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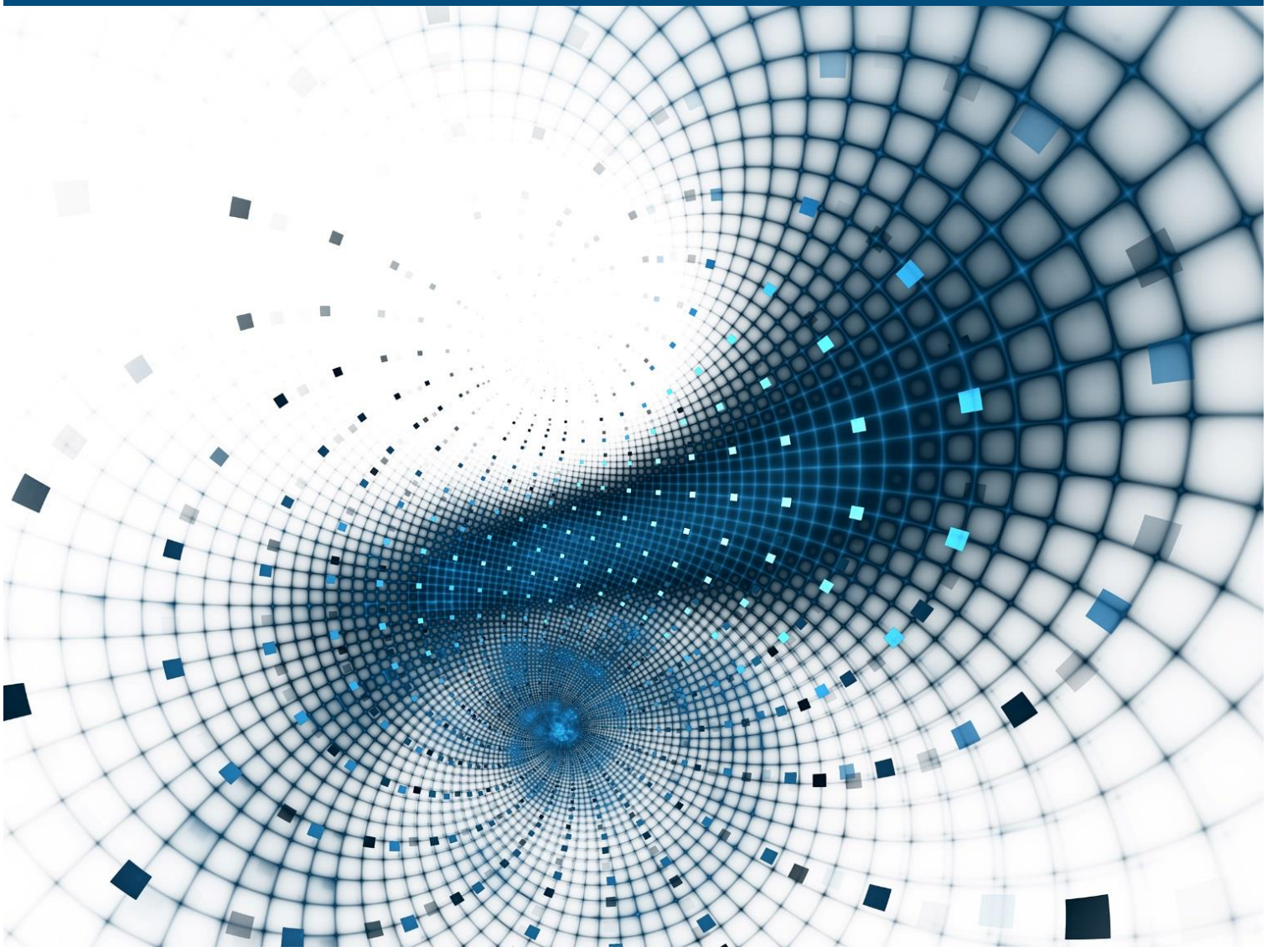
Discount Rate Sensitivities in Pension Plans



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Discount Rate Sensitivities in Pension Plans

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Caveat and Disclaimer

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Executive Summary

Measurement and management of pension plan risks requires a thorough understanding of the relationship between actuarial liabilities and the discount rate used to measure liabilities. Stochastic modeling requires accurate measurement of this relationship over a wide range of discount rates. When data about a pension plan are limited or direct valuation of actuarial liabilities using each possible future discount rate would require too much computation, a simple but accurate means of assessing discount rate sensitivity is required.

We find that the sensitivity of liabilities for pensions in pay does not vary significantly from one pension plan to another. Differences are mostly explained by the discount rate being used to measure liabilities, the presence of postretirement indexation and average age of pensioners. Other factors such as bridge benefits and joint pensions presumably account for the remaining differences between pension plans. The sensitivity results reported for going concern valuations are highly consistent with the sensitivity results reported for solvency valuations.

Liabilities for active pension plan members, deferred pensioners and other plan members vary more widely from plan to plan. Less consistency is also seen between going concern and solvency. Discernible patterns are found by average age and between different benefit accrual formulas, but these do not account for most of the differences. Other factors such as expected retirement age are also important.

Overall, the most important determinant of discount rate sensitivity is the mix of active and retired plan members. An estimate based on this mix can be improved with additional information about the pension plan, such as a breakdown of liabilities between pensioners and other types of members, the average age of members or plan-specific measures of interest sensitivity.

Present values are more sensitive to a change in discount rate when discount rates are low than when discount rates are high, but this convexity effect is predictable, once the exponential nature of present values is considered.

