NAIC National Association of Insurance Commissioners & The Center for Insurance Policy and Research

Capital Markets Special Report

The **NAIC's Capital Markets Bureau** monitors developments in the capital markets globally and analyzes their potential impact on the investment portfolios of US insurance companies. A list of archived Capital Markets Bureau Special Reports is available via the **index**

Quantifying Market Risk: Duration and Convexity

In a risk-focused surveillance and examination process, certain inherent risks are assessed and quantified with respect to the likelihood of occurrence and magnitude of impact. The risk classifications most inherent to investments, and most quantifiable, are credit, market, and liquidity risks. The NAIC *Financial Condition Examiners Handbook*defines market risk as "movement in market rates or prices, such as interest rates, foreign exchange rates or equity prices, that adversely affect the reported and/or market value of investments." The most prevalent market risk measure for bonds is duration, along with the related convexity metric. Given that bonds dominate insurance investment portfolios, this NAIC Capital Markets Bureau Special Report focuses on market risk arising from interest rate movements.

Definition of Duration and Convexity

Duration is the approximate sensitivity of a bond's price to interest rate changes. Market convention is to express duration in terms either of years or the percentage price change for a change in yields of 1.00%. The discounted present value of a given set of cash flows will increase when the discount rate falls, and decrease when it rises. For a bond, the discount rate is its yield to maturity and the cash flows are its coupon and principal payments. *Convexity* measures the change in yield sensitivity (i.e., the change in duration) as yields change, further refining duration's approximation of price sensitivity. A detailed explanation of these concepts is attached as the Appendix.

Insurer Exposure to Market Risk

Insurers are traditionally viewed as "buy and hold" investors matching assets with liabilities and, thereby, largely mitigating market risk. As a hypothetical example, assume a 30-year policy is written with a dollar- and date-certain claim of $100, and simultaneously the insurer invests in a $100 30-year zero coupon bond. The timing of the cash flows, therefore, is "perfectly" matched and potential changes in market values of assets are not consequential. Absent default, principal paid on the $100 bond at maturity would be available to make full payment on the policy claim.

Immunization is an asset-liability management strategy of matching the duration of assets to the duration of liabilities. For example, if an insurer has a $100 liability portfolio with a duration of 4.5 years, then a $100 bond with a duration of 4.5 years will mirror the fair value changes of the liabilities for parallel shifts in the yield curve, even though the cash flows are not perfectly matched. As such, the balance sheet has been "immunized" against rate changes because the liability's market risk exposure is now offset by the assets.

Financial Disclosures

The NAIC *Financial Analyst Handbook* directs the analyst's attention to the insurer's SEC Form 10-K filing Item 7A, Quantitative and Qualitative Disclosures About Market Risk. The language of duration and convexity may be found in these disclosures. For example, one insurer's 2012 10-K said:

"… the difference between our asset and liability duration was a -0.23 gap … we estimate that a 100 basis point immediate, parallel increase in interest rates … would increase the net fair value of the assets and liabilities by $211 million."

A negative "gap" means the duration of assets is less than that of the liabilities; therefore, higher rates will *increase* economic capital because liabilities will fall further in fair value than the assets. The reverse would happen if rates fell. With a net duration of -0.23 many would say this company was largely *immunized* against interest rate risk.

Another insurance group's 10-K disclosed duration by line of business but only for investments. Its P/C investment portfolio's duration was 4.0 years and its life portfolio's duration was 6.3 years, given a 1% *increase* in rates. As no duration was stated for liabilities, the full impact of interest rate changes on this firm cannot be determined, unlike the first example.

While industry-wide data is not readily available, in mid-2013, 26 P/C companies had an average duration of 3.9 years and six life companies averaged 5.6 years. (These figures are in line with portfolios the NAIC Capital Markets Bureau has reviewed.)

