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Index-Linked Variable Annuity (ILVA)/ Registered Index-Linked Annuity (RILA) Policy Paper

American Academy of Actuaries
Index-Linked Variable Annuity Subcommittee

American Academy of Actuaries

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Index-Linked Variable Annuity Subcommittee

Elizabeth Keith, MAAA, FSA; Chairperson
Yolanda Chow, MAAA, FSA
David Hippen, MAAA, FSA
Bryon Robidoux, MAAA, FSA
Ryan Stowe, MAAA, FSA
Shirley Wu, MAAA, FSA

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202-223-8196 | WWW.ACTUARY.ORG

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Any references to current laws, regulations, or practice guidelines are correct as of the date of publication.

Index-Linked Variable Annuity (ILVA)/ Registered Index-Linked Annuity (RILA) Policy Paper

Executive Summary

This policy paper presents a description of definitions, relevant product considerations, and practices believed by the working group to be commonly used by actuaries employed by life insurance companies issuing RILA/ILVA products in the United States.

The purpose of this policy paper is to be a resource that actuaries working in this area could consider as they evaluate the application of, and consistency with, Actuarial Guideline LIV (AG54)[1]. This policy paper does not take into consideration aspects of RILA/ILVA products that are not covered by AG54. These include, but are not limited to:

- U.S. Statutory and U.S. GAAP valuation;
- U.S. Statutory Risk-Based Capital (RBC);
- Separate account characteristics or registration with the Securities and Exchange Commission (SEC); or
- Any compliance and suitability topics.

This policy paper includes Excel Lambda Library which provides functionality in the calculations of the components of the Hypothetical Portfolio.

1 Actuarial Guideline LIV Nonforfeiture Requirements for Index-Linked Variable Annuity Products

Limitations

This policy paper is not a promulgation of the Actuarial Standards Board, is not an actuarial standard of practice (ASOP), is not binding upon any actuary and is not a definitive statement as to what constitutes generally accepted practice in the area under discussion. Events occurring after the publication of this policy paper may make the descriptions and practices described herein irrelevant or obsolete.

No representation of completeness is made, nor is there an assertion as to whether the practices discussed herein constitute all best practices; other reasonable approaches may be appropriate.

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Defining ILVA Products

What constitutes ILVA products?

Index-Linked Variable Annuities are products that contain features of fixed indexed annuities (FIA) and traditional unit-linked variable annuities (VA)[2]. For purposes of this policy paper, ILVA refers to ILVA/RILA products. ILVAs credit the performance of an index subject to limitations on gains in exchange for partial downside protection.

	FIA	ILVA/RILA	VA
Risk of loss of principal	No	Yes	Yes
Direct market investment	No	No	Yes
Registered security	No	Yes	Yes
Interim value required (e.g. daily fluctuation in contract value)	No	Yes	Yes
Statutory non-forfeiture requirements[3]	MO-805	MO-250	MO-250
Statutory accounting treatment	General Account	Separate Account	Separate Account
Statutory risk-based capital (RBC)	General Account	C0 – C1: General Account	
		C3 – C4: Separate Account	Separate Account
US GAAP accounting treatment	General Account	General Account	Separate Account

Limitations on gains credited to the contract, which will be referred to as crediting strategies in this policy paper, may include:

- Cap rates,
- Participation rates,
- Spread rates, or
- A combination of one or more of these.

Downside protection is provided in the form of a buffer, dual direction buffer, or a floor. As these products evolve, there could be additional crediting strategies and/or downside protection features not mentioned in this policy paper.

2 The table refers to accumulation-focused product designs that do not include any optional benefits (e.g., return of premium death benefit, guaranteed living withdrawal benefit). Reserves for these benefits are held in the general account for all three product designs.
3 MO-805: Standard Nonforfeiture Law for Individual Deferred Annuities

Most companies have simple index strategies with some combination of the following parameters: cap rate, participation rate, buffer, and floor. More complex index strategies contain parameters such as a trigger rate, dual direction buffer, and/or performance lock. The complex index strategies provide additional challenges in consumer understanding and the company's ability to hedge and value the strategy. Considerations for valuing strategies could include a replicating portfolio, a closed form solution, stochastic modeling, or using an investment bank.

ILVA product Standard Nonforfeiture law (SNFL) requirements

AG54 identifies the interim value requirements necessary for an ILVA to be considered a variable annuity and therefore be exempt from NAIC Model Law 805, Standard Nonforfeiture Law for Individual Deferred Annuities[4]. The guiding principles from AG54 state:

1. Interim Values defined in the contract provide equity between the contract holder and the insurance company.
2. Interim Values are consistent with the value of the Hypothetical Portfolio over the Index Strategy Term.

