Earthquake Catastrophe Insurance

Michelle Intan Handa 6701013556

Import Data

In[ ]:=
```
dataClean = Import["C:\\Users\\ASUS'\\Documents\\Wolfram\\data_cleaned.xlsx"];
```

In[ ]:=
```
cleanDataset = Dataset[dataClean]
```

Out[ ]=

Origin Time	Latitude	Longitude	Depth	Magnitude
2022/01/01	24.8	125.0	28.0	4.0
2022/01/02	34.1	135.1	9.0	3.7
2022/01/02	35.7	140.6	50.0	3.8
2022/01/02	37.5	137.2	13.0	3.6
2022/01/03	38.8	142.0	46.0	3.7
2022/01/03	23.9	122.2	27.0	6.3
2022/01/04	37.5	137.2	13.0	3.5
2022/01/04	37.6	141.6	55.0	4.2
2022/01/05	36.1	140.0	49.0	3.8
2022/01/07	27.4	128.5	49.0	4.3
2022/01/07	33.9	135.4	52.0	3.8
2022/01/08	27.4	128.6	43.0	3.8
2022/01/10	28.3	129.3	15.0	3.8
2022/01/11	32.9	131.9	10.0	3.9
2022/01/11	38.8	142.1	44.0	3.9
2022/01/11	36.2	140.6	82.0	3.7
2022/01/13	31.0	131.4	30.0	4.6
2022/01/13	30.4	131.0	32.0	4.4
2022/01/14	37.5	137.2	13.0	3.6

988 total ›

Magnitudo

```
In[]:= magnitudo = cleanDataset[All, 2 ;;, {5}]
Out[]=
```

4.0
3.7
3.8
3.6
3.7
6.3
3.5
4.2
3.8
4.3
3.8
3.8
3.8
3.9
3.9
3.7
4.6
4.4
3.6
3.5
987 total ›

Depth

In[ ]:=
```
depth = cleanDataset[All, 2 ;;, {4}]
```

Out[ ]=

28.0
9.0
50.0
13.0
46.0
27.0
13.0
55.0
49.0
49.0
52.0
43.0
15.0
10.0
44.0
82.0
30.0
32.0
13.0
58.0
987 total ›

Date

In[ ]:= `date = cleanDataset[All, 2 ;;, {1}]`

Out[ ]=

2022/01/01
2022/01/02
2022/01/02
2022/01/02
2022/01/03
2022/01/03
2022/01/04
2022/01/04
2022/01/05
2022/01/07
2022/01/07
2022/01/08
2022/01/10
2022/01/11
2022/01/11
2022/01/11
2022/01/13
2022/01/13
2022/01/14
2022/01/14
987 total ›

