An Introduction to CMO Cashflow Structures
Contents

Introduction ............................................................................................................................... 4

Structuring Principal Payments ........................................................................................................ 5
Sequential Structures .................................................................................................................. 5
Collateral Matters ......................................................................................................................... 6
Accrual or Z Bonds ......................................................................................................................... 7
Accretion-Directed Bonds ............................................................................................................... 9
PAC Structures ............................................................................................................................ 12
TAC Structures ............................................................................................................................ 16
Structures With Multiple Redemption Schedules ........................................................................... 20

Structuring Coupon Payments ................................................................................................... 25
Bond Coupons Matter Too .............................................................................................................. 25
Floaters and Inverse Floaters .......................................................................................................... 25
IOs and POs ................................................................................................................................. 26

CMO Bond Characteristics Change as Interest Rates Move ......................................................... 30
Vast Range of Possibilities ........................................................................................................... 31
Figures

Figure 1. Four-Tranche Sequential-Pay CMO — Projected Principal Payments at Selected PSAs .......................................................... 5
Figure 2. Option-Adjusted Characteristics of a Four-Tranche, Sequential-Pay CMO Backed by Current-Coupon Collateral — Market-Implied Vols, LIBOR-Treasury Swap Curve, 5 Oct 00 .................................................................................. 6
Figure 3. Option-Adjusted Characteristics of a Four-Tranche, Sequential-Pay CMO Backed by Discount Collateral — Market-Implied Vols, LIBOR-Treasury Swap Curve, 5 Oct 00 ................................................................. 7
Figure 4. Comparison of Two Four-Tranche Sequential Pay CMOs: Current-Pay Versus Z Structure — Projected Principal Payments at 175% PSA ................................................................................................. 8
Figure 5. Option-Adjusted Characteristics of a PAC CMO Structure Backed by Current-Coupon Collateral with Final Tranche Converted to a Z — Market-Implied Vols, LIBOR-Treasury Swap Curve, 5 Oct 00 ................................................................. 9
Figure 6. Sequential-Pay Z Structure with Accretion-Directed Tranches — Projected Principal Payments at Selected PSAs .............. 10
Figure 7. Weighted-Average Life Profile Comparison: Tranche B from Standard Z Structure Versus Tranches B and VB from Its Accretion-Directed Counterpart .......................................................................................................................... 11
Figure 8. Option-Adjusted Characteristics of a Standard Z Structure Backed by Current-Coupon Collateral Versus Its Accretion-Directed Counterpart — Market-Implied Vols, LIBOR-Treasury Swap Curve, 5 Oct 00 .................................................................................. 12
Figure 9. Creating a PAC Redemption Schedule With a Protected Range of 100%–275% PSA ................................................................................. 13
Figure 10. PAC CMO Structure — Projected Principal Payments at Selected PSAs .................................................................................. 14
Figure 11. Departure from Schedule of Longer PACs — Projected Principal Payments of a PAC CMO Structure at 350% PSA .......... 15
Figure 12. PAC Range Drift — Projected PAC Ranges (% PSA) Over Time at Selected Prepayment Rates ........................................................................ 16
Figure 13. At High Prepayment Rates the Support Tranches are Rapidly Amortized and the PACs “Break” — Projected Principal Payments of a PAC CMO Structure at 500% PSA .................................................. 17
Figure 14. Weighted-Average Life Profile Comparison: Five-Year Sequential Versus Comparable PAC and Support .................. 18
Figure 15. Option-Adjusted Characteristics of a PAC CMO Structure Backed by Current-Coupon Collateral — Market-Implied Vols, LIBOR-Treasury Swap Curve, 5 Oct 00 .................................................................................. 19
Figure 16. TAC CMO Structure — Projected Principal Payments at 175% PSA .................................................................................. 20
Figure 17. TAC CMO Structure — Projected Principal Payments at Selected PSAs .................................................................................. 21
Figure 18. Weighted-Average Life Profile Comparison: Five-Year Sequential Versus Comparable PAC and TAC ......................... 22
Figure 19. Weighted-Average Life Profile Comparison: Long Sequential Versus Comparable PAC Support and TAC Support .......... 23
Figure 20. Option-Adjusted Characteristics of a TAC CMO Structure Backed by Current-Coupon Collateral — Market-Implied Vols, LIBOR-Treasury Swap Curve, 5 Oct 00 .................................................................................. 24
Figure 21. CMO Structure with Multiple Redemption Schedules (PAC I, PAC II, and TAC) — Projected Principal Payments at 175% PSA .................................................................................................................. 25
Figure 22. CMO Structure with Multiple Redemption Schedules—Projected Principal Payments at Selected Prepayment Rates Below the Pricing Speed of 175% PSA .................................................................................. 26
Figure 23. CMO Structure with Multiple Redemption Schedules — Projected Principal Payments at Selected Prepayment Rates Above the Pricing Speed of 175% PSA .................................................................................. 27
Figure 24. Option-Adjusted Characteristics of a CMO Structure with Multiple Redemption Schedules Backed by Current-Coupon Collateral — Market-Implied Vols, LIBOR-Treasury Swap Curve, 5 Oct 00 .................................................................................. 28
Figure 25. Schematic Representation: Splitting a Fixed-Rate PAC into a Floater and an Inverse Floater ................................................ 29
Figure 26. Option-Adjusted Characteristics of a Floater and Inverse Floater Versus Their Underlying Fixed-Rate PAC — Market-Implied Vols, LIBOR-Treasury Swap Curve, 5 Oct 00 .................................................. 30
Figure 27. Projected Price Paths: IO and PO Versus Underlying Current-Coupon Pass-Throughs, 5 Oct 00 .......................................................... 31
Figure 28. Projected Effective Duration and Convexity Paths: IO and PO Versus Underlying Current-Coupon Pass-Throughs, 5 Oct 00 .................................................................................................................. 32
Figure 29. Projected Price, Effective Duration, and Effective Convexity Paths: Ten-Year PAC and Sequential Versus Comparable Duration Treasury, 5 Oct 00 .................................................................................. 33
**Introduction**