These principles set forth a framework for the insurance company to develop ILVA contracts with an interim value calculation consistent with AG54, and therefore subject to variable annuity nonforfeiture requirements under the NAIC Model Law 250[5].

Interim Values under AG54

Align Interim Values with the value of a Hypothetical Portfolio, which is the sum of the Fixed Income Asset Proxy Value plus the Derivative Asset Proxy Value.

The Fixed Income Asset Proxy should represent a hypothetical zero-coupon bond with a yield such that:

- At the beginning of the Index Strategy Term, the book value of the Fixed Income Asset Proxy is equal to the Index Strategy Base, less the Derivative Asset Proxy value; and
- At the end of the Index Strategy Term, the book value of the Fixed Income Asset Proxy, assuming no change in yield, is projected to equal the Index Strategy Base.

4 NAIC Model Law 805 Standard Nonforfeiture Law for Individual Deferred Annuities
5 NAIC Model Law 250 Variable Annuity

The fixed income asset yield allows for the recovery of the "unearned" option budget initially spent to fund option(s) over the Index Strategy Term. The guideline permits flexibility in valuing the Fixed Income Asset Proxy at book value or market value through either a market value adjustment to the calculated book value or by using a first-principles fair value calculation.

The Derivative Asset Proxy represents the value of a package of hypothetical derivative assets established at the beginning of an Index Strategy Term that is designed to replicate credits provided by an Index Strategy at the end of an Index Strategy Term. Important features of the Derivative Asset Proxy may include:

- Daily calculations using assumptions to determine the market value, including implied volatilities, risk-free rates, and dividend yields, which must be consistent with observable market prices of derivative assets whenever possible.
- Trading Cost that reflects reasonably expected or actual costs at the time the Interim Value is calculated.

Describe elements that could be considered when applying equity between the consumer and the insurance company as it applies to interim value calculations under AG54.

- Calculations that impact (positively or negatively) contract and/or surrender values.
  - · Are the calculations different if the effect to the contract/surrender value is positive (increases the value) or negative (decreases the value)?
  - · Are different calculations used based on the reference index performance other than those designed within the crediting strategy (e.g., are cap rates or buffers pro-rated)?
  - · Are there limitations imposed on calculation values (e.g., a market value adjustment cannot exceed contract charges), or are there asymmetrical limitations applied to any calculated values?

- Value of consideration reflects the value of benefits.
  - · Are calculations waived under certain circumstances (e.g., there is no market value adjustment applied upon annuitization, but it is included on surrender value and death benefit proceeds)?

- Margins applied to cover the risk of uncertainty.
    - The timing of withdrawals may impact trading costs and could be passed on to the consumer.
    - Option cost volatility in future contract years will vary based on many factors, including but not limited to index term length, reference index, implied volatility, risk-free rates, dividend yields, and bid-ask spread in derivative pricing. This can be managed and future expected changes from initial pricing may be passed to the consumer through a non-guaranteed elements (NGE) process.
    - If the consumer has a choice that affects the benefit, a risk margin may increase. Unexpected policyholder behavior could impact future crediting strategy options.

In these, or any other situations that may apply to a particular product design, the actuary may consider providing rationale for the design in addition to examples illustrating the equity between the consumer and insurance company.

Expenses and trading costs used in ILVA.

Trading costs should be consistently described, such as quotes from investment banks; executed or inferred hedge costs; or the difference between bid, mid, and ask spreads.

Economic Scenarios used to demonstrate interim value methodology.

The scenarios used are consistent with AG54 Appendix C requirements of the Interim Value calculation. These scenarios include volatility assumptions of 20% and 25%, and include Index Strategy Term performance of -30% to +30% at 5% increments.

Interim Value under Interstate Insurance Product Regulation Compact (IIPRC–A-03-I-ILVA)

At the time of this policy paper, the IIPRC adopted a narrower interpretation of AG54 with respect to alternative approaches to the Hypothetical Portfolio methodology and Interim Value calculation. While AG54 allows for Interim Values that are materially consistent with the Hypothetical Portfolio methodology, the IIPRC requires the use of the Hypothetical Portfolio methodology and does not allow for materially consistent approaches.

Drafting Notes from the IIPRC requirements[6] state:

> Actuarial Guideline 54 allows state approval of Interim Value methodologies that are "materially consistent" with the Hypothetical Portfolio. However, under this standard, Interim Values must be determined using a Hypothetical Portfolio methodology. (iv) Interim Values provide equity between the contract holder and the company as of the calculation date for all Index Strategies and Index Strategy Terms. The certification shall be accompanied by illustrative examples that calculate Interim Values under realistic economic scenarios presented in the format prescribed in Appendix C of these standards.
>
> The illustrative examples do not need to span 1000s of economic scenarios but rather demonstrate the impact on Interim Values for specific realistic index changes over the Index Strategy Term. Illustrative examples showing the components of Interim Values under a few deterministic scenarios may be required. For example, for a buffer and cap strategy, the scenarios could include at least the range of index changes from level of the buffer to the level of the cap.