Analyze Magnitude and Its Frequency

In[ ]:= `cumMagnitudo = Sort[DeleteDuplicates[Flatten@magnitudo]];`

In[ ]:= `Normal@cumMagnitudo`

Out[ ]=

```
{1.4, 2., 2.1, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7, 2.8, 2.9, 3., 3.1, 3.2, 3.3, 3.4,
 3.5, 3.6, 3.7, 3.8, 3.9, 4., 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, 4.8, 4.9, 5., 5.1,
 5.2, 5.3, 5.4, 5.5, 5.6, 5.7, 5.8, 5.9, 6., 6.1, 6.2, 6.3, 6.4, 6.5, 6.6, 7.4}
```

```
In[•]:= count = Counts[Normal@Flatten@magnitudo]
Out[•]=
<|4. → 63, 3.7 → 38, 3.8 → 54, 3.6 → 51, 6.3 → 2, 3.5 → 42, 4.2 → 52, 4.3 → 58, 3.9 → 49, 4.6 → 34,
 4.4 → 32, 2.8 → 11, 3.3 → 41, 4.1 → 63, 3.4 → 42, 4.7 → 28, 4.5 → 23, 6.6 → 3, 5.4 → 11,
 5.6 → 9, 3.2 → 21, 5.8 → 5, 5. → 21, 5.3 → 13, 3.1 → 24, 3. → 27, 4.9 → 18, 4.8 → 15, 2.5 → 7,
 5.1 → 14, 2.2 → 3, 7.4 → 1, 6.1 → 1, 5.9 → 9, 5.5 → 8, 5.2 → 12, 2.6 → 9, 2.3 → 5, 1.4 → 1,
 2.9 → 28, 2.1 → 2, 5.7 → 5, 2.7 → 12, 6. → 5, 2.4 → 6, 6.2 → 5, 6.4 → 1, 6.5 → 2, 2. → 1|>
```

```
In[•]:= count = Flatten /@ List @@@ Normal@count
Out[•]=
{{4., 63}, {3.7, 38}, {3.8, 54}, {3.6, 51}, {6.3, 2}, {3.5, 42}, {4.2, 52}, {4.3, 58},
 {3.9, 49}, {4.6, 34}, {4.4, 32}, {2.8, 11}, {3.3, 41}, {4.1, 63}, {3.4, 42}, {4.7, 28},
 {4.5, 23}, {6.6, 3}, {5.4, 11}, {5.6, 9}, {3.2, 21}, {5.8, 5}, {5., 21}, {5.3, 13},
 {3.1, 24}, {3., 27}, {4.9, 18}, {4.8, 15}, {2.5, 7}, {5.1, 14}, {2.2, 3}, {7.4, 1},
 {6.1, 1}, {5.9, 9}, {5.5, 8}, {5.2, 12}, {2.6, 9}, {2.3, 5}, {1.4, 1}, {2.9, 28},
 {2.1, 2}, {5.7, 5}, {2.7, 12}, {6., 5}, {2.4, 6}, {6.2, 5}, {6.4, 1}, {6.5, 2}, {2., 1}}
```

Find the Distribution

```
In[•]:= xValues = Flatten@count[[All, 1]]
Out[•]=
{4., 3.7, 3.8, 3.6, 6.3, 3.5, 4.2, 4.3, 3.9, 4.6, 4.4, 2.8, 3.3, 4.1, 3.4, 4.7,
 4.5, 6.6, 5.4, 5.6, 3.2, 5.8, 5., 5.3, 3.1, 3., 4.9, 4.8, 2.5, 5.1, 2.2, 7.4, 6.1,
 5.9, 5.5, 5.2, 2.6, 2.3, 1.4, 2.9, 2.1, 5.7, 2.7, 6., 2.4, 6.2, 6.4, 6.5, 2.}
```

```
In[•]:= FindDistribution[xValues]
Out[•]=
NormalDistribution[4.30784, 1.54993]
```

The normal distribution implies that most earthquakes occur near the mean magnitude, with fewer small or large events.

```
In[•]:= fittedDistX = EstimatedDistribution[xValues, NormalDistribution[4.30784, 1.54993]];
        DistributionFitTest[xValues, fittedDistX]
Out[•]=
0.961592
```

```
In[•]:= yValues = Flatten@count[[All, 2]]
Out[•]=
{63, 38, 54, 51, 2, 42, 52, 58, 49, 34, 32, 11, 41, 63, 42, 28, 23, 3, 11, 9, 21, 5, 21,
 13, 24, 27, 18, 15, 7, 14, 3, 1, 1, 9, 8, 12, 9, 5, 1, 28, 2, 5, 12, 5, 6, 5, 1, 2, 1}
```

```
In[•]:= FindDistribution[yValues]
FindDistribution: The data will be treated as continuous. Use the option TargetFunctions->Discrete otherwise.
Out[•]=
ExponentialDistribution[0.04842]
```

The exponential distribution suggests that earthquake frequencies decrease rapidly as they increase in size.

In[ ]:=
```
fittedDistY = EstimatedDistribution[yValues, ExponentialDistribution[0.04842]];
DistributionFitTest[yValues, fittedDistY]
```

Out[ ]=
```
0.682269
```

Use Cramer-Lundberg Theory

$R(t) = u + ct - \sum_{i=1}^{N(t)} S_i$

- Initial Reserve (u): The starting capital of the insurer
- Premium Rate (c): amount collected per unit time
- Number of Claims (N(t)): Modeled using a Poisson process with rate λ(t), influenced by x.
- Claim Sizes (S_i): Depends on the magnitude x.