Since the first collateralized mortgage obligation (CMO) was issued in June 1983, many CMO cashflow structures have been developed. The earliest structure was the sequential-pay CMO. As the name suggests, CMO tranches in a sequential pay structure are amortized in sequence. The sequential pay structure partitions the underlying mortgage collateral into bonds of varying maturities and durations, but does not allow the optionality of the bonds to be tailored. The development of accrual or Z-bonds in October 1983 extended the structuring envelope modestly, allowing the creation of bonds with longer durations and greater negative convexities than was possible in a standard current-pay sequential structure. However, it was not until 1986 that structuring techniques became available to tailor both the effective duration and effective convexity of a tranche. These techniques included principal payment scheduling and prioritization (e.g., planned amortization classes (PACs) and targeted amortization classes (TACs)), variable coupons (e.g., floaters and inverse floaters), and coupon stripping (e.g., interest-only securities (IOs) and principal-only securities (POs)). In this report, we will introduce these techniques by analyzing a selection of cashflow structures. Our focus will be on how the risk characteristics of a CMO are affected by the interaction between the prepayment sensitivity of its underlying collateral, and the structure’s principal and coupon payment rules.
Structuring Principal Payments

Sequential Structures

Figure 1 depicts how the bonds in a hypothetical four-tranche, sequential-pay CMO backed by current-coupon collateral are projected to amortize assuming three different collateral prepayment rates. The sequential structure segments the widely dispersed principal payments of the underlying mortgage collateral into a series of short-, intermediate-, and long-maturity bonds. However, although the maturities of the bonds have been targeted to an extent, they are all still subject to uncertainty stemming from the prepayment risk of the underlying pass-throughs. If realized prepayments are faster than anticipated, all of the bonds will shorten; if realized prepayments are slower than anticipated, all of the bonds will extend.

![Figure 1. Four-Tranche Sequential-Pay CMO — Projected Principal Payments at Selected PSAs](source:image_url)
While Figure 1 clearly shows that the prepayment risk of the underlying collateral is passed through to the CMOs, it is not obvious how this risk is apportioned among the tranches. This is the primary reason that option-adjusted spread (OAS) models — which allow the embedded optionality of each bond to be quantified — have become key analytical tools in the valuation and hedging of CMOs.\(^1\) In Figure 2, using the SSB OAS model, we calculate the option-adjusted characteristics of these CMOs, and compare them to those of the underlying mortgage collateral.\(^2\) We see that the collateral has indeed been parsed into a series of bonds with short, intermediate, and long durations. However, we also see that the option cost of the underlying collateral has been unequally distributed across the tranches. The shortest and longest bonds have lower option costs and better convexities than the underlying pass-throughs, while the intermediate bonds have higher option costs and more negative convexities.

![Figure 2. Option-Adjusted Characteristics of a Four-Tranche, Sequential-Pay CMO Backed by Current-Coupon Collateral — Market-Implied Vols, LIBOR-Treasury Swap Curve, 5 Oct 00](image)

<table>
<thead>
<tr>
<th>Class</th>
<th>Principal Amount (SM)</th>
<th>Coupon Type</th>
<th>Price</th>
<th>Yield</th>
<th>WAL</th>
<th>OAS Cost</th>
<th>Eff Dur</th>
<th>Eff Cnvx</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>$24.85 7.5% Seq</td>
<td>$100.48</td>
<td>7.14%</td>
<td>1.8Yrs.</td>
<td>0bp</td>
<td>35bp</td>
<td>0.9</td>
<td>-1.4</td>
</tr>
<tr>
<td>B</td>
<td>26.57 7.5 Seq</td>
<td>100.16</td>
<td>7.51</td>
<td>5.0</td>
<td>0</td>
<td>66</td>
<td>2.9</td>
<td>-2.0</td>
</tr>
<tr>
<td>C</td>
<td>30.16 7.5 Seq</td>
<td>98.91</td>
<td>7.74</td>
<td>10.2</td>
<td>0</td>
<td>73</td>
<td>4.9</td>
<td>-2.0</td>
</tr>
<tr>
<td>D</td>
<td>18.42 7.5 Seq</td>
<td>99.22</td>
<td>7.67</td>
<td>20.0</td>
<td>0</td>
<td>59</td>
<td>7.0</td>
<td>-0.9</td>
</tr>
<tr>
<td>P-Ta</td>
<td>$100.00 7.5% P-T</td>
<td>$99.66</td>
<td>7.63%</td>
<td>8.6Yrs.</td>
<td>0bp</td>
<td>64bp</td>
<td>3.8</td>
<td>-1.6</td>
</tr>
</tbody>
</table>

\(^a\) Underlying current-coupon pass-throughs.

Source: Salomon Smith Barney.

**Collateral Matters**

Although CMO structures can redistribute prepayment risk among their tranches, the total prepayment risk of their underlying collateral cannot be changed. Consequently, the optionality of CMOs will depend on both their structure and their underlying collateral. This fact becomes evident when the characteristics of the current-coupon-backed sequentials analyzed in Figure 2 are compared to identically structured bonds backed by collateral with a coupon 1% below the current-coupon rate, shown in Figure 3. The discount-backed bonds are longer and less negatively convex than their current coupon-backed counterparts, because their collateral is longer and less negatively convex — and the collateral’s characteristics are passed through to the CMO bonds.

---


\(^2\) For illustrative purposes, all of the CMOs analyzed in this report were priced at a 0bp OAS over the LIBOR-Treasury swap curve of October 5, 2000. Consequently, the option costs shown were also the bonds’ zero-volatility OASs over that curve.
Accrual or Z Bonds

An accrual or Z bond has two phases. The first is an accrual phase, during which interest is not paid currently, but is instead added to the outstanding principal balance of the bond. The second is a payment phase, when the Z is paid interest and its principal is amortized (during this phase the Z is equivalent to a standard, current-pay bond). During the accrual phase, the deferred interest (referred to as Z accretion) can be used to accelerate the amortization of shorter maturity tranches. Accordingly, increasing the size of a Z bond in a structure will increase the degree to which earlier maturity bonds are shortened. Consequently, introducing a Z into a structure will affect the characteristics of other bonds in the structure.

