including changes in rates and implied volatility, and may be compared to returns of a bullet. **The performance of callables relative to bullets is measured in excess return terms, i.e., the holding period return of the callable bond minus that of the bullet.** Mathematically, the excess return of a callable versus a duration-matched bullet over a specific horizon may be approximated by using the following equation:

$$\text{Callable excess returns} = -(\text{Excess duration} * \text{Price} * \Delta Y) + \tfrac{1}{2} * \text{Convexity} * \text{Price} * \Delta Y^2 + \text{Vega} * \Delta\sigma + \text{Approx. excess yield spread of callable over horizon (Theta)} \quad \text{...equation (1)}$$

where, ΔY = change in yield over horizon
$\Delta\sigma$ = change in implied vol over horizon

Since the durations of the callable and the bullet are matched at inception, the first term in the equation above does not impact the excess returns. The excess returns of the callable then become dependent on the magnitude of the move in interest rates and implied volatility, and the theta (or the time decay of the option; this approximately

Chart 15: The partial vega profile of a multi-Euro callable shifts to longer expiries as rates increase
Partial vega to various option expirations of 10nc1 (SA) minus that of vega-weighted 10nc1 (1x), for various interest rate scenarios (*-100)

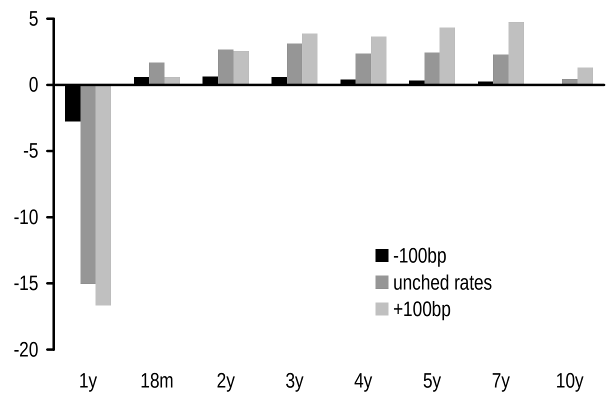
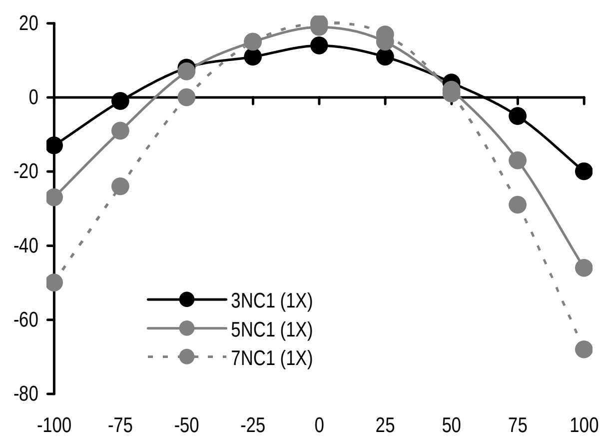


Chart 16: Callable bonds outperform similar-duration bullets if interest rates remain range-bound
Holding period return of callable minus that of forward-duration matched bullet for parallel interest rate shifts over a three-month horizon (bp); assumes constant Libor OAS and implied percentage yield volatility over horizon, as of 10/2/2007



Structure	OAC	-100	-75	-50	-25	unch	25	50	75	100
3NC1 (1X)	-0.57	-13	-1	8	11	14	11	4	-5	-20
5NC1 (1X)	-1.08	-27	-9	7	15	19	15	2	-17	-46
7NC1 (1X)	-1.54	-50	-24	0	15	20	17	1	-29	-68

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equals the excess yield spread of the callable) earned over the horizon. In the following sections, we address the impact of changes in interest rates and implied vol on callable excess returns.

We calculate the returns on a three-month horizon by aggregating the change in price over the horizon period, the coupon earned, and the reinvestment income. The horizon price of the bond is calculated assuming a constant OAS to the Libor curve for a range of interest rate shocks. The analysis assumes delta hedging only at the time of investment, i.e. the horizon durations of the callable and the bullet are matched only at the time of investment; duration mismatches may arise at the horizon period as the duration of the callable may change relative to the bullet.