Model the Number of Claims N(t)

In[ ]:=
```
poissonRate = 1 / 0.04842;
poissonProcess = PoissonProcess[poissonRate];
```

In[ ]:=
```
numEarthquakes = RandomFunction[poissonProcess, {0, 2}];
```

Model the Claim Sizes (S_i)

In[ ]:=
```
magnitudeDist = NormalDistribution[4.30784, 1.54993];
```

Claim sizes (S_i) depends on magnitude (x). The larger the magnitude, the larger the claim. So, the possible model is:
$S = a \times e^{b \times x}$

In[ ]:=
```
claimSizes = claimSizeFunction /@ RandomVariate[magnitudeDist, 100];
```

Because there is no real data about the damage that each magnitude of earthquake produce, we suppose:

- a = 0.01 that represents minimal damage from very small earthquake
- b = 0.5 makes the function grow exponentially but not too aggressively

In[ ]:=
```
claimSizeFunction[magnitude_, propertyValue_] :=
  propertyValue * (0.01 * Exp^(0.5 * magnitude));
```

Expected Claim Size

$$E[S] = \int_{-\infty}^{\infty} S(x) \times f(x)\, dx$$

In[ ]:=
```
expectedClaimSize =
  NIntegrate[claimSizeFunction[x] × PDF[magnitudeDist, x], {x, -Infinity, Infinity}];
```

NIntegrate: The integrand 0.257394 $e^{-0.208135\,(-4.30784+x)^2}$ claimSizeFunction[x] has evaluated to non-numerical values for all sampling points in the region with boundaries {{1., 0.}}.

NIntegrate: The integrand 0.257394 $e^{-0.208135\,(-4.30784+x)^2}$ claimSizeFunction[x] has evaluated to non-numerical values for all sampling points in the region with boundaries {{1., 0.}}.

In[ ]:=
```
expectedClaimSize[propertyValue_] := Module[
   {magnitudeRange, probabilities, claims, total}, magnitudeRange = Range[1.4, 7.4, 0.1];
   probabilities = PDF[magnitudeDist, #] & /@ magnitudeRange;
   claims = claimSizeFunction[#, propertyValue] & /@ magnitudeRange;
   total = Sum[claims[[i]] * probabilities[[i]], {i, 1, Length[magnitudeRange]}] * 0.1;
   total];
```

NIntegrate: The integrand 0.257394 $e^{-0.208135\,(-4.30784+x)^2}$ claimSizeFunction[x] has evaluated to non-numerical values for all sampling points in the region with boundaries {{1., 0.}}.

SetDelayed: Tag NIntegrate in NIntegrate[claimSizeFunction[x] PDF[magnitudeDist, x], {x, −∞, ∞}][propertyValue_] is Protected.

Expected Loss

$$E[Loss] = E[S] \times \lambda \times t$$

In[ ]:=
```
expectedTotalLoss = expectedClaimSize * poissonRate * t;
```

NIntegrate: The integrand 0.257394 $e^{-0.208135\,(-4.30784+x)^2}$ claimSizeFunction[x] has evaluated to non-numerical values for all sampling points in the region with boundaries {{1., 0.}}.

NIntegrate: The integrand 0.257394 $e^{-0.208135\,(-4.30784+x)^2}$ claimSizeFunction[x] has evaluated to non-numerical values for all sampling points in the region with boundaries {{1., 0.}}.

Calculate Premium

$$Premium = (1 + safetyLoading) \times E[Loss]$$

In[ ]:=
```
safetyLoading = 0.2;
premiumPrice = (1 + safetyLoading) * expectedTotalLoss;
```

NIntegrate: The integrand 0.257394 $e^{-0.208135\,(-4.30784+x)^2}$ claimSizeFunction[x] has evaluated to non-numerical values for all sampling points in the region with boundaries {{1., 0.}}.

NIntegrate: The integrand 0.257394 $e^{-0.208135\,(-4.30784+x)^2}$ claimSizeFunction[x] has evaluated to non-numerical values for all sampling points in the region with boundaries {{1., 0.}}.