For example, in Figure 4, we compare (at 175% PSA) the principal amortization diagram of the four-tranche sequential-pay CMO depicted in Figure 1 with that of an identically structured CMO, except that the final tranche has been changed from a current-pay to a Z bond. Several differences are immediately obvious. First, the maturities of the first three bonds in the Z structure are shorter than are those in the current-pay structure. Second, there is a discontinuity in the Z structure’s principal payments, just as the Z starts to amortize. Third, the size of the Z is larger than the size of its corresponding current-pay bond. All of these effects stem from the Z’s accretion. Although the Z and its current-pay counterpart were structured to have the same size principal balances at issue, as the Z accretes its size increases, as its interest payments are used to accelerate the principal payments on the shorter tranches. The discontinuity in the Z structure’s principal payments occurs when all of the shorter tranches in the structure have matured, and the Z’s coupon is no longer used to accelerate the amortization of other bonds, but is instead paid out currently as the coupon on the Z.
In Figure 5, we show the option-adjusted characteristics of the bonds in the Z structure, which contrast with those of its current-pay counterpart shown in Figure 2. As expected, the effective durations of the first three bonds in the Z structure are shorter, and that of the Z is longer, than the corresponding bonds in the standard sequential pay structure. Also evident, from Figure 5, is that the addition of the Z improved the convexities of the other tranches in its structure. In contrast, the convexity of the Z itself is worse than that of its corresponding current-pay bond. These effects occur because the Z accretion, that is directed to the earlier-maturity tranches, not only shortens them, but it reduces their extension risk in rising interest rate (falling prepayment rate) environments — and reduced extension risk results in improved convexity. The reduction in extension risk arises from the Z’s accretion, which is independent of prepayment rates — the Z’s accretion continues to build over time (compounding at the Z’s coupon rate), regardless of how slowly the collateral underlying the CMO prepays.
Accretion-Directed Bonds

We have just seen how the addition of a Z to a standard sequential-pay CMO can shorten and stabilize the other tranches in the structure. Because of their greater stability, tranches benefiting from Z accretion have better convexity and smaller option costs than comparable bonds in a standard current-pay structure and consequently, should theoretically trade at tighter nominal yield spreads over Treasuries (or any other benchmark curve).

However, prior to the early 1990s (when the use of OAS models became widespread), the market was often reluctant to pay a significant premium for this additional stability — probably because the magnitude of the improvement was usually modest and, without an OAS model, difficult to value. This situation changed in the late 1980s, when the first accretion-directed bonds were issued. In the first Z structures with accretion-directed tranches, the Z’s accretion was not used to accelerate the amortization of all shorter tranches, but was instead “directed” to a new category of bonds — the “accretion-directed” tranches. The beauty of the accretion-directed structure was that a very stable cashflow — the Z accretion — was focused on a small group of bonds (instead of being diffused over the entire structure). Because their additional stability was obvious, the market was willing to pay a significant yield premium for the accretion-directed tranches.

Figure 6 depicts how the tranches in the Z structure shown in Figure 4 (modified to include a group of accretion-directed tranches) will amortize at three different prepayment rates. At the slowest prepayment rate shown (100% PSA), the accretion-directed tranches do not exhibit any extension because all of the cashflows to amortize the accretion-directed tranches come from the coupon accretion of the Z, which, in turn, comes from the coupon on the underlying collateral. In fact, because they do not rely on principal payments from the underlying collateral for amortization, even at 0% PSA, these accretion-directed bonds would not extend. Consequently, accretion-directed tranches can provide absolute extension protection. However, they still have call risk, because they must be amortized prior to the paydown of their corresponding Z bond. (A group of accretion-directed tranches must mature prior to the start of amortization of their corresponding Z, because as soon as the Z starts to amortize — and becomes a current-pay bond — the Z accretion is no longer available to amortize the accretion-directed bonds.)

---

3 The size of the Z was reduced to match the weighted-average lives of tranches A, B, and C to those of the standard sequential-pay structure discussed earlier. This was done to improve the comparability of the weighted-average life profiles shown in Figure 7 and the option-adjusted characteristics shown in Figure 8.
In Figure 7, we compare the projected weighted-average lives of three bonds: tranche B from the standard Z structure and tranches B and VB from its accretion-directed counterpart. We see that tranche B from the accretion-directed structure, which is a standard sequential, has the most volatile weighted-average life. Tranche B from the standard Z structure is marginally more stable because it is stabilized, to an extent, by its Z’s accretion. In contrast, tranche VB, which is amortized entirely from Z accretion, is significantly more stable.

With Z re-sized as discussed in footnote 2.
In Figure 8, we compare the option-adjusted characteristics of the bonds in the standard Z structure to those in its accretion-directed counterpart. Given our prior discussion, the results are not surprising. The accretion-directed tranches have the lowest option costs and best convexities, followed, in order, by the sequentials in the standard Z structure and the sequentials in the accretion-directed structure.

Source: Salomon Smith Barney.
PAC Structures

PAC structures are designed to create a stable set of bonds by directing the prepayment risk of the underlying collateral to other bonds in the structure. Conceptually, PAC structures are very simple. One set of bonds (the PACs) is assigned a principal redemption schedule, which is given priority over principal payments to the remaining bonds (the supports) in the structure. PAC redemption schedules are typically created by taking the minimum of two schedules. The two schedules correspond to the principal cashflows available from the underlying collateral when it is amortized at the upper and lower bounds of the desired PAC range. If the collateral prepay at any single speed within this range, the PAC redemption schedule will be met. However, this approach does not guarantee that the PAC redemption schedule will be met for prepayment rates that vary over time, even if they remain within the protected range.

Figure 9 illustrates the creation of a PAC redemption schedule with a protected range of 100%–275% PSA. First, the collateral cashflows available to make principal payments on the PACs assuming the collateral prepay at 100% PSA are plotted. Second, the cashflows available at 275% PSA are superimposed on the first curve. The PAC redemption schedule is defined as the minimum of these two curves, as shown by the height of the shaded region. The area of the shaded region to the right of any point on the time axis represents the face amount of PACs then outstanding, assuming departures from the PAC schedule have not occurred. After the overall PAC schedule has been determined, it can be partitioned to produce bonds with the desired weighted-average lives and principal amortization windows.

Figure 9. Creating a PAC Redemption Schedule With a Protected Range of 100%–275% PSA

Source: Salomon Smith Barney.

Generally, the upper and lower bounds of a PAC redemption schedule’s protected range are significantly above and below the prepayment rate that is anticipated on its underlying collateral when the CMO is issued. This provides the PACs with a degree of both call and extension protection at issuance, as illustrated in Figure 10. The middle panel of Figure 10 shows the allocation of principal cashflows between the PAC and PAC-support bonds of a typical PAC structure assuming that its collateral prepay at 175% PSA (a reasonable long-term prepayment projection for a
newly issued CMO backed by current-coupon collateral). At this speed, the PAC-support bonds amortize simultaneously with the PACs. The top panel illustrates the allocation of principal cashflows assuming a prepayment rate of 125% PSA. In this case, the PAC redemption schedule is still met. The effects of the reduction in available cashflows are transferred entirely to the PAC-support bonds, which undergo a significant amount of extension. The bottom panel of Figure 10 depicts the allocation of principal cashflows, assuming the collateral prepays at 250% PSA. Again, the PAC redemption schedule is met by shifting the effects of the accelerated collateral payments to the PAC-support bonds.