Parallel rate scenarios

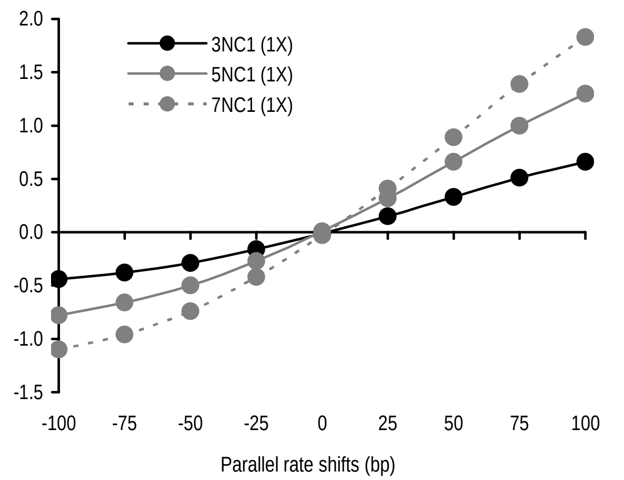
Callables outperform duration-matched bullets if interest rates remain range-bound, but underperform if interest rates move significantly in either direction, assuming that implied volatility remains unchanged. For example, Chart 16 shows that if interest rates remain unchanged, the 5nc1 (1x) earns 19bp in excess return versus a similar-duration bullet; additionally, the 5nc1 (1x) outperforms the similar-duration bullet if interest rates move in parallel in between -60 and +50bp. However if interest rates decline by 100bp in parallel, the callable underperforms the bullet by as much as 27bp. Similarly if interest rates increase by 100bp in parallel, the callable underperforms by 46bp.

This pattern of performance is due to the negative convexity of the callable: the duration of the callable extends relative to the bullet in a sell-off (Chart 17), making it more interest rate sensitive and causing it to underperform. Conversely, the duration of the callable contracts relative to the bullet in a rally, making it less interest rate sensitive and causing it to underperform. Note that the duration of the callable with the most negative convexity extends/ contracts the most relative to the bullet. The performance pattern of callables suggests that **substituting bullets with similar-duration callables is a viable strategy if an investor expects interest rates to be range-bound,** but not if interest rates are expected to move significantly in either direction.

Negative convexity is the price paid for the excess returns of callables (relative to duration matched bullets). As shown in equation 1, the excess returns of the callable are a function of the time decay (sensitivity measured by theta), changes in interest rates (sensitivity measured by delta and gamma), and changes in implied volatility (sensitivity

Chart 17: The duration of a callable extends relative to that of a bullet in a sell-off and shortens in a rally

OA duration of callable minus that of forward duration-matched bullets for parallel interest rate shifts over a three-month horizon (bp); assumes constant Libor OAS, as of 10/2/2007



measured by vega). In this analysis, we assume that the implied yield vol surface remains unchanged over the investment horizon and that the callable is hedged using a similar duration bullet (i.e. forward delta hedged at inception). Therefore, the two main sources of excess returns are: the time decay, which has a positive impact on returns since the investor is short the option, and the convexity of the callable, which has a negative impact on returns. Option theory tells us that the two are linked: the higher the theta, the higher the convexity. The impact of the convexity on callable returns is always negative (unless interest rates remain unchanged) and its magnitude is a function of the change in interest rates: the higher the change in interest rates, the greater the negative returns stemming from convexity (see equation 1). This results in an excess return profile that is positive if rates remain rangebound (from time decay) and negative if rates move significantly in either direction (as negative returns from convexity eat into the positive returns from time decay).

Note that in Chart 16, the callable with the greatest amount of negative convexity has the highest excess returns if interest rates remain range-bound, but has the least excess returns if interest rates move significantly in either direction. The return profile of the 7nc1 (1x) exhibits this in Chart 16, since it is the most negatively convex of the three instruments shown in the chart. Comparing excess returns of callables as shown in Chart 16 does not account for the different convexities between various structures. For example, comparing the excess (duration-hedged) returns of a 5nc1 (1x) with that of a 3nc1 (1x) shows that

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the former outperforms the latter if rates remain range-bound (Chart 16); but this analysis does not take into account that a long position in the 5nc1 carries greater convexity risk than an equivalent notional position in a 3nc1, i.e. 5nc1 has convexity of -1.08 while 3nc1 convexity of -0.57.