NIntegrate: The integrand 0.257394 $e^{-0.208135\,(-4.30784+x)^2}$ claimSizeFunction[x] has evaluated to non-numerical values for all sampling points in the region with boundaries {{1., 0.}}.

General: Further output of NIntegrate::inumr will be suppressed during this calculation.

In[ ]:=
```
calculatePremium[propertyValue_, years_, safetyLoading_, deductible_] := Module[
  {expectedLoss}, expectedLoss = expectedClaimSize[propertyValue] * poissonRate * years;
  expectedLoss * (1 + safetyLoading) * (1 - deductible)];
```

Stimulate Reserve Process (R(t))

In[ ]:=
```
reserve[t_] := initialReserve + premiumRate * t - Total[RandomVariate[
     ExponentialDistribution[expectedClaimSize], RandomVariate[poissonProcess[t]]]];
```

Assess Ruin Probability

In[]:=
```
ruinProbability = Probability[reserve[t] < 0,
   {t, 0, Infinity}, Method → "MonteCarlo"];
```

NIntegrate: The integrand 0.257394 $e^{-0.208135 (-4.30784+x)^2}$ claimSizeFunction[x] has evaluated to non−numerical values for all sampling points in the region with boundaries {{1., 0.}}.

RandomVariate: Parameter 20.6526 t at position 1 in PoissonDistribution[20.6526 t] is expected to be positive.

RandomVariate: The array dimensions RandomVariate[PoissonDistribution[20.6526 t]] given in position 2 of RandomVariate[ExponentialDistribution[NIntegrate[claimSizeFunction[x] PDF[magnitudeDist, x], {x, −∞, ∞}]], RandomVariate[PoissonDistribution[20.6526 t]]] should be a list of non−negative machine−sized integers giving the dimensions for the result.

NIntegrate: The integrand 0.257394 $e^{-0.208135 (-4.30784+x)^2}$ claimSizeFunction[x] has evaluated to non−numerical values for all sampling points in the region with boundaries {{1., 0.}}.

RandomVariate: The array dimensions RandomVariate[PoissonDistribution[20.6526 t]] given in position 2 of RandomVariate[ExponentialDistribution[NIntegrate[claimSizeFunction[x] PDF[magnitudeDist, x], {x, −∞, ∞}]], RandomVariate[PoissonDistribution[20.6526 t]]] should be a list of non−negative machine−sized integers giving the dimensions for the result.

Probability: Invalid input.

NIntegrate: The integrand 0.257394 $e^{-0.208135 (-4.30784+x)^2}$ claimSizeFunction[x] has evaluated to non−numerical values for all sampling points in the region with boundaries {{1., 0.}}.

General: Further output of NIntegrate::inumr will be suppressed during this calculation.

RandomVariate: The array dimensions RandomVariate[PoissonDistribution[20.6526 t]] given in position 2 of RandomVariate[ExponentialDistribution[NIntegrate[claimSizeFunction[x] PDF[magnitudeDist, x], {x, −∞, ∞}]], RandomVariate[PoissonDistribution[20.6526 t]]] should be a list of non−negative machine−sized integers giving the dimensions for the result.

General: Further output of RandomVariate::array will be suppressed during this calculation.

Probability: Invalid input.

Break Even Point

In[]:=
```
calculateBreakEven[propertyValue_, annualPremium_] := propertyValue / annualPremium;
```

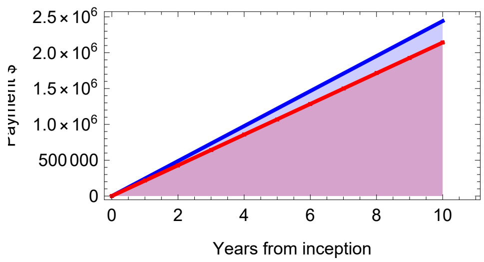
Interactive Visualization

In[]:=
```
(*Clear any existing definitions*)
Clear[expectedClaimSize, claimSizeFunction, calculatePremium, calculateBreakEven];

(*Constants*)
meanMagnitude = 4.30784;
stdDevMagnitude = 1.54993;
```