As previously discussed, PAC redemption schedules are usually structured using a single range (e.g., 100%–275% PSA). However, once the overall redemption schedule is partitioned into a series of short-, intermediate-, and long-maturity
PACs, the individual PACs — with the exception of the longest PAC — will likely have protected ranges that are wider than the range used to structure the schedule. This occurs because, at fast prepayment rates, the PAC-support bonds may still be outstanding during the amortization phase of a short average life PAC, yet may pay down completely prior to the maturity of a longer PAC. In this case, schedule departures would occur only for the longer PACs, as illustrated in Figure 11.

**Figure 11. Departure from Schedule of Longer PACs — Projected Principal Payments of a PAC CMO Structure at 350% PSA**

A further complication is that the protected range of each PAC in a structure will drift over time. For example, in Figure 12 we show how the effective ranges of the PACs analyzed above are projected to drift at three different prepayment rates. At prepayment rates within the bounds of the current PAC range, both the lower and upper bounds of the range drift upwards over time. In contrast, at prepayment rates above the current upper bound, the lower bound still drifts upwards, but the upper bound declines — that is, the PAC range collapses. If a high prepayment rate is sustained long enough, a PAC’s protected range can vanish. When this occurs, the PAC is referred to as a “broken” or “busted” PAC. We can see why this occurs in Figure 13. At fast prepayment rates, the support bonds in the PAC structure are quickly amortized. When all of the supports have matured, the protected ranges of the remaining PACs vanish. Figure 13 also makes clear that, once all of the supports in a structure mature, the remaining PACs — now busted — are simply sequentials.
**Figure 12. PAC Range Drift — Projected PAC Ranges (% PSA) Over Time at Selected Prepayment Rates**

<table>
<thead>
<tr>
<th>Class</th>
<th>WAL</th>
<th>125% PSA For Stated Number of Years</th>
</tr>
</thead>
<tbody>
<tr>
<td>PA</td>
<td>2Yrs</td>
<td>100-415 105-450 105-580 105-1280 Matured Matured</td>
</tr>
<tr>
<td>PB</td>
<td>5Yrs</td>
<td>100-285 105-290 105-315 110-360 110-440 110-600</td>
</tr>
<tr>
<td>PC</td>
<td>10Yrs</td>
<td>100-275 105-275 105-285 110-295 110-310 115-325</td>
</tr>
<tr>
<td>PD</td>
<td>19Yrs</td>
<td>80-275 80-275 80-280 80-280 80-290 80-295</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Class</th>
<th>WAL</th>
<th>250% PSA For Stated Number of Years</th>
</tr>
</thead>
<tbody>
<tr>
<td>PA</td>
<td>2Yrs</td>
<td>100-415 105-435 115-515 125-1045 Matured Matured</td>
</tr>
<tr>
<td>PB</td>
<td>5Yrs</td>
<td>100-285 110-285 120-290 140-300 160-320 170-365</td>
</tr>
<tr>
<td>PC</td>
<td>10Yrs</td>
<td>100-275 110-275 135-275 170-275 205-280 220-280</td>
</tr>
<tr>
<td>PD</td>
<td>19Yrs</td>
<td>80-275 85-275 95-275 115-275 135-275 155-275</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Class</th>
<th>WAL</th>
<th>500% PSA For Stated Number of Years</th>
</tr>
</thead>
<tbody>
<tr>
<td>PA</td>
<td>2Yrs</td>
<td>100-415 110-405 140-360 Matured Matured Matured</td>
</tr>
<tr>
<td>PB</td>
<td>5Yrs</td>
<td>100-285 120-275 175-240 None None Matured</td>
</tr>
<tr>
<td>PC</td>
<td>10Yrs</td>
<td>100-275 130-245 None None None None</td>
</tr>
<tr>
<td>PD</td>
<td>19Yrs</td>
<td>80-275 90-260 140-210 None None None</td>
</tr>
</tbody>
</table>

Source: Salomon Smith Barney.

**Figure 13. At High Prepayment Rates the Support Tranches are Rapidly Amortized and the PACs “Break” — Projected Principal Payments of a PAC CMO Structure at 500% PSA**

Source: Salomon Smith Barney.

In Figure 14, we compare the projected weighted-average lives of three bonds: tranche B from the standard sequential pay structure and tranches PB (a PAC) and SB (a support) from the PAC structure. Because the PAC structure is designed to direct prepayment risk away from the PACs and into the supports, it is not surprising that the PAC is more stable, and the support less stable, than the sequential.
In Figure 15, we show the option-adjusted characteristics of the bonds in the PAC structure, which contrast with those shown in Figure 2 for the sequential structure. Consistent with our prior discussion, we see that the PACs have the smallest option-costs, and the supports the largest option-costs.

**TAC Structures**

In a pure TAC structure, the TAC bonds, like PACs, are shielded, to an extent, from the prepayment risk of the underlying collateral by assigning them a redemption schedule that has priority over principal payments to the remaining bonds (the supports) in the structure. TACs differ from PACs because their prepayment protection is asymmetric. At prepayment rates faster than the pricing speed, the weighted-average life of a TAC contracts less than that of a comparable sequential.

If prepayment rates fall below the pricing speed, however, TACs will extend like sequential CMOs. TAC CMO structures afford TACs a degree of call protection, but do not shield these bonds from extension risk.
To understand why PACs are protected from extension, but TACs are not, it is necessary to know how TAC redemption schedules are devised. In contrast to PAC redemption schedules, TAC redemption schedules are devised by amortizing the underlying collateral at a single prepayment rate — usually the pricing speed. Once the collateral principal cashflows are determined, they are partitioned into the TAC and TAC-support bonds. The way this is accomplished differentiates TACs from PACs. TAC redemption schedules are sized so that, at the pricing speed, the TACs always amortize first; the TAC-support bonds amortize only after the TACs have completely paid down. By comparison, PAC and PAC-support bonds amortize simultaneously at the pricing prepayment rate. A hypothetical pure TAC structure is illustrated at its pricing speed in Figure 16, and contrasts with the PAC structure shown at its pricing speed in the middle panel of Figure 10.