To account for the different convexities, one may adjust the notionals invested in various structures such that the dollar convexity is equal for different positions. Chart 18 shows various structures alongside the notional weights that make the dollar convexity across all positions equal. Excess returns scaled by these weights collapse to closer proximity and become more comparable, since the analysis assumes that investors are taking the same level of dollar convexity risk (by adjusting the notionals) across structures. From Chart 18, we may conclude that per unit dollar convexity, 3nc1 offers the most value among the three structures evaluated.

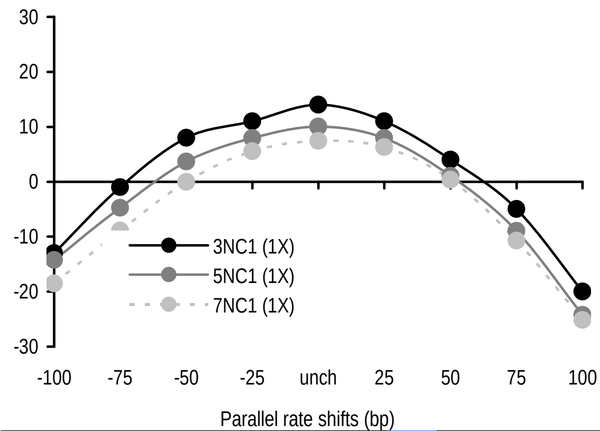
The analysis thus far compares excess returns of callables versus duration-matched bullets, and shows that using callables to replace duration-matched bullets is a viable strategy if rates remain range-bound. However, if interest rates are expected to move significantly, the strategy of substituting bullets with similar-duration callables will lead to underperformance and duration mismatches at the end of the investment horizon; instead investors often use callables to substitute different duration bullets as this may result in better performance. For example, an investor may use callables to replace maturity-matched bullets if he/she is bearish on rates, since the callable will likely extend if these expectations are realized. Conversely, if an investor is bullish on rates, callables may be used as a substitute for lockout-matched (or shorter-duration) bullets, as the duration of callables will likely contract if expectations are realized. Clearly, this type of strategy involves taking duration risk if the trade is executed on a proceeds neutral basis, making its performance dependent on the direction of rates.

Structure Selection: Breakeven Mapping

The two main risks in a long callable position are either that rates break out of their range and start trending, or that implied volatility increases. This raises the question that **given these risks, which callable structures have the most cushion against changes in rates and implied vol?** We propose using 'Breakeven Maps' to identify these callables.

Chart 18: Weighting notionals such that dollar convexity is equivalent across structures enables comparison of excess returns adjusted for varying convexities

Convexity-weighted holding period return of callable minus that of similar-duration bullet for parallel interest rate shifts over a three-month horizon (bp); assumes constant Libor OAS and percentage yield volatility surface



Structure	OAC	Cvx-neutral Weights	-100	-75	-50	-25	unch	25	50	75	100
3NC1 (1X)	-0.57	100%	-13	-1	8	11	14	11	4	-5	-20
5NC1 (1X)	-1.08	53%	-14	-5	4	8	10	8	1	-9	-24
7NC1 (1X)	-1.54	37%	-19	-9	0	6	7	6	0	-11	-25

Charts 19 and 20 graph the breakeven increase in implied yield vol versus the breakeven changes in rates for various par-priced callables over a three-month horizon. The breakeven increase in implied vol, shown on the y-axis of both charts, is the increase in implied yield vol required to completely offset the projected callable excess returns versus the duration-matched bullet if interest rates remain unchanged. A higher breakeven implies that the callable has greater cushion against increases in the level of implied vol. The breakeven change in rates, shown on the x-axes of Charts 19 and 20, is the parallel change in rates required to make callable excess returns relative to duration-matched bullets zero, holding implied vol constant. Note that Chart 19 shows the rate breakevens if markets rally, while Chart 20 shows the rate breakevens if markets sell-off. Callables that have rate breakevens with higher magnitude have greater cushion. Hence, **callables that fall in the upper left quadrant in Chart 19 and the upper right quadrant in Chart 20 are relatively more attractive**.