Considerations and Limitations of Duration

Although not exhaustive, the following are additional factors insurance regulators may wish to consider or keep in mind:

a) Market risk may be a concern if an insurer needs to sells a bond before its maturity; however, only if yields are higher will a loss be realized.

b) An immunization strategy is only as good as its assumptions and execution. For example, if realized residential mortgage-backed securities (RMBS) prepayment speeds (or the timing of liabilities) vary substantially from the original assumptions, then the duration gap will be different than that modeled.

c) An insurer's liabilities should substantially offset the interest rate sensitivity of assets, but usually leave some amount of duration gap.

d) As neither assets nor liabilities are static, their durations and duration gaps may separately evolve over time.

e) Duration expresses no opinion or probability regarding the magnitude, direction or timing of interest rate changes. It measures only the magnitude of impact (severity) of the given yield change, not its likelihood (probability).

f) Some insurers use derivatives to change the duration of their investments. (See the Oct 23, 2013, special report titled, "Insurance Industry's Derivatives Exposure at Year-End 2012.")

g) Duration is often calculated using small changes in yields — e.g., 25 basis points (bps) — but solvency issues are not likely to occur as the result of small changes.

h) Most insurers' bond durations are in the 4-to-6 (year) range; therefore, the impact of a 100 bps change in yields generally will be in the vicinity of a 4% to 6% price impact.

i) The type of duration calculated is often not specified. While the differences may be minor (e.g., Macaulay and modified duration), different measures may be revealing. For example, when modified and option-adjusted durations differ significantly the portfolio probably has significant optionality.

j) Duration calculations assume identical yield change for all bonds in a portfolio; however, yield fluctuations are never perfectly correlated among bond types, maturities, or sectors.

k) While primarily associated with bonds, to varying degrees *all* investments are sensitive to interest rate changes. Direct mortgage loans and preferred stock are two examples of interest-sensitive assets in which many insurers invest.

Summary

For most insurance companies, market risk is a secondary concern after credit risk, although it may be more significant than commonly assumed, given portfolio turnover and asset-liability mismatches. Bonds dominate insurance portfolios, and duration and convexity are the primary approximations of interest rate risk. While there are several different formulas for calculating duration, each emphasizes different aspects of yield sensitivity. The types of investments

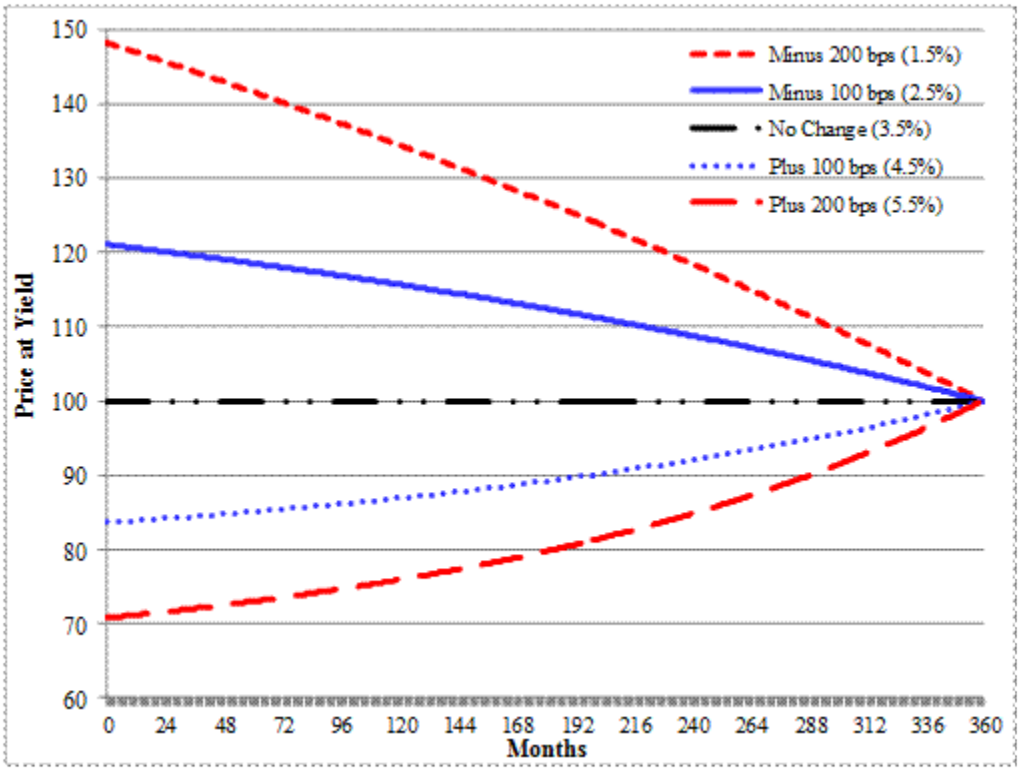
insurers hold will vary in interest rate sensitivity. Robust asset-liability management and immunization strategies can substantially mitigate market risk exposure.
With historically high interest rates in the 1980s, the bond market's focus was on *yield* changes, whereas tomorrow it may be in its *price* changes, as today's historically low interest rates have increased bonds' durations and convexities.
The NAIC Capital Markets Bureau will continue to monitor trends surrounding market risk and report as deemed appropriate.