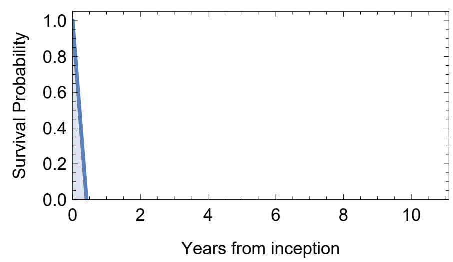
```
poissonRate = 1 / 0.04842;
magnitudeDist = NormalDistribution[meanMagnitude, stdDevMagnitude];

(*Define claim size function separately to avoid protected function issues*)
claimSizeFunction[magnitude_, propertyValue_] :=
  propertyValue * (0.01 * E^(0.5 * magnitude));

(*Define expected claim size using discrete sum*)
expectedClaimSize[propertyValue_] := Module[
   {magnitudeRange, probabilities, claims, total}, magnitudeRange = Range[1.4, 7.4, 0.1];
   probabilities = PDF[magnitudeDist, #] & /@ magnitudeRange;
   claims = claimSizeFunction[#, propertyValue] & /@ magnitudeRange;
   total = Sum[claims[[i]] * probabilities[[i]], {i, 1, Length[magnitudeRange]}] * 0.1;
   total];

calculatePremium[propertyValue_, years_, safetyLoading_, deductible_] := Module[
   {expectedLoss}, expectedLoss = expectedClaimSize[propertyValue] * poissonRate * years;
   expectedLoss * (1 + safetyLoading) * (1 - deductible)];

calculateBreakEven[propertyValue_, annualPremium_] := propertyValue / annualPremium;

(*Main visualization*)
DynamicModule[{lastPropertyValue = 100000,
  lastYears = 10, lastSafetyLoading = 0.2, lastDeductible = 0.05},
 Manipulate[Module[{is, ip, premium, annualPremium, breakEvenYears,
     paymentsData, premiumsData}, is = {280, 140};
   ip = {{50, 2}, {40, 2}};
   premium = calculatePremium[propertyValue, years, safetyLoading, deductible];
   annualPremium = premium / years;
   breakEvenYears = calculateBreakEven[propertyValue, annualPremium];
   paymentsData =
    Table[expectedClaimSize[propertyValue] * poissonRate * t, {t, 0, years}];
   premiumsData = Table[annualPremium * t, {t, 0, years}];
   Grid[{{Labeled[ListLinePlot[{Thread[{Range[0, years], premiumsData}],
          Thread[{Range[0, years], paymentsData}]}, Axes → False, Filling → 0, Frame → True,
        ImageSize → is, PlotMarkers → {Automatic, 4}, PlotRange → All, ImagePadding → ip,
        PlotRangePadding → {{Automatic, Scaled[0.1]}, {Automatic, Scaled[0.05]}},
        AspectRatio → 1 / 2, FrameLabel → {"Years from inception", "Payment $"},
        PlotStyle → {{Blue}, {Red}}], Text@"Insurer Payments"],
      Labeled[ListLinePlot[Table[{t, 1 - t / breakEvenYears}, {t, 0, years}], Axes → False,
        Filling → 0, Frame → True, ImageSize → is, PlotMarkers → {Automatic, 4},
        PlotRange → {{0, years}, {0, 1}}, ImagePadding → ip, PlotRangePadding →
          {{Automatic, Scaled[0.1]}, {Automatic, Scaled[0.05]}}, AspectRatio → 1 / 2,
        FrameLabel → {"Years from inception", "Survival Probability"}],
       Text@"Survival Probability"]}, {TextGrid[{{"Present Value of Expected Claims",
          Row[{"$", NumberForm[expectedClaimSize[propertyValue]]}]},
        {"Present Value of Expected Premium", Row[{"$", NumberForm[premium, {9, 2}]}]},
```

```
      {"Annual Premium Needed to Break Even",
       Row[{"$", NumberForm[annualPremium, {9, 2}]}]}}, Frame → All,
     ItemSize → {14, 1}, Dividers → All, Background → Lighter[Green, 0.8]]}}]],
{{propertyValue, 100000, "Property Value"},
 10000,
 1000000,
 10000,
 Appearance → "Labeled",
 ImageSize → Medium},
{{years, 10, "Coverage Period (Years)"},
 1,
 30,
 1,
 Appearance → "Labeled",
 ImageSize → Medium},
{{safetyLoading, 0.2, "Safety Loading"},
 0.1, 0.5,
 0.05,
 Appearance → "Labeled",
 ImageSize → Medium},
{{deductible, 0.05, "Deductible"}, 0.01, 0.20,
 0.01, Appearance → "Labeled",
 ImageSize → Medium},
Initialization :→ (lastPropertyValue = propertyValue;
  lastYears = years;
  lastSafetyLoading = safetyLoading;
  lastDeductible = deductible), SaveDefinitions → True]]
```