When using this framework to identify callables with wide breakevens, **one may merge the two charts into a single one that plots the vol breakevens versus the minimum of the two rate breakevens (i.e. the 'breakeven-to-worst'),** since the minimum of the two breakevens is the more conservative measure of the cushion to changes in rates. For example, all callables evaluated here have

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greater cushions if rates rally than if rates sell-off; i.e., the magnitude of rally-side breakevens (Chart 19) is greater than the magnitude of sell-off breakevens (Chart 20). This is because the options embedded in the par-priced callables evaluated are currently in-the-money, resulting in shorter durations at inception. Hence, the magnitude of duration extension in a sell-off is greater than the magnitude of duration contraction in a rally, resulting in a skew in the rate breakevens. Since the magnitude of breakevens is smaller if rates sell-off, these are more relevant while making investment decisions. Consequently, only Chart 20 may be used to identify callables that have wide breakevens. **It is relevant to examine these breakevens in the context of the recent observed volatility in changes in rates and implied vol.** The dotted lines in the charts represent 1-standard deviation of three-month changes in the level of rates and implied vol respectively, calculated since the Fed went on hold in 2006. The charts show that several structures have vol and rate breakevens greater than this cut-off in implied vols and rates.

Callables that meet rate and volatility breakeven cut-offs in the framework described above may subsequently be ranked by using criteria preferred by the investor. We recommend using convexity-weighted excess returns to rank these callables, since using outright excess returns does not take into account the varying convexity risk among callable structures. Table 7 shows a ranking by convexity-weighted excess returns for callables screened using Chart 20.

Table 7: Callables with relatively wide breakevens may be ranked by convexity-weighted excess returns
Callables selected using Chart 20, ranked by convexity-weighted returns versus duration-matched bullets (bp)

	Convexity weighted excess return
5NC1 (1X)	12
3NC1 (1X)	11
10NC1 (1X)	11
7NC1 (1X)	11
5NC1 (SA)	9
2NC1 (1X)	7

* Convexity-weighted returns are calculated by adjusting the notionals such that the dollar convexity is equivalent in each structure

Performance of callables and the term structure of implied volatility

As discussed previously, a long position in a callable bond involves being short the embedded option, which results in a short position in implied volatility. Consequently, an increase in the level of implied volatility has a negative impact on callable returns, while a decrease in the levels of implied vol has a positive impact on returns. **When making investment decisions in callables with high vega, in addition to the outlook on the level of implied vol, one should consider the term structure of the vol surface as well**, since it is possible that the vol surface is

Chart 19: Breakeven increase in implied vol versus decrease in rates required to break even
Increase in implied yield vol (%) required to completely offset projected 3-month excess return of callable (relative to (forward) duration-matched bullets) versus decrease in rates required to breakeven (bp) , as of 10/2/2007

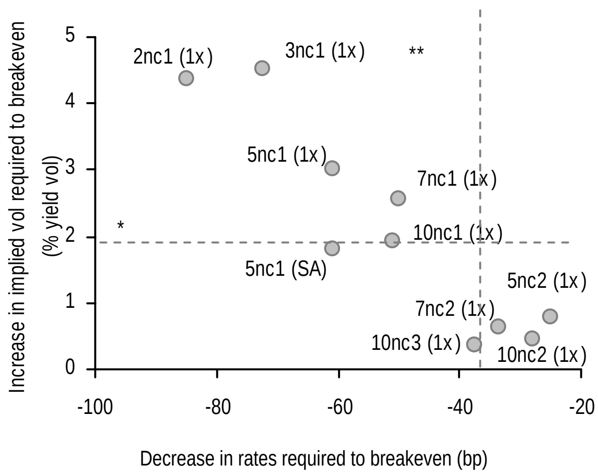
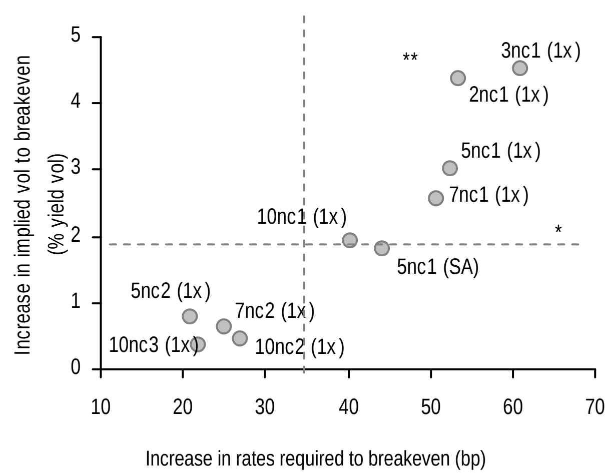


Chart 20: Breakeven increase in implied vol versus increase in rates required to break even
Increase in implied yield vol (%) required to completely offset projected 3-month excess return of callable (relative to (forward) duration-matched bullets) versus decrease in rates required to breakeven (bp) , as of 10/2/2007



* 1 standard deviation change in implied yield vol, calculated for 3-month changes since the Fed went on hold.
** 1 standard deviation change in yields, calculated for 3-month changes since the Fed went on hold.