6 Standards for Individual Deferred Index Linked Variable Annuity Contracts - IIPRC-03-I-ILVA

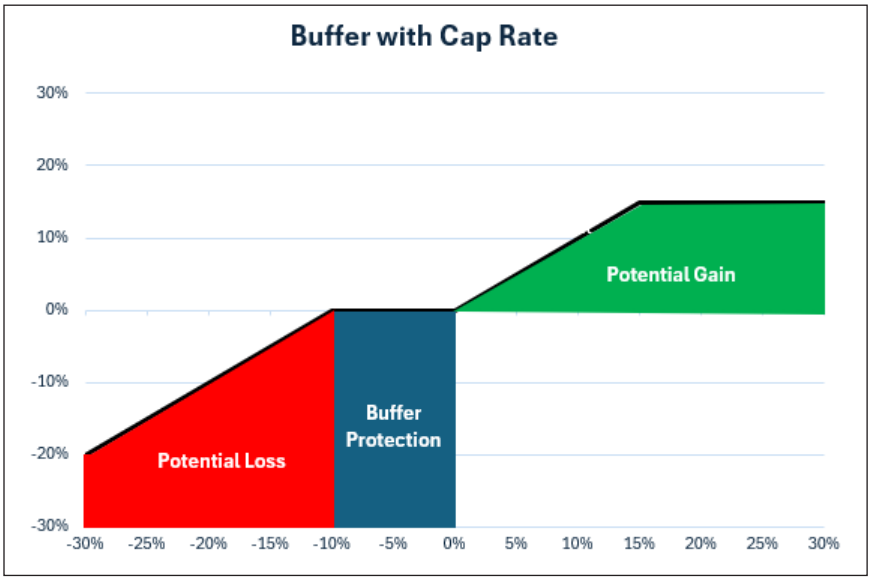
Index Strategy Examples and Components

Example #1: Buffer with Cap Rate[7]

Key considerations:

- Reference Index – market inputs such as implied volatility and dividend yield will directly affect the insurance company's affordable crediting rate (e.g., the cap rate).
- Index Strategy Term Length – the longer the term length, the greater the upside potential (e.g., the cap rate).
- Cap Rate – if the reference index performance is positive over the Index Strategy Term, the reference index performance will be credited to the contract up to and including the cap rate.
- Buffer Rate – if the reference index performance is negative over the Index Strategy Term, the buffer is applied as follows:
    - If the reference index performance is between -0.01% and the buffer rate, no performance of the reference index is applied to the contract.
    - If the reference index performance is less than the buffer, then the negative index performance plus the buffer rate is credited to the contract.

The table below shows the potential loss, buffer protection, and potential gain at the end of the index strategy term for a policyholder assuming a buffer rate of 10% and a cap rate of 15%.



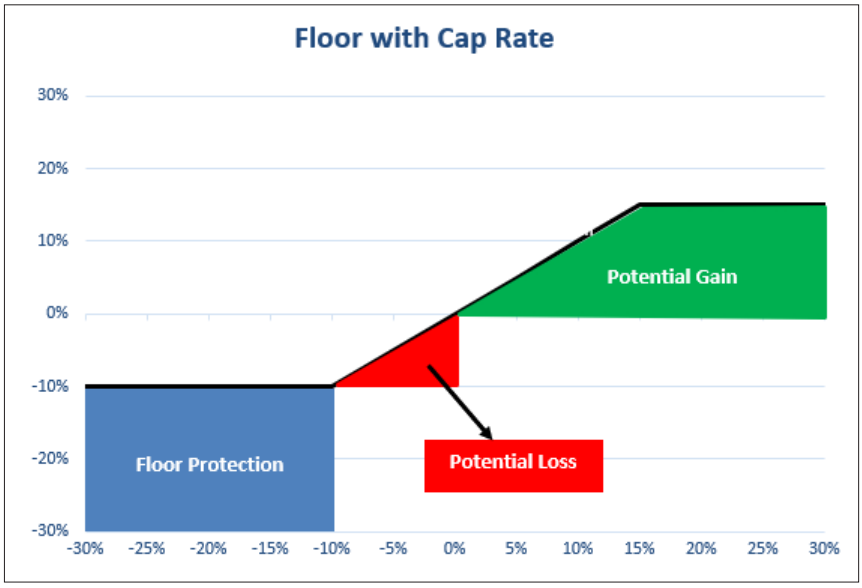
7 Assumes 100% participation rate up to the cap rate with no spread rate.