Although TAC redemption schedules are structured differently than those of PACs, TAC structures can still display a protected-range effect, similar to that of their PAC counterparts. A protected range generally will not exist for the entire TAC redemption schedule, but protected ranges will usually apply to each of the individual TAC bonds except the longest one.

If the collateral prepays at a rate below the pricing speed, there are no cashflows available to be diverted from the TAC-support bonds to the TACs. Consequently, the lower bound of a TAC-protected range will be equal to the pricing speed. This is the reason for the asymmetry of TAC prepayment protection. The upper bound of the TAC prepayment range is highest for the shortest average life TAC because it is scheduled to be redeemed first. At a fast prepayment rate, the TAC-support bonds might still be outstanding during the scheduled amortization period of a short TAC, but could be exhausted before the maturity of a long TAC.

Figure 17 depicts the principal payments on our hypothetical TAC structure at three different prepayment rates. The top panel demonstrates that, at prepayment rates below the pricing speed (175% PSA), all of the bonds in a TAC structure extend like standard sequential CMOs. The bottom panel shows that, at prepayment rates above the pricing speed, a short TAC may meet its payment schedule even when departures from a long TAC’s redemption schedule occur.
The longest maturity TAC is an exception: Typically it will only meet its schedule if the collateral prepays at the pricing speed. The longest TAC does not normally have a protected range. At prepayment rates moderately above the pricing speed, the weighted-average life of the longest TAC will actually extend. At prepayment rates well above the pricing speed, the weighted-average life of the longest TAC will contract, but less than that of a comparable sequential.

The extension of the longest TAC at prepayment rates moderately in excess of the pricing speed is caused by the amortization of the TAC-support classes. In this case, when the longest TAC starts to pay down, less collateral is outstanding than had the collateral prepaid at the pricing speed. Consequently, although prepayments continue to occur, at a rate in excess of the pricing speed, the principal payments generated by the reduced collateral balance are less than those specified in the TAC schedule. If prepayment rates are fast enough, however, the effect of the reduced collateral balance is overcome, and the TAC’s weighted-average life will contract.
The extension of the longest TAC at prepayment rates moderately in excess of the pricing speed can be seen in the bottom panel of Figure 17.

In Figure 18, we compare the projected weighted-average lives of three bonds: tranche B from the standard sequential pay structure, tranche PB (a PAC) from the PAC structure, and tranche TB (a TAC) from the TAC structure. The asymmetry of the TAC’s prepayment protection is obvious: its weighted-average life extends like that of the sequential at slow prepayment rates, but it is to an extent protected from contraction — like the PAC — at fast prepayment rates.

Figure 18. Weighted-Average Life Profile Comparison: Five-Year Sequential Versus Comparable PAC and TAC

A similar comparison is shown in Figure 19 for the long sequential, the long PAC-support, and the long TAC-support. The asymmetry, of the TAC’s prepayment protection just demonstrated, is reflected in a corresponding asymmetry in the increase in the prepayment risk of its support: The TAC-support bond extends like a sequential, but contracts like a PAC support.

Figure 19. Weighted-Average Life Profile Comparison: Long Sequential Versus Comparable PAC Support and TAC Support
In Figure 20, we show the option-adjusted characteristics of the bonds in the TAC structure, which contrast with those shown in Figure 2 and Figure 15 for the sequential and PAC structures, respectively. Not surprisingly, the rank order of the bonds’ option costs is consistent with the rank order of the stability of their weighted-average lives.

Figure 20. Option-Adjusted Characteristics of a TAC CMO Structure Backed by Current-Coupon Collateral — Market-Implied Vols, LIBOR-Treasury Swap Curve, 5 Oct 00

<table>
<thead>
<tr>
<th>Principal</th>
<th>Class</th>
<th>Amount ($MM)</th>
<th>Coupon</th>
<th>Type</th>
<th>Price</th>
<th>Yield</th>
<th>WAL</th>
<th>OAS</th>
<th>Opt Cost</th>
<th>Eff Dur</th>
<th>Eff Conv</th>
</tr>
</thead>
<tbody>
<tr>
<td>TA</td>
<td>24.85</td>
<td>7.5%</td>
<td>TAC</td>
<td>$100.82</td>
<td>7.01%</td>
<td>2.1Yrs.</td>
<td>0bp</td>
<td>23bp</td>
<td>1.4</td>
<td>-1.0</td>
<td></td>
</tr>
<tr>
<td>TB</td>
<td>26.55</td>
<td>7.5</td>
<td>TAC</td>
<td>100.50</td>
<td>7.43</td>
<td>5.3</td>
<td>0</td>
<td>58</td>
<td>3.0</td>
<td>-2.2</td>
<td></td>
</tr>
<tr>
<td>TC</td>
<td>30.75</td>
<td>7.5</td>
<td>TAC</td>
<td>99.91</td>
<td>7.59</td>
<td>10.9</td>
<td>0</td>
<td>57</td>
<td>5.4</td>
<td>-1.5</td>
<td></td>
</tr>
<tr>
<td>SA</td>
<td>17.85</td>
<td>7.5</td>
<td>Supp</td>
<td>96.50</td>
<td>7.99</td>
<td>18.4</td>
<td>0</td>
<td>92</td>
<td>5.5</td>
<td>-2.2</td>
<td></td>
</tr>
</tbody>
</table>

Source: Salomon Smith Barney.

Structures With Multiple Redemption Schedules

In the hypothetical PAC and TAC CMOs illustrated above, we included only a single redemption schedule in each structure. This was done for two reasons. First, it simplified the explanations of these structuring techniques. Second, it was faithful to the historical evolution of the market — the first PAC and TAC CMOs issued in the late 1980s were structured with single redemption schedules. However, since the early 1990s, many PAC CMOs have contained multiple levels of PACs, and most TACs have been issued out of structures that contained PACs. This occurred because the use of multiple redemption schedules allowed greater flexibility in allocating the prepayment risk in the underlying collateral among the CMO bonds.