Section 1: Acknowledgments

The author extends thanks to the individuals who volunteered their time and expertise to support the preparation of this report, including the actuaries recognized below. This report does not necessarily reflect their views or the views of their employers. Any errors are the author's alone.

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1.1 Reviewers

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1.2 Modeling Oversight Group

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Section 2: Data

Since 2012, Canadian pension actuaries have included information on the sensitivity to a 1% decrease in discount rates in valuation reports prepared for funding purposes. The British Columbia Financial

Institutions Commissioner (FICOM) has updated their Actuarial Information Summary to include this sensitivity information. This report provides summary statistics and analysis of valuation sensitivities, based on reports submitted to FICOM with December 31, 2013, valuation dates.

Canadian actuarial valuation reports include results of two distinct types of valuations. The "going concern" valuation is prepared on the presumption that the pension plan will continue to operate indefinitely. The "solvency" valuation is prepared as if the benefits from the plan had been settled at market rates on the valuation date through purchase of annuities or payment of commuted values.

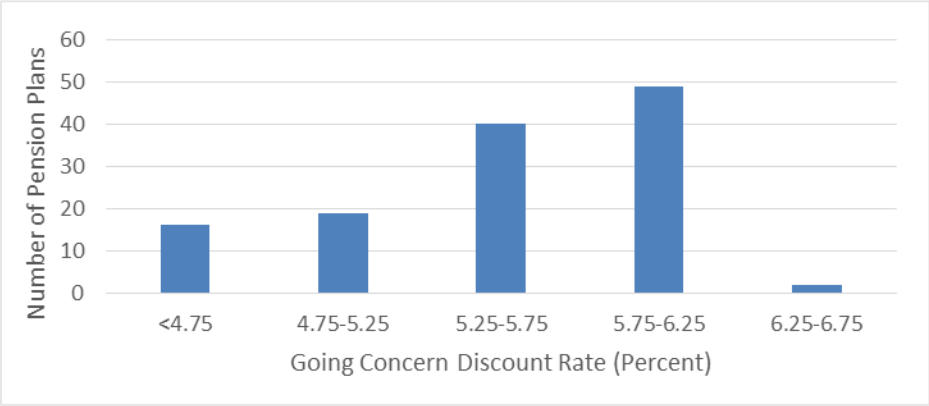
All 126 Actuarial Information Summaries submitted as of December 31, 2013, included a going concern discount rate and are included in the distribution of going concern discount rates. Some pension plans are excluded from other charts and tables because data were incomplete. For example, a pension plan that provides both defined benefits and defined contributions might be described as "combination," with no indication of the type of defined benefit formula.

In a few instances, the data were not entered according to the Actuarial Information Summary instructions, but the correct interpretation was obvious. For example, the effect of a 1% decrease in liability might have been shown as the net change rather than the increased liability. Where the intent was clear and the result was reasonable, the data were adjusted.

Section 3: Discount Rates

For going concern valuations, the discount rate reflects the expected return on pension fund investments, with margins for fees and adverse deviations. Thus, different pension plans will have different discount rates, depending on asset mix, plan size and other considerations. Figure 1 shows the distribution of going concern discount rates.

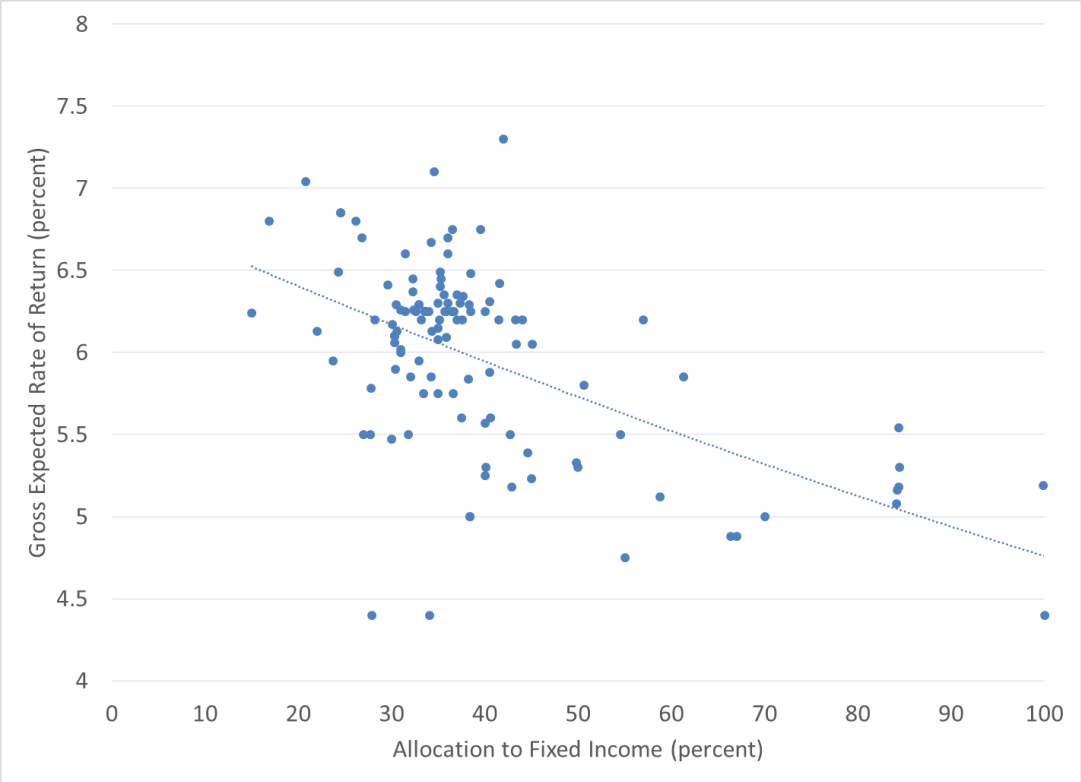
Figure 1
Distribution of Reported Discount Rates



Components of the discount rate are also provided in the Actuarial Information Summary. Variations in discount rates are mostly due to variations in expense allowances (with smaller plans having larger expense allowances) and variations in asset mix. The scatter chart in Figure 2 shows the relationship between the gross expected return on assets used to derive the discount rate (before adjustment for

active management premium or expenses) and the proportion of the plan's assets allocated to fixed income investments.