Example #2: Floor with Cap Rate[8]

Key considerations:

- Reference Index – market inputs such as implied volatility and dividend yield will directly affect the insurance company's affordable crediting rate (e.g., the cap rate).
- Index Strategy Term Length – the longer the term length the greater the upside potential (e.g., the cap rate).
- Cap Rate – if the reference index performance is positive over the Index Strategy Term, the reference index performance will be credited to the contract up to and including the cap rate.
- Floor Rate – if the reference index performance is negative over the Index Strategy Term, the floor is applied as follows:
    - If the reference index performance is between -0.01% and the floor rate, then the negative index performance is applied to the contract.
    - If the reference index performance is less than the floor rate, then the negative floor rate is credited to the contract.

The table below shows the potential loss, floor protection, and potential gain at the end of the index strategy term for a policyholder assuming a floor rate of 10% and a cap rate of 15%.



8 Assumes 100% participation rate up to the cap rate with no spread rate.

Example #3: Interim Value Calculation (Positive Index Performance)

Assumptions:

10% Buffer

500% Cap Rate

100% Participation Rate (no spread rate)

Generic reference index: At-the-money strike price = 1,000

Risk-free yield (r) = 4%

At-the-money Implied vol ()= 20.47%; an implied volatility surface is used for different option moneyness and maturity term

Dividend yield (q) = 2%

Index Strategy Term (t) = 6 years

6-year zero coupon bond with 2.33% yield.

The Derivative Asset Proxy Value for call options (C) and put options (P) are computed based on the Black-Scholes formula as follows:

$$d_1 = \frac{\ln(\frac{S}{K}) + t(r - q + \frac{\sigma^2}{2})}{\sigma\sqrt{t}}$$

$$d_2 = d_1 - \sigma\sqrt{t}$$

$$C = S\,e^{-qt}\,N(d_1) - K\,e^{-rt}\,N(d_2)$$

$$P = K\,e^{-rt}\,N(-d_2) - S\,e^{-qt}\,N(-d_1)$$

Trading costs are included for illustration purposes, and can vary in practice by many factors including, but not limited to, counterparties used, reference index, index term length, and/or complexity of the crediting strategy.

Time	Index Level	Fixed Proxy		Derivative Proxy				Trading Costs	Contract Value	Interim Value
		Yield	Value	OTM Put (Short)	ATM Call (Long)	OTM Call (Short)	Total Value			
0	1,000.00	2.33%	$ 87.09	$ (9.10)	$ 22.04	$ (0.00)	$ 12.94	$ 0.01	$ 100.02	$ -
1	1,100.00	2.33%	$ 89.12	$ (6.65)	$ 24.97	$ (0.00)	$ 18.32	$ 0.02	$ 107.43	$ 107.43
2	1,210.00	2.33%	$ 91.20	$ (4.48)	$ 28.03	$ (0.00)	$ 23.55	$ 0.02	$ 114.73	$ 114.73
3	1,331.00	2.33%	$ 93.32	$ (2.60)	$ 30.99	$ (0.00)	$ 28.39	$ 0.03	$ 121.68	$ 121.68
4	1,464.10	2.33%	$ 95.50	$ (0.84)	$ 34.68	$ (0.00)	$ 33.84	$ 0.03	$ 129.31	$ 129.31
5	1,610.51	2.33%	$ 97.72	$ (0.09)	$ 38.55	$ (0.00)	$ 38.46	$ 0.04	$ 136.14	$ 136.14
6	1,771.56	2.33%	$ 100.00	$ -	$ 77.16	$ -	$ 77.16	$ -	$ 177.16	$ -

Example #4: Interim Value Calculation (Negative Index Performance)

Assumptions:

10% Buffer

500% Cap Rate

100% Participation Rate (no spread rate)

Generic reference index: At-the-money strike price = 1,000

Risk-free yield (r) = 4%

At-the-money Implied vol ()= 20.47%; an implied volatility surface is used for different option moneyness and maturity term

Dividend yield (q) = 2%

Index Strategy Term (t) = 6 years

6-year zero coupon bond with 2.33% yield.

The Derivative Asset Proxy Value for call options (C) and put options (P) are computed based on the Black-Scholes formula as follows:

$$d_1 = \frac{\ln(\frac{S}{K}) + t(r - q + \frac{\sigma^2}{2})}{\sigma\sqrt{t}}$$

$$d_2 = d_1 - \sigma\sqrt{t}$$

$$C = S\, e^{-qt}\, N(d_1) - K\, e^{-rt}\, N(d_2)$$

$$P = K\, e^{-rt}\, N(-d_2) - S\, e^{-qt}\, N(-d_1)$$

Trading costs are included for illustration purposes, and can vary in practice by many factors including, but not limited to, counterparties used, reference index, index term length, and/or complexity of the crediting strategy.