Many structures are possible, but the key to the behavior of the bonds in all of these CMOs is the relative priorities of their schedules. In Figure 21, we illustrate a relatively simple structure containing three redemption schedules: PAC Is, PAC IIs, and TACs. The PAC Is were structured with a protected range of 100%–275% PSA; the PAC IIs were structured with a protected range of 125%–225% PSA; and the TACs were “TACed” at 175% PSA. The rules for allocating available principal payments in this structure are as follows: (1) scheduled payments on the PAC Is; (2) scheduled payments on the PAC IIs; and, (3) scheduled payments on the TACs. If, after making all scheduled principal payments, principal is still available, make excess principal payments in the following order: (1) supports; (2) TACs; (3) PAC IIs; and, (4) PAC Is.

Given these structuring ranges and paydown rules, it is clear that the PAC Is in this structure are identical to the PACs in the simple PAC structure analyzed in Figure 9 through Figure 15 above. The changes relative to the earlier structure have all occurred in the support bonds. After the PAC I schedule was determined, the PAC II schedule was carved out of the support bonds, by calculating its redemption schedule using a narrower (125%–225% PSA) protected range than that used to size the PAC Is. After the PAC II schedule was determined, a portion of the remaining
supports were then TACed at 175% PSA. The resulting schedules are represented in Figure 21, which shows the structure’s projected principal paydowns at 175% PSA.

The effects of these schedules and paydown rules are illustrated in Figure 22 and Figure 23. At slow prepayment rates (Figure 22), the TACs and support extend first (see 125% PSA panel); then the PAC IIs extend (see 100% PSA panel); finally the PAC Is extend (see 75% PSA panel). At fast prepayment rates (Figure 23), the support shortens first (see 200% PSA panel); then the TACs shorten (see 225% PSA panel); followed by the PAC IIs (see 275% PSA panel); and ultimately by the PAC Is (see 400% PSA panel).
Figure 22. CMO Structure with Multiple Redemption Schedules—Projected Principal Payments at Selected Prepayment Rates Below the Pricing Speed of 175% PSA

Source: Salomon Smith Barney.
Figure 23. CMO Structure with Multiple Redemption Schedules — Projected Principal Payments at Selected Prepayment Rates Above the Pricing Speed of 175% PSA

Source: Salomon Smith Barney.
In Figure 24, we show the option-adjusted characteristics of the bonds in this structure. Not surprisingly, the rank order of the bonds’ option costs is generally consistent with the rank order of the stability of their weighted-average lives.

<table>
<thead>
<tr>
<th>Class</th>
<th>Principal Amount ($MM)</th>
<th>Coupon</th>
<th>Type</th>
<th>Price</th>
<th>Yield</th>
<th>WAL</th>
<th>OAS</th>
<th>Opt Cost</th>
<th>Eff</th>
<th>Eff Dur</th>
<th>Eff Cnvx</th>
</tr>
</thead>
<tbody>
<tr>
<td>PA</td>
<td>16.01</td>
<td>7.5%</td>
<td>PAC I</td>
<td>$101.01</td>
<td>6.88%</td>
<td>2.0Yrs.</td>
<td>0bp</td>
<td>11bp</td>
<td>1.4</td>
<td>-0.7</td>
<td></td>
</tr>
<tr>
<td>PB</td>
<td>18.84</td>
<td>7.5%</td>
<td>PAC I</td>
<td>101.35</td>
<td>7.21</td>
<td>5.0</td>
<td>0</td>
<td>37</td>
<td>2.5</td>
<td>-2.0</td>
<td></td>
</tr>
<tr>
<td>PC</td>
<td>25.97</td>
<td>7.5%</td>
<td>PAC I</td>
<td>100.41</td>
<td>7.51</td>
<td>10.0</td>
<td>0</td>
<td>52</td>
<td>4.3</td>
<td>-1.6</td>
<td></td>
</tr>
<tr>
<td>PD</td>
<td>6.01</td>
<td>7.5%</td>
<td>PAC I</td>
<td>101.36</td>
<td>7.45</td>
<td>19.1</td>
<td>0</td>
<td>37</td>
<td>7.5</td>
<td>-0.4</td>
<td></td>
</tr>
<tr>
<td>GA</td>
<td>2.97</td>
<td>7.5%</td>
<td>PAC II</td>
<td>99.57</td>
<td>7.70</td>
<td>2.0</td>
<td>0</td>
<td>92</td>
<td>2.2</td>
<td>-2.1</td>
<td></td>
</tr>
<tr>
<td>GB</td>
<td>2.94</td>
<td>7.5%</td>
<td>PAC II</td>
<td>98.11</td>
<td>8.02</td>
<td>5.0</td>
<td>0</td>
<td>118</td>
<td>3.5</td>
<td>-2.0</td>
<td></td>
</tr>
<tr>
<td>GC</td>
<td>2.23</td>
<td>7.5%</td>
<td>PAC II</td>
<td>97.41</td>
<td>7.96</td>
<td>10.0</td>
<td>0</td>
<td>96</td>
<td>4.1</td>
<td>-1.9</td>
<td></td>
</tr>
<tr>
<td>GD</td>
<td>5.27</td>
<td>7.5%</td>
<td>PAC II</td>
<td>96.65</td>
<td>7.95</td>
<td>18.7</td>
<td>0</td>
<td>88</td>
<td>4.9</td>
<td>-2.3</td>
<td></td>
</tr>
<tr>
<td>TA</td>
<td>5.85</td>
<td>7.5%</td>
<td>TAC</td>
<td>97.68</td>
<td>8.53</td>
<td>2.7</td>
<td>0</td>
<td>169</td>
<td>4.0</td>
<td>-2.1</td>
<td></td>
</tr>
<tr>
<td>TB</td>
<td>4.71</td>
<td>7.5%</td>
<td>TAC</td>
<td>96.25</td>
<td>8.15</td>
<td>10.4</td>
<td>0</td>
<td>97</td>
<td>5.3</td>
<td>-1.4</td>
<td></td>
</tr>
<tr>
<td>TC</td>
<td>1.55</td>
<td>7.5%</td>
<td>TAC</td>
<td>96.02</td>
<td>8.02</td>
<td>17.6</td>
<td>0</td>
<td>93</td>
<td>5.5</td>
<td>-1.9</td>
<td></td>
</tr>
<tr>
<td>SA</td>
<td>7.65</td>
<td>7.5%</td>
<td>Supp</td>
<td>96.83</td>
<td>8.00</td>
<td>16.4</td>
<td>0</td>
<td>98</td>
<td>5.9</td>
<td>-3.2</td>
<td></td>
</tr>
</tbody>
</table>

Source: Salomon Smith Barney.
Structuring Coupon Payments

Bond Coupons Matter Too

So far, we have focused almost exclusively on the effects of principal payment schedules and paydown rules — with a brief aside about the role of underlying collateral — on CMO bond characteristics. Implicit in our discussions of CMO bond optionality was the assumption that all of the CMOs had fixed coupons, and were priced near par. This assumption allowed us to establish an intuitive correspondence between greater weighted-average life variability and increased option cost. However, the optionality of CMOs can also be changed by varying their coupons. Examples of this approach are illustrated in the following two sections.