Figure 2
Gross Rate of Return and Asset Mix

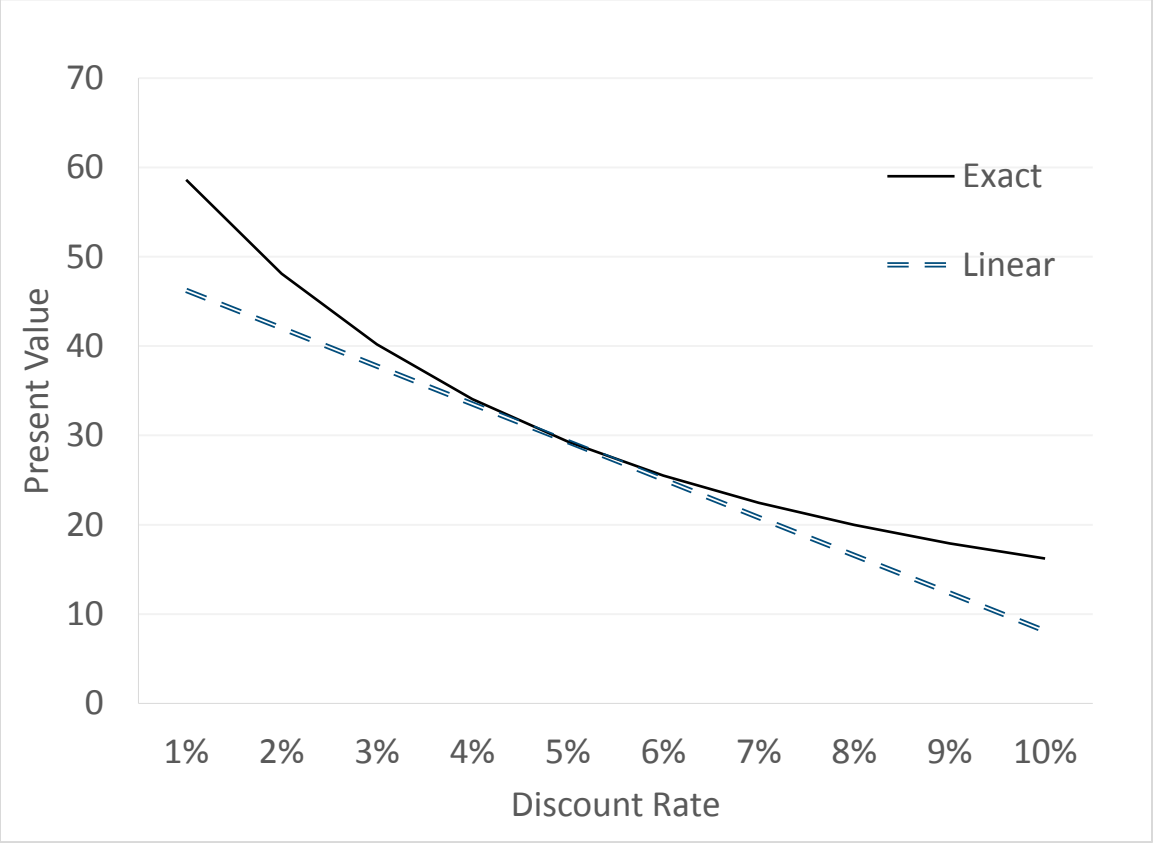


For solvency valuations, the selection of discount rates is restricted. For plan members who would be expected to elect a commuted value in a plan windup, the discount rates prescribed for the calculation of commuted values on the valuation date are used. For other plan members, guidance provided by the Canadian Institute of Actuaries on the pricing of annuities is typically used. The annuity pricing guidance requires discount rates that vary according to the duration of the liabilities of the affected group. These discount rates reflect the return on investments expected by insurance companies, along with implicit adjustments for insurers' mortality assumptions, expenses and risk charges. Information on sensitivity of solvency liabilities is provided in Actuarial Information Summaries for each type of plan member but is not broken down according to whether plan members are expected to elect commuted values.

Section 4: Adjusting for Differences in Discount Rates

In order to compare sensitivity information from different pension plans with different valuation discount rates, the sensitivities must be adjusted to the same discount rate. Figure 3 compares the exact value of a pension plan's liability to a linear estimate determined from a liability at one particular discount rate and information about the sensitivity of that liability to changes in discount rates.

Figure 3
Linear Estimate of Discount Rate Sensitivity



It is apparent from this chart that a simple linear adjustment of liabilities using the sensitivity information in a valuation report will lead to an understatement of the liabilities. The sensitivity of liabilities payable at a range of dates in the future to a change in discount rate depends on the discount rate. The lower the discount rate and the broader the range of payment dates, the greater the sensitivity. This property of the relationship between liabilities and yields is referred to as "convexity."