Time	Index Level	Fixed Proxy		Derivative Proxy				Trading Costs	Contract Value	Interim Value
		Yield	Value	OTM Put (Short)	ATM Call (Long)	OTM Call (Short)	Total Value			
0	1,000.00	2.33%	$ 87.09	$ (9.10)	$ 22.04	$ (0.00)	$ 12.94	$ 0.01	$ 100.02	$ -
1	950.00	2.33%	$ 89.12	$ (10.33)	$ 17.84	$ (0.00)	$ 7.50	$ 0.01	$ 96.62	$ 96.62
2	902.50	2.33%	$ 91.20	$ (11.36)	$ 13.37	$ (0.00)	$ 2.01	$ 0.00	$ 93.21	$ 93.21
3	857.38	2.33%	$ 93.32	$ (12.65)	$ 8.78	$ (0.00)	$ (3.87)	$ 0.00	$ 89.45	$ 89.45
4	814.51	2.33%	$ 95.50	$ (14.05)	$ 4.36	$ (0.00)	$ (9.70)	$ 0.01	$ 85.79	$ 85.79
5	773.78	2.33%	$ 97.72	$ (16.61)	$ 0.89	$ (0.00)	$ (15.72)	$ 0.02	$ 81.99	$ 81.99
6	735.09	2.33%	$ 100.00	$ (16.49)	$ -	$ -	$ (16.49)	$ -	$ 83.51	$ -

Common Product Features

- Contingent deferred sales charge (CDSC) for durations of three to 10 years
- Free withdrawal provisions ranging from 1% to 20%
- Fixed accounts common or transfer accounts for interim holding of premiums
- Index crediting methods include:
    - · Point-to-Point (PTP) buffer with cap rate, participation rate, or trigger rate
    - · PTP dual direction buffer with cap rate or trigger rate
    - · PTP floor with cap rate, participation rate, or trigger rate
- Performance lock
- Index crediting periods of one, two, three, or six years
- Market value adjustment formulas are typically calculated at the contract level and analogous fixed income proxy market values can be incorporated into the interim value formula within each index strategy option
- Withdrawals made during the interim period typically include a proportional reduction to optional benefit bases when the benefit base is not equal to the account value
- Black-Scholes and Monte-Carlo are commonly used methodologies for valuing option costs within the Derivative Asset Proxy
- Fixed Asset Hypothetical discount rate is often an external index such as the Bloomberg US aggregate index rate, Treasury Constant Maturity yield, Bloomberg US Credit or Corporate Index
- Separate account structure can vary by company:
    - · None are registered with the SEC,
    - · All are non-unitized, and
    - · May be insulated or non-insulated.
- Most contracts do not have explicit fees other than for optional benefits

Actuarial Standards of Practice (ASOPs)

According to ASOP No. 1, Section 4.3, "Actuaries are responsible for determining which ASOPs apply to the task at hand." The following ASOPs, as of the date of this policy paper, are among those the actuary may wish to consider:

- ASOP No. 1, *Introductory Actuarial Standard of Practice*
- ASOP No. 2, *Nonguaranteed Charges or Benefits for Life Insurance Policies and Annuity Contracts*
- ASOP No. 7, *Analysis of Life, Health, or Property/Casualty Insurer Cash Flows*
- ASOP No. 12, *Risk Classification* (for all practice areas)
- ASOP No. 15, *Dividends for Individual Participating Life Insurance, Annuities, and Disability Insurance*
- ASOP No. 19, *Appraisals of Casualty, Health, and Life Insurance Businesses*
- ASOP No. 22, *Statements of Opinion Based on Asset Adequacy Analysis by Actuaries for Life and Health Insurers*
- ASOP No. 41, *Actuarial Communications*
- ASOP No. 52, *Principle-Based Reserves for Life Products under the NAIC Valuation Manual*
- ASOP No. 54, *Pricing of Life Insurance and Annuity Products*
- ASOP No. 56, *Modeling*

At the time this policy paper was written, there were some exposure drafts out for updating ASOPs or potential new ASOPs. ASOP No. 1, Section 3.1.7 explains: "Exposure drafts of the ASOP … form part of the literature of the actuarial profession; actuaries may look to them at their discretion for advisory guidance. An ASOP is not binding until the effective date of the ASOP."

Sources of Information

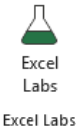
1. Actuarial Guideline LIV Nonforfeiture Requirements for Index-Linked Variable Annuity Products
2. NAIC Model Law 805 Standard Nonforfeiture Law for Individual Deferred Annuities
3. NAIC Model Law 250 Variable Annuity
4. Standards for Individual Deferred Index Linked Variable Annuity Contracts - IIPRC-03-I-ILVA

Appendix A—Excel Lambda Example Library

To make this policy paper more helpful in understanding, Excel Lambda library has been included with this policy paper. Lambda functions are part of a new suite of Dynamic Array Functions introduced in 2021. These new functions change how Excel is used because they allow actuaries/developers to separate logic from data. Therefore, allowing the creation of reusable and extendable libraries in Excel. The calculations are no longer done within the cells. The library now spills the calculations into the cells to display results.