Floaters and Inverse Floaters

A floating-rate CMO is a bond structured so that its coupon resets periodically (typically monthly) at a rate equal to that of an index (usually one-month LIBOR) plus a spread (the reset margin), subject to a lifetime cap and floor (and potentially subject to interim caps and floors as well). In contrast, an inverse floater has a coupon that resets in a direction opposite to that of its index, also subject to caps and floors.

Splitting a fixed-rate CMO into two pieces, which amortize simultaneously, is how floaters and inverse floaters are typically created. The face amounts, coupon reset equations, and caps and floors of the floater and inverse must be selected so that the weighted-average coupon of the pair is always equal to that of the underlying fixed-rate bond. For example, in Figure 25, we illustrate splitting the PB PAC I shown in Figure 21 to Figure 24 into a floater (class FB) and an inverse floater (class IB). The ratios of the face amounts of the bonds are 3:1. Consequently, the reset equation of the inverse must have a multiplier of negative three, in order for the weighted-average coupon of the bonds to equal that of the underlying fixed-rate bond for all levels of LIBOR. In addition, the cap on the floater must be aligned with the floor on the inverse (and vice versa). For example, when LIBOR equals 9.75%, the floater’s coupon hits its 10% cap; simultaneously, the inverse floater’s coupon hits its 0% floor.

Figure 25. Schematic Representation: Splitting a Fixed-Rate PAC into a Floater and an Inverse Floater

<table>
<thead>
<tr>
<th>Fixed-Rate PAC</th>
<th>Floater/Inverse PAC</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>&quot;Parent&quot;</strong></td>
<td><strong>&quot;Children&quot;</strong></td>
</tr>
<tr>
<td>Principal Amt: $18.84MM</td>
<td>Principal Amt: $14.13MM</td>
</tr>
<tr>
<td>Coupon: 7.5%</td>
<td>Coupon: L + 0.25%</td>
</tr>
<tr>
<td></td>
<td>Coupon Cap: 10%</td>
</tr>
<tr>
<td>Principal Amt: $4.71MM</td>
<td>Principal Amt: 3*(9.75-L)</td>
</tr>
<tr>
<td></td>
<td>Coupon: 3*(9.75-L)</td>
</tr>
<tr>
<td></td>
<td>Coupon Floor: 0%</td>
</tr>
</tbody>
</table>

Source: Salomon Smith Barney.
In Figure 26, we compare the option-adjusted characteristics of the underlying fixed-rate PAC to those of the floater and inverse floater. If the floater did not have a cap, its effective duration would be negligible, and its effective convexity neutral. The presence of the 10% coupon cap adds some duration and negative convexity to the floater. However, even accounting for its cap, the floater is still shorter and less negatively convex than the fixed-rate PAC. Because the floater and inverse floater add up to the fixed-rate PAC, the inverse floater must, therefore, be longer and more negatively convex than the underlying PAC. Another way of thinking about this relationship is that the inverse floater is a leveraged position in the underlying fixed-rate PAC. That is, an investor in the inverse floater is, in effect, buying the fixed-rate PAC and financing it with the floater.

<table>
<thead>
<tr>
<th>Class</th>
<th>Principal Amount ($MM)</th>
<th>Coupon</th>
<th>Type</th>
<th>Price</th>
<th>Yield</th>
<th>WAL</th>
<th>OAS</th>
<th>Opt Cost</th>
<th>Eff Dur</th>
<th>Eff Cnvx</th>
</tr>
</thead>
<tbody>
<tr>
<td>FB</td>
<td>$14.13</td>
<td>L+0.25 %</td>
<td>PAC I</td>
<td>$99.89</td>
<td>6.93%</td>
<td>5.0Yrs.</td>
<td>0bp</td>
<td>11bp</td>
<td>0.4</td>
<td>-0.5</td>
</tr>
<tr>
<td>IB</td>
<td>4.71</td>
<td>3*(9.75-L)</td>
<td>PAC I</td>
<td>105.70</td>
<td>8.03</td>
<td>5.0</td>
<td>0</td>
<td>112</td>
<td>8.3</td>
<td>-6.3</td>
</tr>
<tr>
<td>PB</td>
<td>$18.84</td>
<td>7.5 %</td>
<td>PAC I</td>
<td>$101.35</td>
<td>7.21%</td>
<td>5.0Yrs.</td>
<td>0bp</td>
<td>37bp</td>
<td>2.5</td>
<td>-2.0</td>
</tr>
</tbody>
</table>

Source: Salomon Smith Barney.

**IOs and POs**

IOs and POs are typically created by dividing the cashflows from an underlying mortgage security into two pieces: the IO, which receives 100% of the interest payments; and the PO, which receives 100% of the principal payments. The largest and most liquid segment of the IO/PO sector is comprised of STRIP IOs and POs. STRIP IOs and POs mimic (add up to) the cashflows of the underlying mortgage pass-throughs. Consequently, the cashflows of STRIP IOs and POs are sometimes referred to as being “unstructured.” Most STRIP IOs and POs have been issued out of dedicated trusts — that is, the only bonds produced from the underlying pass-throughs were STRIP IOs and POs. However, any CMO bond can be divided into an IO and PO during the structuring process. IOs and POs produced by splitting the interest and principal payments of bonds with “structure” (bonds with cashflows that differ from those of the underlying pass-throughs) are referred to as structured IOs and POs.

IOs and POs have investment characteristics that differ markedly from those of most other mortgage securities. These characteristics are best illustrated by examining their price movements under moving interest rates. In the top panel of Figure 27, we use the SSB OAS model to project the price paths of a STRIP IO and PO, backed by current-coupon pass-throughs. When interest rates rise, the projected IO prices increase rapidly, while the projected PO prices fall sharply. In other words, the IO displays large negative effective durations, and the PO displays large positive effective durations. These price movement characteristics can be explained by the prepayment response of the underlying collateral relative to movements in interest rates, shown in the bottom panel of Figure 27.
For an IO, the amount of interest received varies directly with the principal balance outstanding, which in turn depends on the prepayment rate of the underlying pass-throughs. Faster prepayments reduce the principal balance more quickly, leading to smaller interest payments in future periods. Slower prepayments diminish the outstanding balance more slowly, and result in larger interest payments. Because prepayments accelerate when interest rates fall, and vice versa, the size of the payments from an IO will vary in the same direction as interest rates. Thus, the value of this IO falls when interest rates fall, and rises when interest rates rise — that is, the IO’s effective duration is negative.