Duration measures the rate of change in present value corresponding to a specific discount rate. The relationship between the present value of a stream of future cash flows and the discount rate is defined by the following equations:

$$PV(i) = \sum P_t(1+i)^{-t},$$

$$\frac{dPV(i)}{di} = \sum tP_t(1+i)^{-t-1}.$$

The modified (or effective) duration at a particular discount rate is defined as

$$D(i) = -\frac{dPv(i)}{di}/PV(i) = -\frac{dln(PV(i))}{di}.$$

Since the most common going concern discount rate in January 1, 2015, valuations was 5.75%, the sensitivity data available have been used to determine the duration of each pension plan at a discount rate of 5.25%. This is comparable to the effect of a 1% decrease in the discount rate from 5.75% to 4.75%.

The duration at 5.25% has been determined from the effect of a 1% decrease in the valuation discount rate from i to $i - 1\%$ using the following formula:

$$D(5.25\%) = D(i - 0.5\%) \times \big(1 + 8(i - 5.75\%)\big),$$

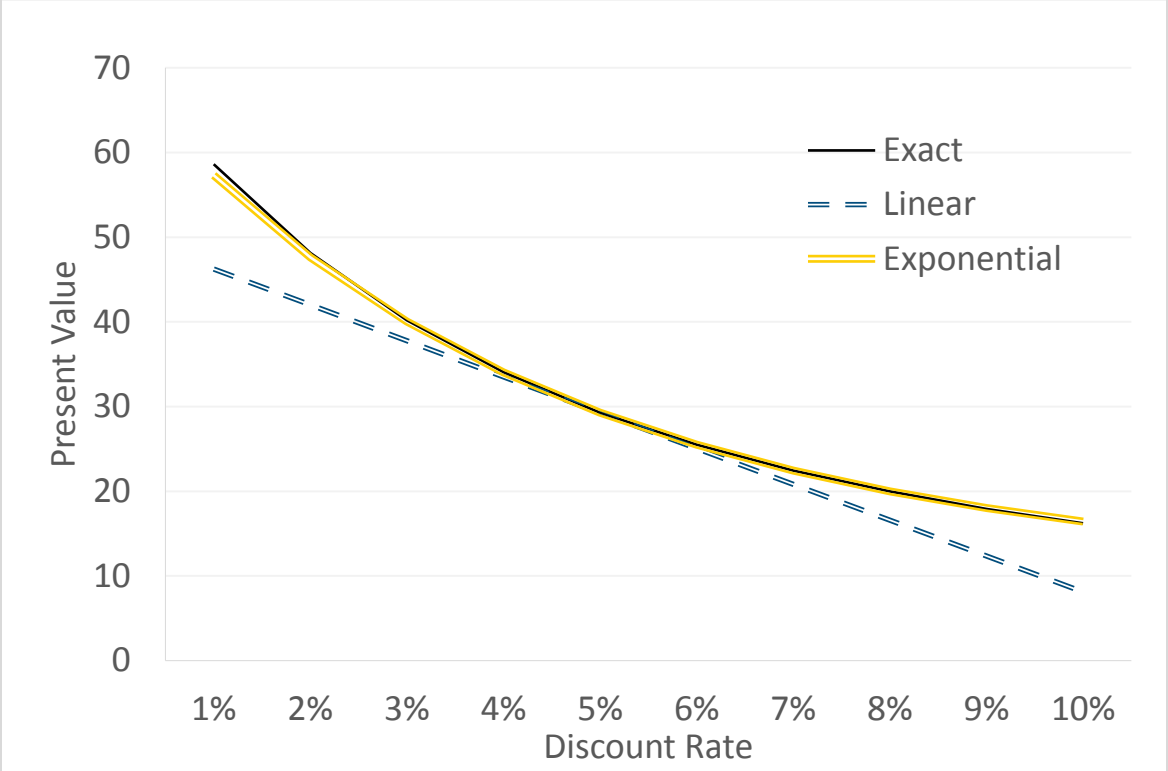
where 8 represents a typical pension plan convexity adjustment

Convexity is normally defined as the second derivative of the present value with respect to a change in discount rate and calculated as a second difference of present values. The convexity adjustment of 8 shown in the formula above can be thought of as the usual second derivative divided by the duration. In our testing of synthetic cash flows from a wide range of pension plans, we found that the convexity adjustment expressed in this way does not vary significantly with the discount rate or between pension plans with different features. Subgroups of a pension plan such as individual or joint annuitants, all pensioners together or all active plan members together have a convexity factor close to 7, while an entire pension plan that includes a mixture of both active and retired members has a convexity factor close to 8. This pattern is a consequence of the fact that the primary benefit from a pension plan (other than a cash balance plan) is a level lifetime pension, with a pattern of expected payments that changes gradually over several decades. In contrast, the ratio of convexity to duration varies widely for bonds, depending on the term to maturity, coupon and yield.

In our testing of cash flows from life annuities, bonds and synthetic pension plans, we found that the logarithm of present value can be more accurately approximated by a linear or quadratic function than the present value itself. An exponential extrapolation using a fixed convexity adjustment produces estimates of present values of liabilities at different discount rates that are far superior to simple linear extrapolation, and even superior to quadratic extrapolation using both duration and a customized measure of convexity.[1]

[1] For a discussion of the application of the traditional approach to discount rate sensitivity in pension plans, see M. McCaulay, "Duration and Convexity for Pension Liabilities", *Pension Section News,* September 2013. Retrieved from https://www.soa.org/Library/Newsletters/Pension-Section-News/2013/september/psn-2013-iss81-mccaulay.aspx.