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such that as the time to the exercise date elapses, the vol used to price the embedded option in the callable changes. The change in volatility used for pricing the option over the horizon assuming an unchanged spot vol surface is referred to as the vol slide. Chart 21 shows the 6-month skew-adjusted vol slide[1] by structure; the chart shows that the skew-adjusted volatility for a 30nc10 increases by 0.09% points on a six-month horizon (i.e. it has a positive vol slide), which contributes negatively to returns.

The impact of the vol slide on callable returns depends the on its vega, and is shown in Chart 22. The chart shows that even though the 3nc1 has the highest (detrimental) vol slide of 1.5% on a six-month horizon, its estimated return impact is only -4bp. In contrast, the 30nc10 has a detrimental vol slide of a smaller magnitude of 0.09%, but its return impact is similar at -5bp. A similar return impact despite a lower magnitude of vol slide in the 30nc10 is a result of its higher vega relative to the 3nc1.

Expressing views on the implied vol surface

Callables may also be used to implement relative value views in volatility between different parts of the curve. The volatility used to price the embedded option is one of the variables that determine its yield pick: the higher the implied vol, the higher the value of the embedded option and the higher the yield pick. Hence, if volatility on a part of the curve is trading rich (high) relative to the rest of the curve, there is value in preferring callables that use the rich volatility to price the embedded option. In particular, European callables may be used for positioning for volatility relative value trades since the vol input for pricing Euro callables is relatively unambiguous.

An example of a relative value vol surface trade is shown in Charts 23 and 24. Chart 23 shows that the spread between the implied vol for 10nc2 (1x) and 30nc5 (1x) is close to its narrowest level since 1998. This spread is expected to widen if the Fed continues to ease, as shown in Chart 24. Furthermore, technicals also support this trade: we expect fixed-rate Agency MBS supply to increase since new purchase loans are now increasingly being securitized as Agency MBS (rather than non-Agency) and ARMS are refinanced into fixed-rate mortgages. Hedging activity for

[1] Calculated as projected future spot vol (assuming unchanged vol surface) minus spot vol. For e.g., 6-month vol slide for 2nc1 = 6mx1y vol – 1yx1y vol, adjusted for skew. The skew adjustment recommended by the BMA guidelines for trading European callables has been used. Please refer to Appendix II for details.

Chart 21: The vol slide is currently detrimental for most callables

Projected change in applicable skew-adjusted percentage yield volatility[1] for select European callables over a six-month horizon (%), as of 10/2/2007

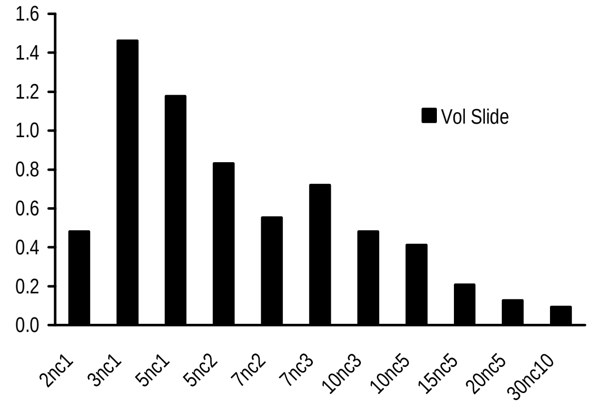

Chart 22: The impact of vol slide on callable returns depends on its vega

Estimated impact on return due to change in skew-adjusted yield volatility for select European callables over a six-month horizon, i.e., vol slide x vega (%); as of 10/2/2007

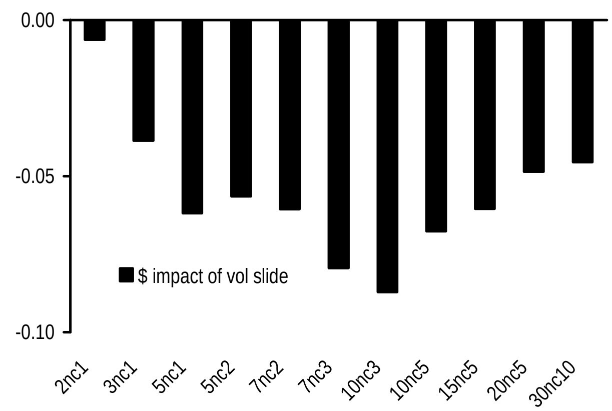

Chart 23: Relative value on the vol surface: The weighted spread between 10nc2 and 30nc5 implied vols is close to its narrowest level since 1998