APPENDIX

Market Risk – and Duration – of Bonds

The following graph shows a 3.5% coupon 30-year bond's value, or price, over time from issuance to maturity following five different yield-to-maturity paths, assuming immediate and permanent changes in market interest rates and yield-to-maturity:
1) No change in market interest rates or in yield-to-maturity.
2) 100 basis point increase.
3) 100 basis point decrease.
4) 200 basis point increase.
5) 200 basis point decrease.
For purposes of this discussion, bonds are assumed to be "plain vanilla" (i.e., no embedded options) except as noted.

Chart 1: Price of a 3.5% Coupon 30-year Bond at Different Yields

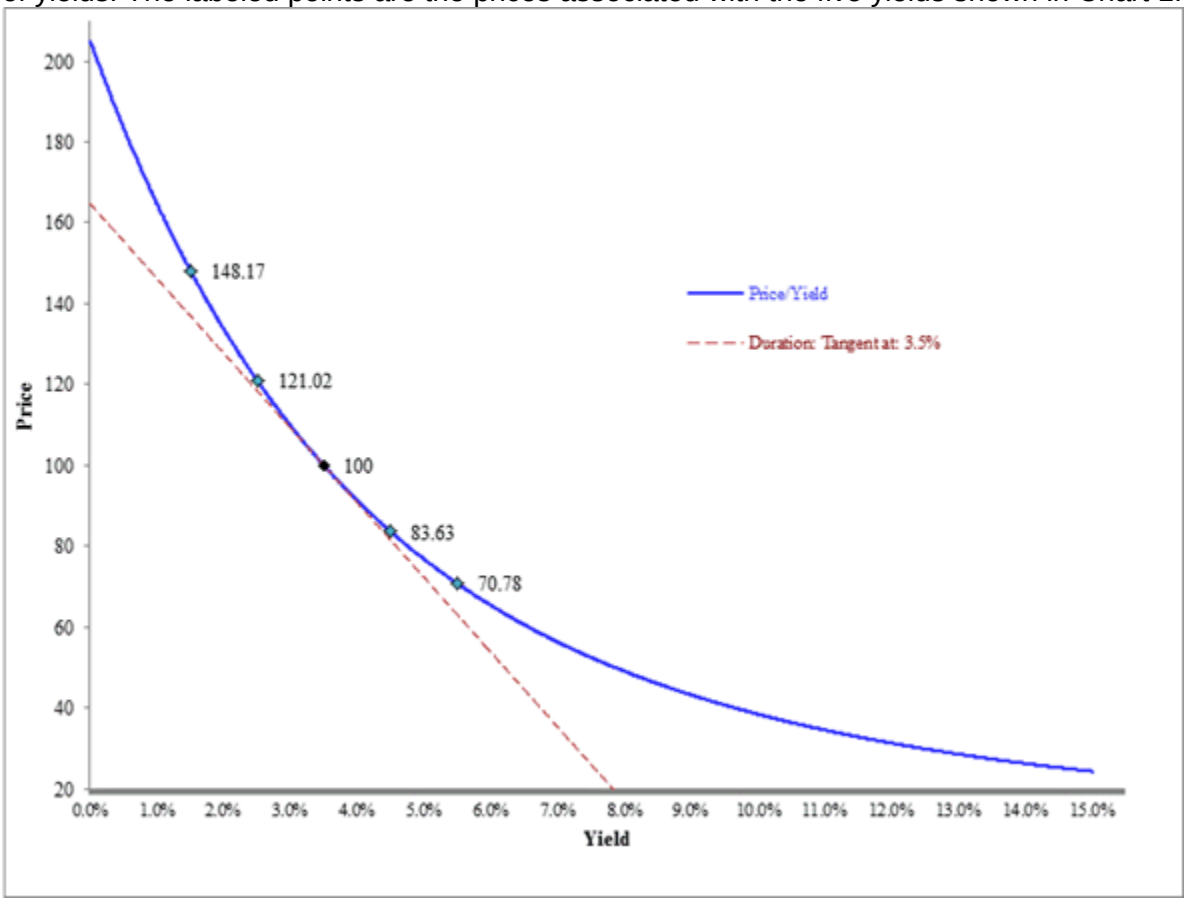


If yields to remaining maturity stay at 3.5% for the life of the bond, then its price will not vary from par (100). However, if rates immediately increase by 100 bps to 4.50%, the bond's value falls by 16.37 to 83.63% of par. Conversely, if yields decrease by 100 bps, the bond's value rises to 121.02% of par. While the magnitude of the yield change is the same (100 bps), the magnitude of impact is not. The same concept holds true for the plus and minus 200 bps