Figure 4
Exponential Estimate of Discount Rate Sensitivity



In Figure 4, the exponential estimate of the present value is determined from the present value at 5% and the duration at a midpoint between 5% and each specific discount rate using the following formula:

$$PV(i) = PV(5\%) \times e^{-D(5\%)\times(i-5\%)\times\left(1-8\times\frac{i-5\%}{2}\right)}$$

While less accurate approaches may be satisfactory over a narrow range of discount rates, this exponential approach will be an important refinement when present values of pension liabilities need to be extrapolated over a wide range of discount rates, as is the case in stochastic modelling.

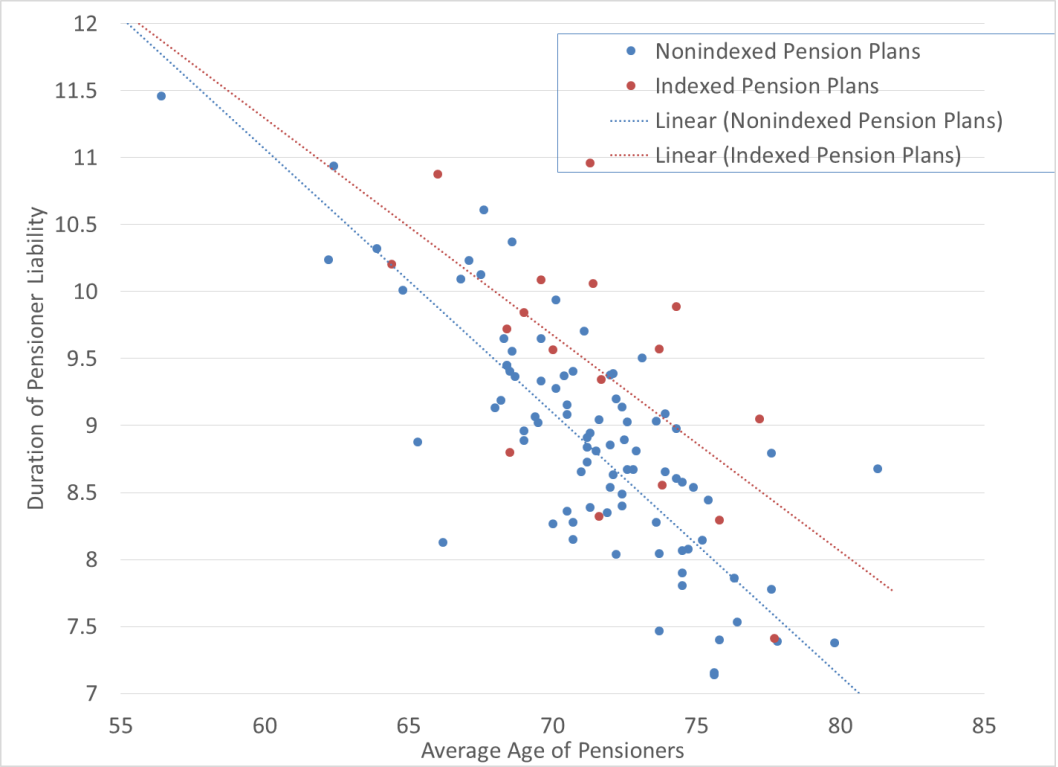
Section 5: Results and Analysis

5.1 Pensions in Pay

The scatter chart in Figure 5 compares duration of going concern liabilities for pensioners to average age of pensioners. Results are shown separately for nonindexed and indexed plans, with no distinction between partially and fully indexed pensions. Very similar results would be obtained using solvency liabilities. After correcting for the difference between the solvency discount rate and 5.25%, most plans show a duration of solvency liability within 0.25 years of the duration derived from going concern liabilities. Exceptions appear to be due to the following:

- Indexed pension plans:
  - Indexation extends the duration of payments
  - Indexation might or might not be guaranteed on settlement
  - The effect on solvency liabilities is estimated using real return bond yields rather than an assumed rate of inflation
  - Plans may have partial indexation with cumulative caps or other formulas with different effects on the duration of liabilities.
- Mortality assumptions:
  - The annuity pricing guidance in effect at December 31, 2013, referenced the UP94 mortality table with generational projection on scale AA, whereas most going concern valuations had been updated to use some variation on CPM-2014 with generational projection on the CPM-B scale
  - Where a heavier going concern mortality table was used (e.g., 120% of CPM-2014 Private Sector table), the going concern duration was as much as 0.5 years lower than the solvency duration.