2Yx8Y implied vol minus 5Yx25Y implied vol (bp/day)

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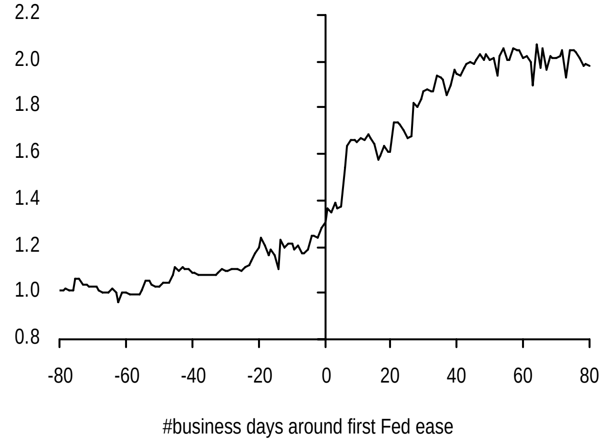
these fixed-rate MBS will likely create a bid for 2Yx8Y vol (and implied vol with similar expirations/ tails), pressuring it higher. Additionally, constraints on bank balance sheets require them to issue more debt, which could also result in issuance of trust preferred securities. If realized, this would increase the supply of vol in longer expirations/ tails and bias 5Yx25Y vol lower. Consequently, in this case, we would recommend overweighting 30nc5 callables versus 10nc2 callables (i.e. buy 2Yx8Y vol versus selling 5Yx25Y vol) to benefit from a widening in this spread. In the event the vol spread increases by 0.8bp/day to its long-term average of 1.7, it would imply a return impact of approximately 39bp.

Chart 24: The 10nc2/ 30nc5 implied vol spread is expected to widen if the Fed eases further

2Yx8Y implied vol minus 5Yx25Y implied vol (bp/day) averaged around first Fed eases in 1998 and 2001*



* Dates used are 9/29/98 and 1/3/01

Conclusion

Callables offer yield pickup relative to Agency bullets, but their performance depends on several variables, including changes in the level of rates, slope of the curve, and volatility. Therefore, expectations of changes in these variables should be considered when making investment decisions in callables.

- If interest rates are expected to be range-bound, then callables may be used to substitute bullets with similar durations. Callables outperform duration-matched bullets as interest rates remain range-bound, but start underperforming bullets if interest rates move significantly in either direction. The reason for this performance pattern is the negative convexity of the callable, which causes its duration to extend in a sell-off and contract in a rally.

- To account for the different convexities, we recommend adjusting the notionals invested in various structures such that the dollar convexity is equal for different positions. Excess returns scaled by these weights collapse to closer proximity and become more comparable, since the level of convexity risk is the same across structures. In a portfolio context, **we recommend looking at convexity-weighted excess returns of callables, and overweighting those callables that offer greatest excess returns per unit dollar-convexity risk**.

- **Using a callable to substitute a duration-matched bullet changes the partial duration profile of the portfolio** while keeping the overall duration unchanged. It is thus essentially a butterfly trade, albeit one where the risk weights on the wings can change as yields and/or the slope of the yield curve change.

- The partial duration profile of the callable may be used to assess the curve exposure in a long callable position.

- If volatility is expected to decline, then callables with high vega may be used to enhance returns, since being long the callable implies being short volatility. Conversely, an increase in vol reduces the excess return of the callable.

- The return impact of the vol slide should be considered when investing in callables with high vega, especially if implied volatility levels are expected to remain rangebound over the investment horizon. A positive vol slide will contribute to returns negatively and vice versa. The return impact of the vol slide will depend on the vega of the callable.

- **'Breakeven Maps' help identify callables that have wide breakevens to changes in implied vol and rates.** Structures that meet vol and rate breakeven cut-offs may be ranked by convexity-weighted excess returns, since this enables comparison of excess returns that are convexity neutral. This framework allows for a balanced comparison of excess returns against convexity as well as vega risk, and assists portfolio managers in choosing the best callable bonds for their bond portfolios on a risk-adjusted basis.