changes in yields to remaining maturity, thus illustrating the nonlinearity, or *convexity,* of the price/yield relationship.
Convexity is also illustrated by the curvature of the plus and minus yield change lines in Chart 1. Duration and convexity vary with the level of interest rates. They are also functions of a bond's coupon and maturity.
As a bond moves closer to maturity its price sensitivity decreases — as illustrated in Chart 1 — the distance between each pair of lines narrows. Similarly, bonds issued with shorter maturities (less than the 30 years in this example) are less yield-sensitive. If the 3.5% coupon bond in the example had a 10-year maturity, beginning at month 240 in the Chart 1 (120 months to maturity), the impact of yield changes would be much less and, therefore, its duration or price sensitivity would also be less.
In every case, because bonds are redeemed at par (absent default), their prices must converge to par, and lifetime unrealized gains and losses converge to zero. Market risk may be an issue if an insurer needs to sells a bond before its maturity, but only if yields are higher will a loss be realized.

The Price/Yield Relationship

Chart 2 shows the price/yield relationship of the same 3.5% 30-year bond across a wide range of yields. The labeled points are the prices associated with the five yields shown in Chart 1.



The price/yield line is steeper when yields are low so small increases or decreases in yield have a larger price impact than when yields are high. Also, while the price reaches the vertical axis at a 0% yield, it will never touch the horizontal axis (e.g., at a yield of 1,000%, the price is 0.35). This asymmetry illustrates the nature of duration and convexity. Duration is the sensitivity to price for a given change in yield but, as shown in Chart 2, that sensitivity depends on where

today's yield is on the curve because of the changing slope. If duration were a constant then the price/yield relationship would follow the tangent line in Graph 2.
The formula for price given yield is:
Price = coupon/(1+yield)^1 + coupon/(1+yield)^2 + … coupon/(1+yield)^n + Principal/(1+yield)^n
where "n" equals the total number of periodic coupon payments, and coupon and yield reflect payment frequency (e.g., semiannual).
Changes in yields (such as by 100 bps or 200 bps as in the example in Chart 1) will have a nonlinear impact on price. Table 1 shows the yield and price pairs in column 1 and column 2 and the price change for each successive 100 bps change in yield in the third column labeled "Price Change."

Table 1: Bond Prices and Price Changes

Yield	Price	Price Change	Duration (Avg chg)	Change in Price Chg
0.50%	183.48			
		35.31		
1.50%	148.17		*31.23*	8.15
		27.16		
2.50%	121.02		*24.09*	6.14
		21.02		
3.50%	**100.00**		***18.70***	*4.64*
		16.37		
4.50%	83.63		*14.61*	3.53
		12.85		
5.50%	70.78		*11.50*	2.69
		10.16		
6.50%	60.62			

For our 3.5% 30-year bond example, if yields move down by 100 bps from 3.5% to 2.50%, the price impact is 21.02, as shown in Table 1 in the "Price Change" column. But if the yield moves up 100 bps, from 3.5% to 4.50%, the impact is only 16.37, because of the convexity of the price/yield relationship. A bond's duration is defined as the average of the two price changes resulting from up and down 100 bps yield changes — in this case, the average of 21.02 and 16.37 — therefore, the bond's calculated duration at a 3.5% yield is 18.70.
As shown in the "Change in Price Change" column in the table above, as yields rise the price impact of each successive 100 bps change becomes smaller. For example, when yields move from 2.5% to 3.5%, the price change is 21.02, and when yields move from 3.5% to 4.5%, it is 16.37. Therefore, the change in the price change is 4.64. This decreasing rate of price sensitivity at higher yields, and increasing sensitivity at lower rates, illustrates the price/yield function's *convexity.* In Chart 2, this concept is shown by the flattening of the price/yield curve at higher yields.
The accuracy of duration-based estimates of price sensitivity can be improved by making an additional adjustment for convexity. However, the primary point to keep in mind about convexity is that the price sensitivity of a given bond or bond portfolio is a function of the level of interest rates; i.e., neither duration nor convexity are constants. This is true for bonds with call options, and is especially the case for residential mortgage-backed securities (RMBS), given the borrower's ability to prepay at any time without penalty.
Note that while market convention is to present duration in terms of 100 bps changes, the underlying calculations are often done using the average of a plus 25 bps and a minus 25 bps price change.