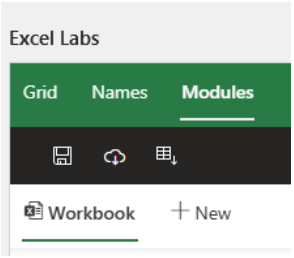
Lambda functions are built on a functional programming paradigm and are pure. Pure means that given the same set of parameters, the functions will always give the same result, which is much different from Visual Basic for Applications (VBA). There is no manipulation of state outside of the function itself, which means there is no setup required to get the expected result. The Hypothetical Portfolio is a composition of multiple functions representing its constituent parts. Purity means that each of the constituent functions of the Hypothetical Portfolio can be called independently to understand how the portfolio works. Each paragraph of the policy paper has a corresponding function, which will allow the user to understand the note more thoroughly.

How To Get Started



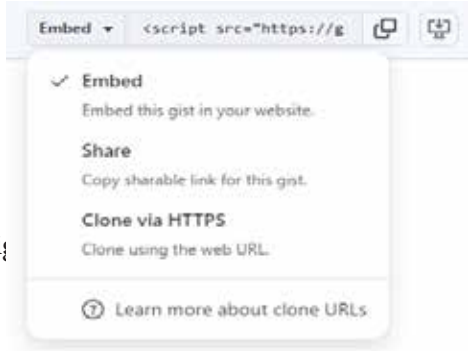
Excel Labs

To facilitate easy development of libraries, Excel has introduced an Excel Labs add-in, which is available for use with Excel 2016 or later versions on Windows, Mac, and Excel on the web. After installation the Excel Labs icon will be on the Home ribbon , pick the Advanced formula environment (AFE) when prompted.



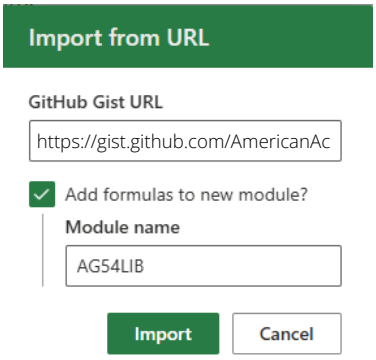
► Go to Modules and select the cloud icon in the middle, which will ask you for the URL of the Gist. Select "Add formulas to new module?"

► Make the module name anything that you like, which is called AG54LIB in the picture below, and paste in the following URL: https://gist.github.com/AmericanAcademyofActuaries-LPC/06a9413a13b451a8e4ba7686bf5d59aa



► You do not need to go to the website. But if you do, in the upper ri corner select share and then hit the copy button.

► Paste the URL into the GitHub Gist URL box pictured right.



Replicate Policy Paper

To reproduce the results within the policy paper, then put in any cell =**AG54LIB.RunExample(TRUE)** will replicate the index upward index path and =**AG54LIB.RunExample(FALSE)** will replicate the downward index path. To replicate the buffered RILA graph or floored RILA graph, call =**AG54LIB.CreateGraphData(2)** or =**AG54LIB.CreateGraphData(3)**, respectively.

Library Functions Prerequisites

Category theory notation is used to explain types and composition of functions. The following is a quick guide.

F :: **A** ⇢ **B** is a function F that takes parameter A and returns B.

G :: **A** ⇢ **B** ⇢ **C** is a function G that takes parameters A and B and returns C.

H:: (**A** ⇢ **B**)⇢ **C** is a function H that returns C. This function has a single parameter which is itself a function with parameter A that returns B. In other words, parentheses signify that either a parameter or a return type is a function. In functional programming, functions can have functions as parameters and can also return functions. In this library, **CreateStrategy** is a great example of this. One of its parameters is a function to read the volatility surface. It returns a function which calculates the option strategy.

An example is the **RunExample::** *Bool→ N→ExcelRange* function mentioned below. It has two parameters a Boolean and natural number, which is 1, 2, or 3. It returns an ExcelRange, which is a matrix of text headers and numeric data.

The library functions below are in order from lowest level to highest level. As you move down the list, the functions are composed of functions higher in the list. To put in more Categorical concepts and ignoring the function details, the function composition is:

BlackScholes,GetVol °Option Strategy ° DerivativeProxyAsset,FixedProxyAsset ° HypotheticalPortfolio
Or
HypotheticalPortfolio(FixedAssetProxy,DerivativeAssetProxy(Option Strategy(BlackScholes,GetVol))).