Figure 5
Average Age of Pensioners and Duration

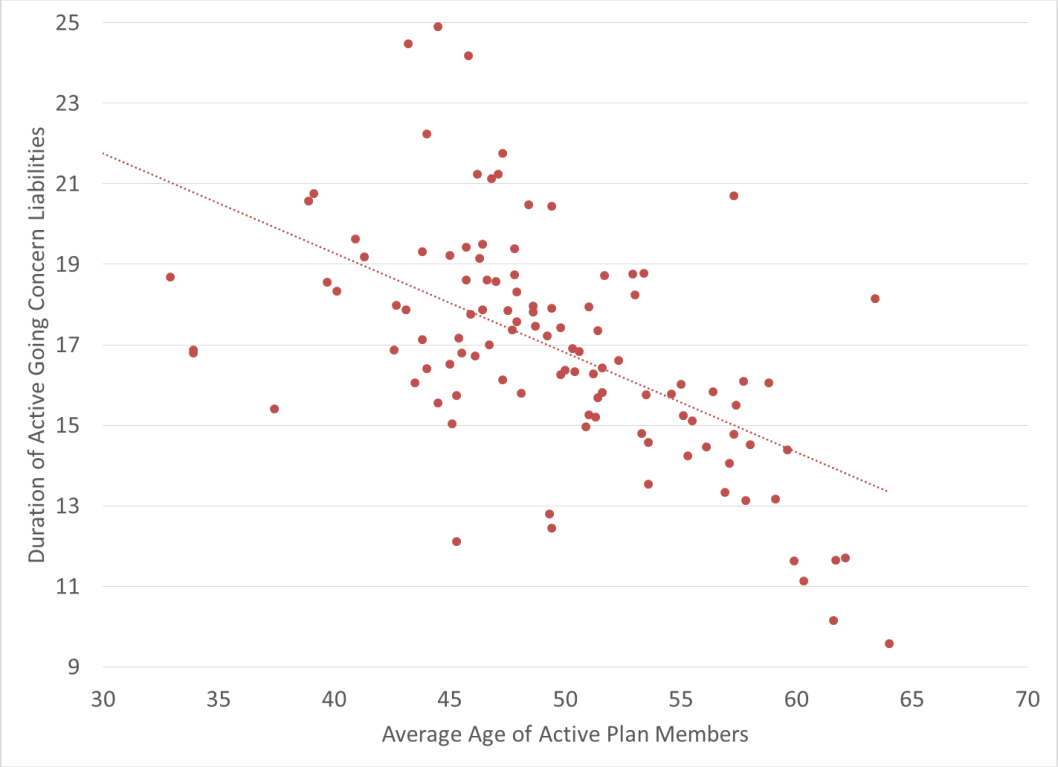


In summary, no evidence is found of differences between solvency and going concern valuations in the way pensioner liabilities are being calculated, aside from the discount rate, the mortality scale and the treatment of indexation.

5.2 Active Plan Members

The scatter chart in Figure 6 shows duration of going concern liabilities relative to the average age of active plan members.

Figure 6
Average Age of Active Members and Duration



Although plans with a higher average age of active plan members typically have lower durations, other important factors are at play. One factor could be the benefit accrual formula. Key statistics for plans with different benefit accrual formulas are shown in Table 1.

Table 1
Statistics for Pension Plan Members Actively Accruing Service

	Flat Benefit	Career Average	Nonindexed Final or Best Average	All Final or Best Average
Number of plans	23	17	29	43
Average age	46.7	48.3	49.4	50.6
Average pensionable service	12.7	13.3	14.1	14.4
Median duration	16.5	16.9	17.4	17.2
Range of durations (15th to 85th percentile)	15.1–18.6	15.6–18.7	14.6–20.0	14.5–20.2

Overall, flat benefit plans are slightly less sensitive to changes in discount rates than final average pension plans, despite the fact that they have a lower average age. This is not attributable to the benefit formula, since the projected unit credit actuarial cost method attributes an equal projected pension at retirement to each year of service, regardless of the benefit formula. One possible explanation is that flat benefit plans are more likely to provide bridge benefits or subsidized early retirement.

The sensitivity of active member going concern liabilities to changes in discount rates depends upon:

- The number of years until the pension commences (either at retirement from active service or at the pension commencement age used to determine preretirement termination benefits)
- The number of years the pension is expected to be paid after commencement, under the assumed form of pension and
- Variations in annual payments due to the form of pension (indexation, bridge benefits or survivor pensions).

The effect of the form of pension is illustrated by Table 2, showing the sensitivity to various forms of payment. Factors are calculated using a 5.25% discount rate and unisex mortality rates (50% male) from the CPM 2016 mortality table projected using CPM-B.

Table 2
Duration of Annuity Factors

Form	Monthly Pension	Annuity Factor at Age 60	Lump Sum Value	Macaulay Duration
Single life	$1,000	14.26	$171,000	11.03
Joint and 60% survivor	$940	15.18	$171,000	11.68
Integrated single life	$1,277 until age 65 $877 after age 65	4.37 until 65 14.26 lifetime	$171,000	9.97
Indexed single life	$800	17.88	$171,000	12.56

The duration of benefit payments for an individual active plan member who will retire at age 60 is equal to the duration shown above for that plan member's expected form of pension, plus the number of years from the plan member's current age to age 60.

Although the longer duration of indexed pensions is evident in the annuity factors and the reported sensitivity of liabilities for pensioners, no apparent difference exists in the sensitivity of liabilities for active plan members between indexed and nonindexed pensions. This may simply be because the number of indexed pension plans is relatively small and other factors happen to be more important in these specific cases.

Going concern actuarial valuations determine the active member liability using the normal form of pension, and so this would be the basis for determining the sensitivity results, even if the majority of plan

members elect an optional form of pension that produces higher or lower sensitivity. All else being equal, the valuation of a plan with a slightly subsidized joint pension would produce greater discount rate sensitivity for active members than the valuation of a plan with an actuarially equivalent joint pension option, simply because the actuarial assumptions would make provision for joint pensions. In reality, there might be no difference in the proportion of members electing a joint pension as a result of the subsidy.