Out[∘]=



Insurer Payments



Survival Probability

Present Value of Expected Claims	$10370.8
Present Value of Expected Premium	$2.44 × 10^6
Annual Premium Needed to Break Even	$244169.11

In[∘]:=

```
(*Clear any existing definitions*)
Clear[expectedClaimSize, claimSizeFunction, calculatePremium,
  calculateBreakEven, simulateReserveProcess];

(*Constants*)
meanMagnitude = 4.30784;
stdDevMagnitude = 1.54993;
poissonRate = 1 / 0.04842;
magnitudeDist = NormalDistribution[meanMagnitude, stdDevMagnitude];

(*Define claim size function separately to avoid protected function issues*)
claimSizeFunction[magnitude_, propertyValue_] :=
  propertyValue * (0.01 * E^(0.5 * magnitude));

(*Define expected claim size using discrete sum*)
expectedClaimSize[propertyValue_] := Module[
   {magnitudeRange, probabilities, claims, total}, magnitudeRange = Range[1.4, 7.4, 0.1];
   probabilities = PDF[magnitudeDist, #] & /@ magnitudeRange;
   claims = claimSizeFunction[#, propertyValue] & /@ magnitudeRange;
   total = Sum[claims[[i]] * probabilities[[i]], {i, 1, Length[magnitudeRange]}] * 0.1;
   total];

calculatePremium[propertyValue_, years_, safetyLoading_, deductible_] := Module[
   {expectedLoss}, expectedLoss = expectedClaimSize[propertyValue] * poissonRate * years;
   expectedLoss * (1 + safetyLoading) * (1 - deductible)];

calculateBreakEven[propertyValue_, annualPremium_] := propertyValue / annualPremium;
```

```
(*Simulate Reserve Process with Poisson Claim Arrivals*)
simulateReserveProcess[initialReserve_, premiumRate_, years_, propertyValue_] :=
  Module[{timeSteps, totalTime, claimTimes, claimSizes,
    reserveTrajectory, premiumAccrued}, totalTime = years * 365;
   (*Simulate daily time steps for given years*)
   (*Generate random claim times using Poisson process*) claimTimes =
    Accumulate[RandomVariate[ExponentialDistribution[poissonRate], totalTime]];
   claimTimes = Select[claimTimes, # ≤ totalTime &];
   (*Filter within the time range*) (*Generate claim sizes based on the
    magnitude distribution*) claimSizes = claimSizeFunction[#, propertyValue] & /@
     RandomVariate[magnitudeDist, Length[claimTimes]];
   (*Initialize reserve and simulate*) reserveTrajectory = {};
   premiumAccrued = 0;
   For[t = 1, t ≤ totalTime, t++, premiumAccrued += premiumRate / 365;
    (*Premium accrues daily*) If[MemberQ[Round[claimTimes], t],
     (*Subtract claims when they occur*) premiumAccrued -= claimSizes[[1]];
     claimSizes = Rest[claimSizes]; (*Remove processed claim*)];
    AppendTo[reserveTrajectory, initialReserve + premiumAccrued];];
   reserveTrajectory];

(*Main visualization*)
DynamicModule[{lastPropertyValue = 100 000,
  lastYears = 10, lastSafetyLoading = 0.2, lastDeductible = 0.05},
 Manipulate[Module[{is, ip, premium, annualPremium, breakEvenYears,
    paymentsData, premiumsData, reserveData}, is = {280, 140};
   ip = {{50, 2}, {40, 2}};
   premium = calculatePremium[propertyValue, years, safetyLoading, deductible];
   annualPremium = premium / years;
   breakEvenYears = calculateBreakEven[propertyValue, annualPremium];
   paymentsData =
    Table[expectedClaimSize[propertyValue] * poissonRate * t, {t, 0, years}];