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Appendix I: Introducing option adjusted spread (OAS)

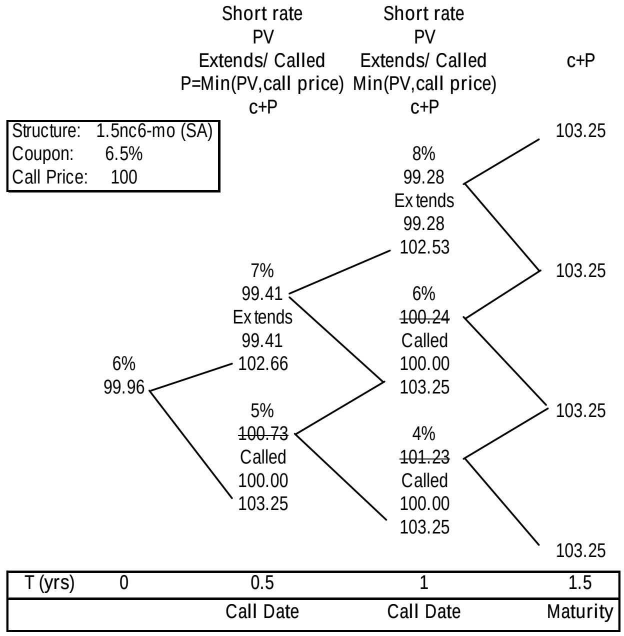
The OAS is a measure of value that accounts for the variability in future cash flows of fixed-income securities with embedded options. **It is the constant spread must be added to the forward rates in the bond pricing model in order for the discounted coupon and principal cash flows to sum up to the dirty price of the bond plus the present value of the call.** The OAS may be calculated relative to any curve, such as the swap, Treasury or the Agency bullet curves.

In this section, we illustrate a stylized calculation of OAS for a callable bond with multiple call dates using a tree-based approach, which allows for the evolution of rates; for simplicity, and to focus on illustrating the notion of OAS rather than term structure modeling, we assume that all spot and forward rates are the same (i.e., a fully flat yield curve) and that rates shift up or down by 1% with equal probability in constructing the tree. Details of actual tree construction, and calibration to the options market, are beyond the scope of this piece[2].

The tree shown in Chart 1 outlines the evolution of rates; at each node of the tree, short rates (used for discounting) as well as the forward rate to final maturity (used to price the residual bond at that node) are known. Clearly, the bond has a forward (undiscounted) value of 103.25 at terminal nodes, since at maturity the bond is redeemed at par plus the semiannual coupon. Now, we consider a node in the previous "layer" – i.e., a node that corresponds to the 1-year forward horizon. Since this node can lead to one of two "child" nodes in the next time step, the value of this node is simply the discounted value (discounted at the short rate corresponding to the current node) of the average of the two child node values (since we assume equal probability), plus the coupon payment due at the current node; however, regardless of what the total value is, the current node's value cannot exceed 103.25, since the bond is callable at par (plus coupon payment). Working successively backwards, we may construct the node values as shown in Chart 1; in particular, we recover a current price of 99.96 in this simple example.

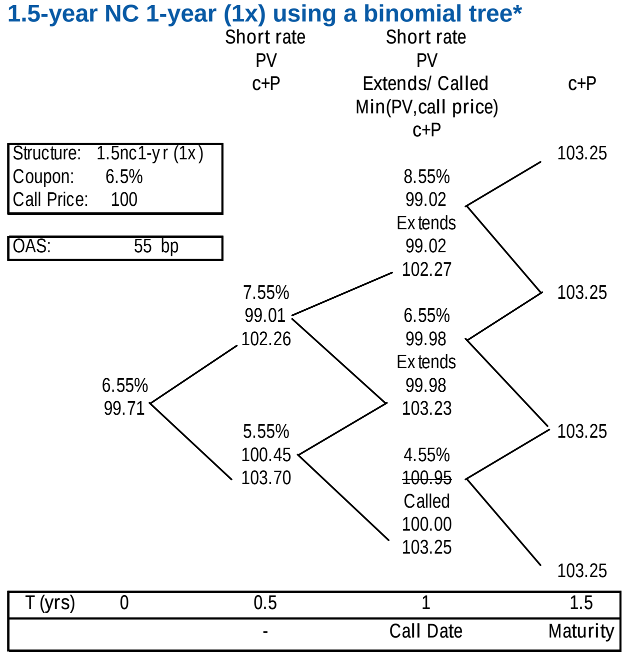
Suppose now that we observe that the market price of the Agency callable bond changes due to a change in demand. Clearly, the tree as constructed above does not change at all, nor does our calculated price of 99.96. In general, we find that the market price of the callable is different from the model price of the bond as calculated in Chart 1. This motivates the notion of an option adjusted spread. Consider what would happen if we calculated node values by discounting child node values not at the short rate, but at the short rate plus a spread. The larger the spread, the