Duration Methodologies

Among the several methods of calculating duration the most commonly encountered are Macaulay duration, modified duration and option-adjusted duration (OAD), which are defined as follows:

- Macaulay duration: Introduced by Frederick R. Macaulay in 1938, "Macaulay duration" expresses *in years* the time- and dollar-weighted average life of a bond's cash flows (principal and interest). In the case of a zero coupon bond, duration equals maturity because *all* of the cash flows occur on the maturity date.

- Modified duration: Modified duration converts Macaulay duration from weighted average life into the change in price for a given change in yield. For example, the price of a bond with a modified duration of "5" will increase or decrease by 5% from its current price for a given increase or decrease in rates of 1.00% (i.e., plus or minus 100 bps). Modified duration is the "magnitude of impact" of an assumed 1% change in yield. Rather than converting Macaulay duration, modified duration can be calculated directly, by pricing a bond at two different yields and taking the difference.

  Although Macaulay and modified durations are different measures, because their respective numeric values are usually close, they are often used interchangeably in discussion. For example, issued at par a 3.5% 30-year bond's Macaulay duration is 18.5 *years* and its modified duration 18.7 *percent*.

- Option-adjusted duration (OAD): Optionality in a bond's structure will increase convexity because changes in yields change not only the discount rate applied to the cash flows, but also the *amount* and *timing* of those cash flows. OAD adjusts for those factors. RMBS typically exhibit a large degree of "convexity" because of their optionality (prepayments). Other investments with optionality include callable corporate and municipal bonds, convertible bonds or bonds with payment-in-kind (PIK) features.

  Negative convexity refers to how the price/yield line will bend when embedded options are in-the-money. For example, when yields fall below a callable bond's coupon the probability of it being called (prepaid) at par increases; therefore, while an otherwise identical non-callable bond may trade at 110% of par, a currently callable bond would remain closer to its 100 call price. While all bonds have convexity, a bond or bond portfolio is said to "have convexity" or be "negatively convex" if it has embedded options, as these increase convexity significantly beyond that of more conventional bonds. Duration calculations for asset- and mortgage-backed securities, but especially RMBS, are not as formulaic as they are for other types of bonds, because assumptions must be made about borrower behavior in order to estimate the amount and timing of prepayments. Prepayments change both the timing of principal cash flows and decrease the amount of total interest paid. While yield-sensitive refinancing is a large component of prepayment activity, there are non-rate-sensitive considerations such as closing costs and availability of financing, as well as nonfinancial factors, making the duration of RMBS more difficult to estimate.
  Call options are also found in municipal and corporate bonds. However, in recent years, corporate bonds have shifted to spread-based "make-whole" call structures; these have much less exposure to market yields. Convertible bonds are more complex, as the underlying stock price may exert more influence on price than yields.
  While OAD takes optionality into account, similar to other duration metrics, it also is calculated based on a limited change in yield, but that range may not be sufficiently broad to capture how

near each option or prepayment threshold in the portfolio may be to its point of exercise. For example, prepayments on a pool of 3.5% mortgages may not change much if rates fall 25 bps from 3.75% to 3.5%, but they may increase substantially if rates fall by 100 bps to 2.75%. If a portfolio's OAD differs significantly from its Macaulay or modified duration, then identifying the sources of that optionality may be worthwhile.

Other forms of duration that may be encountered are spread, key-rate and dual duration. Spread duration measures sensitivity compared to a yield benchmark, typically U.S. Treasury bonds for dollar-denominated securities. Key-rate duration measures a portfolio's sensitivity to certain parts of the yield curve; e.g., if only the 5-year yield moves by 1%. Dual duration is usually in the context of inflation-indexed bonds as those are sensitive to both changes in nominal yields and the inflation rate.