Another important actuarial assumption affecting the sensitivity of active member actuarial liabilities is the rate of early retirement. Whereas going concern liabilities reflect a best estimate of expected future utilization of the pension plan's early retirement benefits, solvency liabilities assume that plan members will take maximum advantage of the early retirement benefits they have earned as of the valuation date. In a typical solvency valuation, members who are already entitled to an immediate subsidized pension as of the valuation date are assumed to retire immediately, while members who are not yet entitled to retire early are assumed to retire at the normal retirement date. In a going concern valuation of a plan with early retirement benefits that are of equivalent value to normal retirement benefits, the precise retirement assumption might have very little effect on overall liabilities. Going concern valuation retirement assumptions can provide a good estimate of going concern liabilities and normal costs without providing a good estimate of average retirement age. Variations in early retirement assumptions can lead to an earlier or later average retirement age for the plan as a whole, depending on the age and service distribution of the membership.

Table 3 compares reported median durations of active plan member liabilities on the solvency valuation basis to the going concern basis. Indexed plans and plans with missing or invalid data are excluded.

Table 3
Duration of Active Liabilities by Benefit Type

	Flat Benefit	Career Average	Final or Best Average
Number of plans	21	14	24
Median duration of going concern liabilities	16.5	16.9	17.5
Median duration of solvency liabilities	15.7	16.7	13.7
Median duration of normal cost (on the going concern basis)	17.3	18.5	19.2

The duration of solvency liabilities is less than the duration of going concern liabilities for final or best average pension plans, but not significantly less for career average or flat benefit plans. There is provision for future salary increases in a going concern valuation but not in a solvency valuation, and this means more weight is placed on younger plan members in a going concern valuation of a final or best average pension plan.

The duration of liabilities is less than the duration of normal costs. Liabilities are proportional to years of pensionable service, whereas normal costs are for a single year of pensionable service. Thus, liabilities are weighted toward the active members who are closest to retirement.

5.3 Liabilities for Pension Plans as a Whole

In addition to members who are actively accruing service and pensions in pay, pension plans typically include liabilities for:

- Deferred pensions for members whose employment terminated prior to retirement
- Members whose pension will depend on future employment benefits but who are not accruing pensionable service because their benefits are suspended, transferred or frozen and
- Lump sum amounts not yet paid for administrative or other reasons (see Table 4).

The importance of these benefits varies widely from one pension plan to another, but in general they are not a significant component of overall defined benefit pension obligations.

Table 4
Statistics for All Classes of Membership

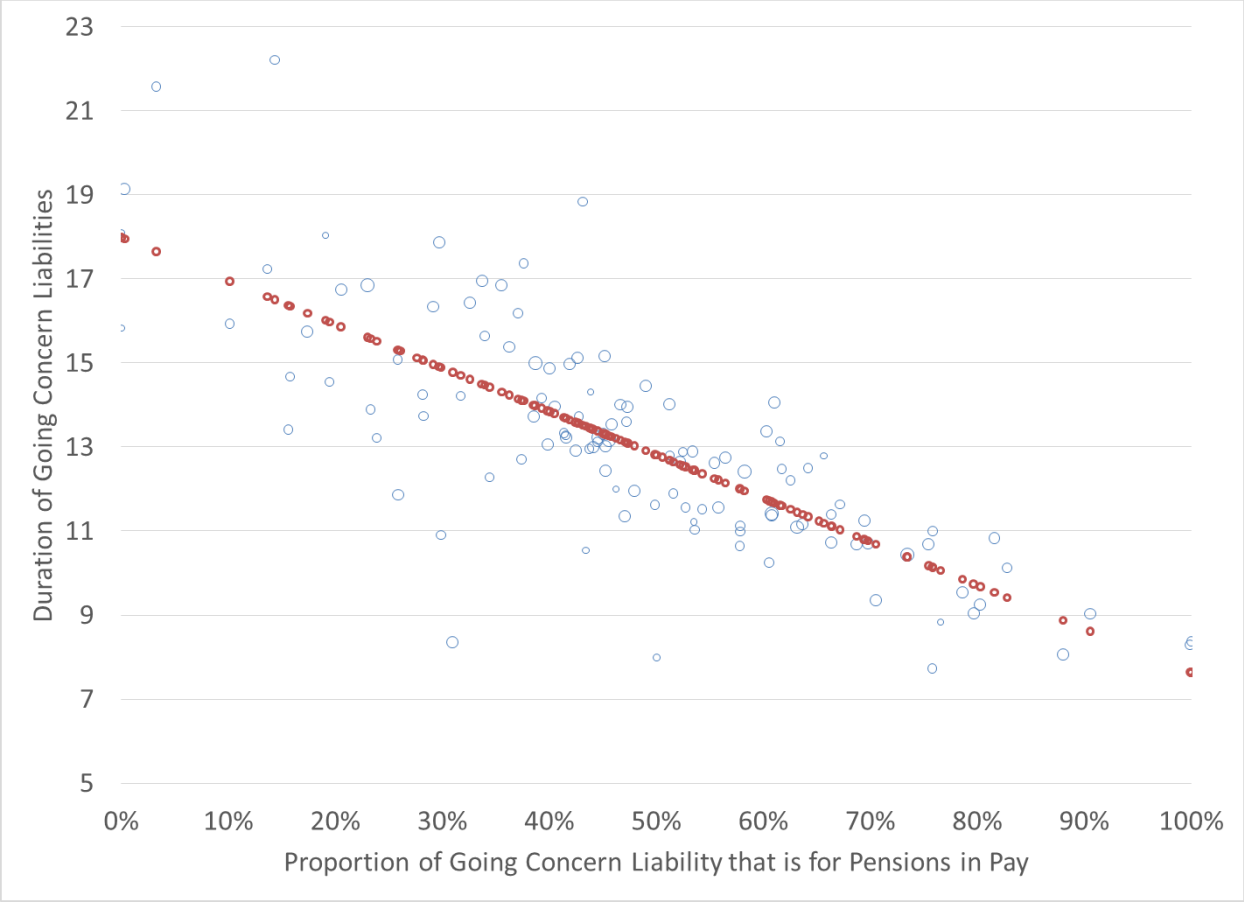
Class of Membership	Median Proportion of Liability	Proportion of Aggregate Liability for All Plans	Duration (Median, 15th and 85th Percentile)*
Actively accruing service	40%	39%	16.9 (14.5–19.4)
Receiving a pension	46%	49%	8.9 (8.0–9.9)
Entitled to a deferred pension	5%	7%	17.2 (14.3–20.9)
Other classes (transferred or suspended)	0%	2%	15.6 (11.6–18.8)
Outstanding payments	0%	2%	Nil
All classes combined	100%	100%	12.9 (10.7–15.8)