Chart 1: Pricing a 1.5-year NC 6-month (SA) using a binomial tree*



* The tree assumes that the short rate may move by 1% per period; short rates shown assume no OAS adjustment

Chart 2: Calculating the OAS for a given price for the 1.5-year NC 1-year (1x) using a binomial tree*



* The tree assumes that the short rate may move by 1% per period

[2] See 'The Handbook of Fixed Income Securities' by Frank J. Fabozzi

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cheaper each node will be. There exists some spread at which the price calculated by the tree will equal the market price of the bond. This is defined to be the option adjusted spread, or OAS. Chart 2 illustrates this calculation assuming an idiosyncratic 0.25 point cheapening in the callable bond used in the previous example, with all else being held constant.

It should be noted that European callables may be priced using a formula-based approach rather than a tree-based approach. In fact, the Bond Market Association has issued standard guidelines for quoting and trading European callables, which we discuss in Appendix II. Unlike for European callables, the SIFMA has not issued any standard guidelines for quoting prices of multi-European callables. Different models and assumptions may be used for pricing the embedded option and this will lead to different values for the OAS. Additionally, the yield curve used to calculate the OAS may also differ.

Appendix II: SIFMA guidelines for trading European callables

The Securities Industry and Financial Markets Association (SIFMA, formerly BMA) has issued voluntary guidelines for quoting the prices of European Agency callables. These guidelines were first introduced in 2003 and subsequently revised in 2004. The guidelines are applicable to European callables that meet certain requirements, such as it should have a minimum size of $1bn, be callable at par, and have a call date that is a coupon payment date. The OAS calculated using these guidelines is commonly known as the AOAS.

The **SIFMA guidelines specify (i) the formula used for pricing the embedded option, (ii) the volatility skew adjustment and (iii) the designated yield curve**. The guidelines recommend that the embedded option be priced using the Black’76 formula for swaptions using a skew-adjusted implied volatility parameter and discount factors that are computed using the OAS-adjusted forwards. Specifically, the skew adjustment is done using the Blyth-Uglum approximation as shown below:

$$\boxed{\text{Skew adjusted vol} = \text{Sqrt}(F/C) * V}$$

where,

F = the relevant forward rate
C = coupon of the callable
V = base swaption volatility (percentage yield)

The skew adjustment has the impact of lowering the applicable swaption yield vol for an in-the-money callable (since the forward rate is lower than its coupon). Conversely, it also has the impact of increasing the applicable swaption yield vol for an out-of-the-money callable.

Finally, the guidelines recommend calculating the OAS to a designated yield curve, which is the issuer-specific constant maturity yield curve, when available. FNMA and FHLMC constant maturity yield curves are available on Bloomberg and their websites. FHLB callables use the swap curve.

The SIFMA guidelines involve pricing the callable by pricing the bond and the embedded call option separately, unlike the binomial tree-based approach described in Appendix I which does not split the callable into two parts. For a given OAS, the price of the callable is calculated by first pricing the bullet component (which has maturity and coupon equal to the final maturity and coupon of the callable). The bullet is priced by discounting the future cash flows using the zero rates calculated from OAS-adjusted forward rates, using the yield curve of choice. The given OAS needs to be added to the forward rates used for discounting cash flows in the option pricing model as well. Finally, price of the callable bond is computed by subtracting the price of the option from the price of the bullet calculated above. Note that if the price of the bond had been given (instead of the OAS), the process of OAS calculation would have involved an iterative process of adding a constant spread to the forward rates till the model price equaled the market price of the bond.

It should be noted that the SIFMA guidelines are a standard market convention for trading and quoting European callables. However, OAS may be calculated using different assumptions for the purpose of relative value. For example, different volatility skew adjustments or yield curves may be used by investors in assessing relative value among callables.

For details on the trading guidelines recommended by the SIFMA, please visit their website www.sifma.org.

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