General Characteristics of Duration

All else being equal, characteristics of duration include:

- Duration becomes shorter at higher yields and longer at lower interest rates because of the discounting (time-value) of each cash flow (as illustrated by the changing slope of the price/yield line in Chart 2).
- Bonds with higher coupons have shorter durations because relatively more of the total cash flows' "weight" is in the coupons.
- Bonds with longer maturities have longer durations as the cash flows' largest payment (i.e., principal at maturity) is further away. There are more interest payments, but they are usually outweighed by principal.
- As time passes, duration decreases as maturity draws closer (as shown in Chart 1) because, regardless of how high or low rates move, all paths converge to par at maturity (absent default) when the bond is paid in cash. Cash is the zero-duration asset.

Amortizing bonds (such as RMBS) have shorter durations than non-amortizing bonds, as most principal and interest payments occur well before maturity. Any acceleration in mortgage prepayments will further shorten duration because principal cash flows would occur earlier (and so less total interest will be received); conversely, lower prepayment levels extend duration as principal flows are delayed (and more interest received).

June 20, 2014 Major Insurer Share Prices			Change %			Prior		
		Close	Week	QTD	YTD	Week	Quarter	Year
Life	Aflac	$63.10	1.5	0.1	(5.5)	$62.14	$63.04	$66.80
	Ameriprise	119.14	2.9	8.2	3.6	115.74	110.07	115.05
	Genworth	17.65	2.0	(0.5)	13.7	17.30	17.73	15.53
	Lincoln	52.61	4.2	3.8	1.9	50.47	50.67	51.62
	MetLife	56.45	3.7	6.9	4.7	54.44	52.80	53.92
	Principal	50.37	3.3	9.5	2.1	48.74	45.99	49.31
	Protective	69.39	0.1	31.9	37.0	69.32	52.59	50.66
	Prudential	91.10	3.5	7.6	(1.2)	88.06	84.65	92.22
	UNUM	35.50	1.9	0.5	1.2	34.83	35.31	35.08
PC	ACE	$105.03	1.4	6.0	1.4	$103.63	$99.06	$103.53
	Axis Capital	45.16	(1.1)	(1.5)	(5.1)	45.68	45.85	47.57
	Allstate	58.82	0.0	4.0	7.8	58.81	56.58	54.54
	Arch Capital	57.54	0.9	0.0	(3.6)	57.00	57.54	59.69
	Cincinnati	48.79	0.9	0.3	(6.8)	48.37	48.66	52.37
	Chubb	93.37	0.1	4.6	(3.4)	93.32	89.30	96.63
	Everest Re	159.36	0.2	4.1	2.2	159.12	153.05	155.87
	Progressive	25.78	1.1	6.4	(5.5)	25.50	24.22	27.27
	Travelers	94.59	(0.9)	11.2	4.5	95.46	85.10	90.54
	WR Berkley	45.96	2.1	10.4	5.9	45.02	41.62	43.39
	XL	32.80	0.6	5.0	3.0	32.61	31.25	31.84
Other	AON	$90.69	1.0	7.6	8.1	$89.76	$84.28	$83.89
	AIG	55.58	1.1	11.1	8.9	54.98	50.01	51.05
	Assurant	68.12	1.8	4.9	2.6	66.92	64.96	66.37
	Fidelity National	32.89	0.6	4.6	1.4	32.70	31.44	32.45
	Hartford	36.02	1.1	2.1	(0.6)	35.64	35.27	36.23
	Marsh	52.15	2.8	5.8	7.8	50.74	49.30	48.36
Health	Aetna	$81.92	1.7	9.3	19.4	$80.57	$74.97	$68.59
	Cigna	91.86	1.3	9.7	5.0	90.70	83.73	87.48
	Humana	127.15	3.3	12.8	23.2	123.05	112.72	103.22
	United	81.41	4.4	(0.7)	8.1	78.00	81.99	75.30
	WellPoint	108.55	2.3	9.0	17.5	106.10	99.55	92.39
Monoline	Assured	$26.50	4.3	4.7	12.3	$25.41	$25.32	$23.59
	MBIA	12.80	2.9	(8.5)	7.2	12.44	13.99	11.94
	MGIC	9.21	(0.2)	8.1	9.1	9.23	8.52	8.44
	Radian	15.08	(0.6)	0.3	6.8	15.17	15.03	14.12
	XL Capital	32.80	0.6	5.0	3.0	32.61	31.25	31.84