The PO is also sensitive to prepayments, but its price response is the opposite that of the IO. Because a PO only receives principal payments, it is priced at a discount to par and, consequently, its value will increase when principal is returned (at par) at a faster rate. This occurs when interest rates fall and prepayments accelerate. When interest rates rise and prepayments slow, the value of the PO decreases. Thus, the PO’s effective duration is positive.

Another way to interpret the price behavior of the IO and PO is to view their underlying pass-throughs as the sum of the IO and PO. Thus, if all three instruments
were priced at the same OAS, the prices of the IO and PO would add up to the price of the pass-throughs, and the effective duration of the pass-throughs would equal the weighted average of the effective durations of the IO and PO.

The price patterns in Figure 27 illustrate an additional feature of IOs and POs backed by current-coupon collateral. For a region around the current market price, the PO path is curved in the investor’s favor. In other words, for interest-rate movements of similar magnitude, the prices rise more rapidly under market rallies than they fall under market declines. This represents positive convexity. The IO, in contrast, is negatively convex — its prices fall more rapidly than they rise.

These properties can also be explained in terms of the response of prepayments to interest-rate movements. The projected long-term average prepayment rate for the underlying pass-throughs for various market levels is displayed in the bottom panel of Figure 27. The prepayment rate is projected to rise substantially under a market rally, but to fall only moderately under a market decline. Consequently, the price gain on the PO, in a rally, will be greater than the price loss in a decline, given comparable movements in interest rates. Similarly, the price loss on the IO in a rally will be greater than the price gain in a decline.

This pattern holds until interest rates rally about 100bp to 150bp; then, the relationship reverses. The price levels of the IO and PO explain the reversal of this relationship. If interest rates were to rally more than about 100bp, the expected rapid prepayment rate of the underlying mortgages reduces the value of the IO and raises the value of the PO, so that these issues trade at relatively low and high price levels, respectively. At these levels, the IO price has much more room to expand than to decline further. In contrast, the value of the PO has much more room to fall than to rise. These characteristics are illustrated explicitly in Figure 28, which shows the projected duration and convexity paths that correspond to the projected price paths of Figure 27.
Figure 28. Projected Effective Duration and Convexity Paths: IO and PO Versus Underlying Current-Coupon Pass-Throughs, 5 Oct 00

Source: Salomon Smith Barney.
Figure 27 and Figure 28 show that the investment characteristics of IOs, POs, and pass-throughs are not static. In fact, they can change dramatically as interest rates move. The same is true for any CMO tranche, although the magnitudes of the changes for most tranches are much smaller than those shown for the IO and PO. To illustrate the magnitudes of changes that are more typical, in Figure 29, we compare the projected price, duration, and convexity paths (versus interest-rate move) of the ten-year PAC and sequential CMOs discussed in this chapter to those of a comparable duration Treasury.

Source: Salomon Smith Barney.
**Vast Range of Possibilities**

In this report, we have provided an introduction to CMO bond types and structuring techniques by analyzing a selection of structures. However, this is only the tip of the iceberg. A vast range of bond types (with widely differing investment characteristics) have been produced, largely by using combinations of the techniques we have outlined. For example, coupon stripping has been combined with principal payment scheduling and prioritization to produce PAC IOs and POs, TAC IOs and POs, and support IOs and POs. Similarly, fixed-rate PACs, TACs, and supports have been divided into floating-rate and inverse-floating-rate PACs, TACs, and supports. The end result has been the production of a range of bonds, selections of which can be used to express virtually any view on interest rates or prepayment rates.
ADDITIONAL INFORMATION AVAILABLE UPON REQUEST

For securities recommended in this report, Salomon Smith Barney (SSB), including its parent, subsidiaries, and/or affiliates (the Firm), usually makes a market, may sell to or buy from customers as principal, and may from time to time perform investment banking or other services for or solicit investment banking or other business from any company mentioned in this report. Securities recommended, offered, or sold by SSB: (i) are not insured by the Federal Deposit Insurance Corporation; (ii) are not deposits or other obligations of any insured depository institution (including Citibank); and (iii) are subject to investment risks, including the possible loss of the principal amount invested. The Firm, or any individuals preparing this report, may at any time have a position in any securities or options of any of the issuers in this report. An employee of the Firm may be a director of a company mentioned in this report.

Although information has been obtained from and is based upon sources SSB believes to be reliable, the Firm does not guarantee the accuracy of the information, and it may be incomplete or condensed. All opinions and estimates included in this report constitute SSB’s judgment as of the date of this report and are subject to change without notice. This report is for informational purposes only and is not intended as an offer or solicitation with respect to the purchase or sale of any security. This report does not take into account the investment objectives, financial situation, or particular needs of any particular person. Investors should obtain individual financial advice based on their own particular circumstances before making an investment decision on the basis of the recommendations in this report. Investors who have received this report from the Firm may be prohibited in certain states from purchasing securities mentioned in this report from the Firm. Please ask your Financial Consultant for additional details.

This publication has been approved for distribution in the United Kingdom by Salomon Brothers International Limited, which is regulated by the Securities and Futures Authority. The investments and services contained herein are not available to private customers in the UK. This report was prepared by SSB and, if distributed by Nikko Salomon Smith Barney Limited, is so distributed under license. This report is made available in Australia through Salomon Smith Barney Australia Securities Pty. Ltd. (ACN 003 114 832), a Licensed Securities Dealer, and in New Zealand through Salomon Smith Barney New Zealand Limited, a member firm of the New Zealand Stock Exchange.

The research opinions of the Firm may differ from those of The Robinson-Humphrey Company, LLC, a wholly owned brokerage subsidiary of Salomon Smith Barney Inc. Salomon Smith Barney is a service mark of Salomon Smith Barney Inc. © Salomon Smith Barney Inc., 2001. All rights reserved. Any unauthorized use, duplication, or disclosure is prohibited by law and will result in prosecution.

(7024N, 7008N, 7224N, 7014N)

F03B029