* For plans with valid data.

Figure 7 shows the duration of total going concern liabilities, relative to the proportion of the liability that relates to plan members who are receiving a pension. The ratio of liability for pensions in pay to total liability accounts for 63% of the total variation in duration. [2] This is mostly because pensions in pay are less sensitive to discount rate changes than active liabilities but also in small measure because members of plans that have a large liability for pensions in pay are typically older.

[2] The correlation coefficient between duration and proportion of liabilities that is for pensions in pay is –0.794, and 63% is –0.794[2]. The total standard deviation of duration is 2.7 years, while the standard deviation of the distance of points from the regression line is 1.6 years.

Figure 7
Duration of Entire Pension Plan



Section 6: Conclusions and Commentary

6.1 Updating the Funded Status of a Pension Plan as a Whole

The proportion of a plan's total liabilities that is attributable to pensions in pay and the proportion of assets allocated to fixed income are key statistics for regulators and financial statement users concerned about asset/liability mismatches. The approximate duration of pension plans with lifetime benefits (measured at 5.25%) ranges from 18 years for a plan with no pensioners to 7.5 years for a plan with 100% pensioners. The effect of a change in liability due to a change in discount rate from i_0 to i_1 can be reasonably estimated for any pension plan (that provides lifetime pensions after retirement) by multiplying the liability by

$$e^{-(18-10.5p)\times(i_1-i_0)\times\left(1-8\left(\frac{i_0+i_1}{2}-5.25\%\right)\right)},$$

where p is the proportion of the pension plan liability that relates to pensions in pay. The error in this estimate for a 1% change in liability will generally be less than 2% of the liability.

Regulators, plan sponsors and others could use this formula along with current asset data (see, for example, the information required by the OSFI Solvency Information Return) to monitor changes in funded status between full valuations.

The key to the effectiveness of this formula is that pensions are expected to be paid out gradually over 30 years or so. This formula and others in the report will work well for a typical Canadian or U.S. pension plan that provides lifetime pensions. They would not work as well for a cash balance plan, a plan that provides lump sums based on fixed rates (e.g., a pension equity plan) or a hybrid plan (i.e., a pension plan that provides the greater of a defined benefit pension and a defined contribution pension). The availability of market-priced commuted values such those required in Canada or the option to purchase annuities at market prices does not undermine the formulas because those interest-sensitive options do not alter the interest sensitivity of the plan as a whole.

The formulas provide for adjustments to liabilities determined using a single level discount rate. There is no direct extension of these formulas to liabilities determined using a full yield curve. They might provide reasonable results for a parallel shift in a yield curve, but not for a rotation or other non-parallel yield-curve shift. However, where yield curves have been synthesized into a single equivalent level discount rate (as is often the case when accounting for pension plan obligations in the financial statements of a sponsor), these formulas could be useful. Logarithmic duration and fixed convexity would represent an improvement over a linear interpolation or extrapolation when interpreting IAS 19 or critical accounting estimate disclosures concerning the effect of a 1% or 0.25% change in discount rates.

6.2 Considerations for Liabilities Other than Pensions in Pay

Although the average age of active members is relevant to discount rate sensitivity, it is only one end of the rope. The total years until benefits commence also depend upon expected retirement age, and actuarial assumptions concerning retirement age depend upon the purpose of the valuation.

Benefit accrual types, the normal form of pension and other plan provisions make a difference to the discount rate sensitivity of active liabilities but are not as important as the expected number of years until benefits commence.

Deferred pensioners and other classes of pension plan members are generally not a significant part of (Canadian) pension plan liabilities. In any event, these classes have a benefit duration similar to active members.

6.3 Investment Considerations

Given that a long-term bond portfolio has an interest rate sensitivity of only about 11 years (at a 5.25% yield to maturity), defeasing discount rate risk through direct investment in bonds is more practical for pensions in pay than for other classes of membership. Derivative contracts or other strategies might be used to increase the interest sensitivity of a pension fund beyond the duration available through direct investments, but these strategies do not address uncertainties around retirement date, salary increases and other factors affecting future benefits for members who have not yet retired.

Optimization of the risk/return trade-off in pension plan investments often involves stochastic modeling of pension plan assets and liabilities. Typically, such a project will require a set of current and projected valuations at a range of discount rates, so that the interest rate sensitivity of liabilities will reflect convexity and projected changes to duration as the plan matures. It would be simpler to project the mix of pensioner and nonpensioner liabilities at a single discount rate, and to estimate interest rate sensitivity using the initial aggregate duration, fixed convexity and the logarithmic approach presented here. For the wide range of possible discount rates that arises in stochastic modeling, this might be more accurate than approaches that assume a linear or quadratic relationship between actuarial liabilities and discount rates.

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