June 20, 2014 Major Market Variables	Close	Change %			Prior		
		Week	QTD	YTD	Week	Quarter	Year
Dow Jones Ind	16,947.08	1.0	3.0	2.2	16,781.01	16,457.66	16,576.66
S&P 500	1,962.87	1.3	4.8	6.2	1,937.78	1,872.34	1,848.36
S&P Financial	307.90	1.8	2.3	4.5	302.57	301.06	294.71
S&P Insurance	297.67	1.7	6.3	3.0	292.77	280.10	289.10
US Dollar $		Change %			Prior		
/ Euro	$1.36	0.2	(1.2)	(1.0)	$1.36	$1.38	$1.37
/ Crude Oil bbl	107.26	0.4	5.6	9.0	106.80	101.58	98.42
/ Gold oz	1,316.20	3.2	2.6	9.5	1,274.90	1,283.40	1,202.30
Treasury Ylds %	%	Change bp			%	%	%
1 Year	0.08	(0.02)	(0.03)	(0.03)	0.10	0.11	0.11
10 Year	2.61	0.01	(0.11)	(0.42)	2.60	2.72	3.03
30 Year	3.44	0.04	(0.12)	(0.53)	3.40	3.56	3.97
Corp Credit Spreads -bp		Change %			Prior		
CDX.IG	13.50	3.8	(22.3)	1.7	13.00	17.37	13.27

June 20, 2014

Major Insurer Bond Yields

				Weekly Change					YTD
				Price			Spread over UST		Spread
	Company	Coupon	Maturity	Current	Change	Yield	B.P.	Change	Change
Life	Aflac	8.500%	5/15/2019	$128.80	$0.07	2.25%	57	(1)	(35)
	Ameriprise	5.300%	3/15/2020	$114.15	($0.08)	2.62%	70	(1)	(11)
	Genworth	6.515%	5/15/2018	$115.58	$0.05	2.32%	99	(1)	(64)
	Lincoln National	8.750%	7/15/2019	$129.39	($0.01)	2.48%	72	0	(36)
	MassMutual	8.875%	6/15/2039	$157.69	($0.66)	4.86%	158	0	(18)
	MetLife	4.750%	2/15/2021	$111.41	($0.04)	2.85%	71	1	(17)
	New York Life	6.750%	11/15/2039	$131.58	($1.77)	4.62%	132	5	4
	Northwestern Mutual	6.063%	3/15/2040	$122.37	($0.94)	4.58%	127	2	3
	Pacific Life	9.250%	6/15/2039	$151.69	($0.31)	5.44%	216	(1)	(18)
	Principal	6.050%	10/15/2036	$120.28	($1.15)	4.59%	145	6	7
	Prudential	4.500%	11/15/2020	$109.76	$0.10	2.82%	73	(1)	(5)
	TIAA	6.850%	12/15/2039	$132.11	($0.73)	4.68%	139	1	6
P&C	ACE INA	5.900%	6/15/2019	$116.78	$0.00	2.31%	58	1	(5)
	Allstate	7.450%	5/15/2019	$124.09	($0.03)	2.22%	51	1	(12)
	American Financial	9.875%	6/15/2019	$130.37	($0.49)	3.22%	143	8	(44)
	Berkshire Hathaway	5.400%	5/15/2018	$113.96	$0.07	1.68%	37	(2)	(2)
	Travelers	3.900%	11/15/2020	$107.64	$0.06	2.59%	49	(1)	(12)
	XL Group	6.250%	5/15/2027	$117.90	($0.29)	4.41%	161	1	(21)
Other	AON	5.000%	9/15/2020	$111.69	$0.08	2.94%	88	0	(1)
	AIG	5.850%	1/15/2018	$113.79	$0.01	1.83%	65	(1)	(9)
	Hartford	5.500%	3/15/2020	$114.38	$0.10	2.78%	84	(2)	(21)
	Marsh	9.250%	4/15/2019	$130.24	$0.02	2.53%	85	(1)	(40)
	Nationwide	9.375%	8/15/2039	$153.76	($0.84)	5.43%	214	1	(21)
Health	Aetna	3.950%	9/15/2020	$107.88	($0.07)	2.56%	51	2	(35)
	CIGNA	5.125%	6/15/2020	$112.64	($0.29)	2.81%	84	9	(13)
	United Healthcare	3.875%	10/15/2020	$106.77	($0.23)	2.70%	62	0	(3)
	Wellpoint	4.350%	8/15/2020	$108.60	$0.24	2.81%	79	(3)	(19)

Questions and comments are always welcomed. Please contact the Capital Markets Bureau at CapitalMarkets@naic.org

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