Library Function Definitions

BlackScholes::

INPUTS:

1. **currTime** is current time of valuation in years.
2. **stockPrice** is the price of index.
3. **strikePrice** is the strike price of the option.
4. **vol** is the annual implied volatility of the option.
5. **riskFreeRate** is the risk-free rate of interest.
6. **dividend** is dividend rate on the index.
7. **maturity** is the number years of the maturity of the options.
8. **isCall_** is an optional parameter that specifies whether calculating call or put option. Default is TRUE for a call option.

RETURNS: The Black Scholes option price for a European Option

GetVol:: R→ R→*ExcelRange* →R

INPUTS:

1. **moneyness** is the degree at which the option is in the money, where 1 indicates ATM.
2. **tenor** is the time of option maturity in years.
3. **surfaceWithHeaders** is volatility surface with row and column headers, which are moneyness and tenor, respectively.

RETURNS: The volatility from the surface

COMMENTS: *This function is for demonstration purposes only. It does not interpolate decimal values for moneyness or tenor.*

CreateStrategy:: R→ R→R→(R→R→R)→N →R→R→(R→R→R→R→R^{1xn+1})

INPUTS:

1. **capRate** is the rate of the upside potential.
2. **riskFreeRate** is the risk-free rate of interest.
3. **dividend** is dividend rate on the index.
4. **fxyVol** is a function that returns the volatility based on moneyness and tenor.
5. **strategyId_** is an integer [1,3]. Default: 2.
    i. is FIA PTP,
    ii. is buffered RILA,
    iii. is floored RILA.

buffer_ is rate of downside protection until losses occur.

floorRate_ is the rate of the downside potential.

RETURNS: a function that values an option strategy. This function requires four parameters: **stockPriceAtIssue**, **maturity**, **currTime**, and **stockPricet**. It returns a row vector of, n, option values and a net derivative value.

FiaPtpStrategy:: R→ R→R→R→ R→R→(R→R→R)→R →R^{1x3}

INPUTS:

1. **capRate** is the cap rate for Fixed Index Annuity
2. **currTime** is current time of valuation in years.
3. **stockPriceAtIssue** is the index value at issue.
4. **riskFreeRate** is the risk-free rate of interest.
5. **dividend** is dividend rate on the index.
6. **maturity** is the number years of the maturity of the options.
7. **fxyVol** is a function that returns the volatility based on moneyness and tenor.
8. **stockPricet_** is an optional value of the index value at the current time. Default: **stockPriceAtIssue**.

RETURNS: a row vector of long ATM call, short OTM call, and net derivative value.

COMMENT: *In option trading terms, it is a Bull Call Spread. The long ATM call returns the upside of the index. The short OTM call reduces the costs of the option strategy to get more for the option budget, but the tradeoff is it reduces the upside potential.*

RilaDownsideBufferStrategy:: R→ R→R→R→ R→R→R→(R→R→R)→R →R^{1x4}

INPUTS:

1. **buffer** is rate of downside protection until losses occur.
2. **capRate** is the rate of the upside potential.
3. **currTime** is current time of valuation in years.
4. **stockPriceAtIssue** is the index value at issue.
5. **riskFreeRate** is the risk-free rate of interest.
6. **dividend** is dividend rate on the index.
7. **maturity** is the number years of the maturity of the options.
8. **fxyVol** is a function that returns the volatility based on moneyness and tenor.
9. **stockPricet_** is an optional value of the index value at the current time. Default: **stockPriceAtIssue**.

RETURNS: a row vector of short OTM put, long ATM call, short OTM call, and net derivative value.

COMMENT: *In other terms, short OTM put + FIA PTP Bull Call Spread. The short OTM put further reduces the cost of Bull Call Spread and getting more for the option budget, but the tradeoff is that this exposes the option strategy to downside risk. Hence, the significant reason why RILA required interim values and to be registered like variable annuities.*

RilaNegFloorStrategy:: R→R→R→ R→R→R→R→(R→R→R)→R →R^{1x4}

INPUTS:

1. **floorRate** is the rate of the downside potential.
2. **capRate** is the rate of the upside potential.
3. **currTime** is current time of valuation in years.
4. **stockPriceAtIssue** is the index value at issue.
5. **riskFreeRate** is the risk-free rate of interest.
6. **dividend** is dividend rate on the index.
7. **maturity** is the number years of the maturity of the options.
8. **fxyVol** is a function that returns the volatility based on moneyness and tenor.
9. **stockPricet_** is an optional value of the index value at the current time. Default: **stockPriceAtIssue**.

RETURNS: a row vector of long OTM put, underlying security, short OTM call, and net derivative value.

COMMENT: *In option trading, this is known as a Collar.*

DerivativeAssetProxy:: $R\rightarrow R\rightarrow(R\rightarrow R\rightarrow R\rightarrow R\rightarrow R^{1xn+1})\rightarrow(R\rightarrow R^{Tx1})\rightarrow(R\rightarrow R^{Tx1}\rightarrow R^{Tx1})\rightarrow R^{Txn+1}$ $R\rightarrow R\rightarrow(R\rightarrow R\rightarrow R\rightarrow R\rightarrow R^{1xn+1})\rightarrow(R\rightarrow R^{Tx1})\rightarrow(R\rightarrow R^{Tx1}\rightarrow R^{Tx1})\rightarrow R^{Txn+1}$

INPUTS:

1. **stockPriceAtIssue** is the index value at issue.
2. **maturity** is the time of option maturity in years, T.
3. **fwxyxStrategy** is a function with four parameters: **stockPriceAtIssue**, **maturity**, **currTime** , **stockPricet**, which returns the value of the option strategy at each time, t.
4. **fxTime** is a function, when given the maturity time in years, will return a column vector of times, t, to value the options.
5. **fxyIndex** is a function, that given a starting index value and a time column vector, returns a column vector containing index values at each time, t.

RETURNS: a txn+1 matrix representing the strategies' option values and net derivative values at each time, t.

FixedIncomeAssetProxy:: $R\rightarrow R\rightarrow(R\rightarrow R^{Tx1})\rightarrow R^{Tx2}$

INPUTS:

1. **bondYield** is the yield rate for the bond of the fixed income proxy.
2. **maturity** is the time of option maturity in years, T.
3. **fxTime** is a function, when given the maturity time in years, will return a column vector of times to value the options.

RETURNS: a range of fixed asset proxy values containing the bond yield and fixed asset values for each time, t.

HypotheticalPortfolio:: $R \to R \to R \to R \to R \to (R \to R \to\ R \to R \to R^{1xn+1} \to (R \to R^{Tx1}) \to (R \to R^{Tx1} \to R^{Tx1}) \to R^{Txn+4}$

INPUTS:

1. **startingContractValue** is the contract value as of issue.
2. **bondYield** is the yield rate for the bond of the fixed income proxy.
3. **tradingCostRate** is the cost of trading relative to option value.
4. **stockPriceAtIssue** is the index value at issue.
5. **maturity** is the time of option maturity in years, T.
6. **fwxyxStrategy** is a function with four parameters: **stockPriceAtIssue**, **maturity**, **currTime**, **stockPricet**, which returns the value of the option strategy at time, t.
7. **fxTime** is a function, when given the maturity time in years, T, will return a column vector of times, t, to value the options.
8. **fxyIndex** is a function, that given a starting index value and a time column vector, returns a column vector containing index values at each time, t.

RETURNS: a T x n+4 matrix representing the fixed income asset proxy, derivative asset proxy, trading cost, contract value, and interim value at each time point of the hypothetical portfolio.

HypoPortfolioPretty is the same as the **HypotheticalPortfolio** but it prints the column headers for pretty output.

RunExample:: *Bool*→ N→*ExcelRange*

INPUTS:

1. **isPositiveExample_** is an optional parameter. TRUE(FALSE) to replicate the index increasing(decreasing) in the example. Default is TRUE.
2. **strategyId_** is an optional integer parameter from [1,3] indicating the option strategy to run. Default: 2.
   - ·1 is FIA PTP,
   - · 2 is buffered RILA,
   - · 3 is floored RILA.

RETURNS: The replication of the examples in the policy paper.

AtIssuePayoffs :: N→*ExcelRange*

INPUTS:

1. **strategyId_** is an optional integer parameter from [1,3] indicating the option strategy to run. Default: 2.
    - 1 is FIA PTP,
    - 2 is buffered RILA,
    - 3 is floored RILA.

RETURNS: The replication of the option maturity payoffs as of issue of a strategy for different possible index returns of the policy paper.

CreateGraphData:: *ExcelRange*→ N→*ExcelRange*

INPUTS:

1. **strategyId_** is an optional integer parameter from [1,3] indicating the option strategy to run. Default: 2.
    - 1 is FIA PTP,
    - 2 is buffered RILA,
    - 3 is floored RILA.

RETURNS: The replication of graph data which produces the index returns and net derivative values for easily replicating the graphs in the policy paper.

Extending the Library

This library was built to facilitate comprehension of the policy paper, regardless of actuarial experience. It can be extended so that it can become the basis of testing and be used for other purposes. The simplest way to do extend the library is to look at the implementation of the **RunExample** and **AtIssuePayoffs** functions to see how to compose the various pieces together. Each of the function parameters that are functions themselves can be overridden with your own implementation, such as **fxyVol**, **fxTime**, **fxyIndex**, and **fwxyxStrategy**, for volatility surface, valuation times, index values, and option strategies, respectively.

1850 M STREET NW, SUITE 300, WASHINGTON, D.C. 20036

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