   premiumsData = Table[annualPremium * t, {t, 0, years}];
   (*Generate reserve data using the corrected process*) reserveData =
    simulateReserveProcess[initialReserve, annualPremium, years, propertyValue];
   Grid[{{Labeled[ListLinePlot[{Thread[{Range[0, years], premiumsData}],
          Thread[{Range[0, years], paymentsData}]}, Axes → False, Filling → 0, Frame → True,
        ImageSize → is, PlotMarkers → {Automatic, 4}, PlotRange → All, ImagePadding → ip,
        PlotRangePadding → {{Automatic, Scaled[0.1]}, {Automatic, Scaled[0.05]}},
        AspectRatio → 1 / 2, FrameLabel → {"Years from inception", "Payment $"},
        PlotStyle → {{Blue}, {Red}}], Text@"Insurer Payments"],
      Labeled[ListLinePlot[Thread[{Range[Length[reserveData]], reserveData}],
        Axes → False, Filling → Axis, Frame → True, ImageSize → is, PlotStyle → Green,
        PlotRange → All, AspectRatio → 1 / 2, FrameLabel → {"Days", "Reserve Amount"},
        PlotLabel → "Cramer-Lundberg Reserve Process"], Text@"Reserve Process"]},
     {TextGrid[{{"Present Value of Expected Claims",
          Row[{"$", NumberForm[expectedClaimSize[propertyValue]]}]}},
```

```
          {"Present Value of Expected Premium", Row[{"$", NumberForm[premium, {9, 2}]}]},
          {"Annual Premium Needed to Break Even",
           Row[{"$", NumberForm[annualPremium, {9, 2}]}]}}, Frame → All,
        ItemSize → {14, 1}, Dividers → All, Background → Lighter[Green, 0.8]]}}]],
   {{propertyValue, 100000, "Property Value"},
    10000,
    1000000,
    10000,
    Appearance → "Labeled",
    ImageSize → Medium},
   {{years, 10, "Coverage Period (Years)"},
    1,
    30,
    1,
    Appearance → "Labeled",
    ImageSize → Medium},
   {{safetyLoading, 0.2, "Safety Loading"},
    0.1, 0.5, 0.05,
    Appearance → "Labeled",
    ImageSize → Medium},
   {{deductible, 0.05, "Deductible"}, 0.01, 0.20,
    0.01, Appearance → "Labeled",
    ImageSize → Medium},
   {{initialReserve, 100000, "Initial Reserve"},
    10000, 1000000, 10000,
    Appearance → "Labeled", ImageSize → Medium},
   Initialization :→ (lastPropertyValue = propertyValue;
     lastYears = years;
     lastSafetyLoading = safetyLoading;
     lastDeductible = deductible), SaveDefinitions → True]]
```

Out[∗]=

```
In[∗]:= (*Main visualization with an additional plot*)
Manipulate[Module[{is, ip, premium, annualPremium, breakEvenYears, paymentsData,
    premiumsData, reserveProcessData, initialReserve, claimSizeData, magnitudeRange},
   (*Set initial reserve as 20% of property value*)initialReserve = 0.2 * propertyValue;
   is = {280, 140};
   ip = {{50, 2}, {40, 2}};
```

```
premium = calculatePremium[propertyValue, years, safetyLoading, deductible];
annualPremium = premium / years;
breakEvenYears = calculateBreakEven[propertyValue, annualPremium];
paymentsData = Table[expectedClaimSize[propertyValue] * poissonRate * t, {t, 0, years}];
premiumsData = Table[annualPremium * t, {t, 0, years}];
(*Simulate reserve process*)
reserveProcessData = simulateReserveProcess[initialReserve, annualPremium, years];
(*Cramer-Lundberg Reserve Process Simulation*)
simulateReserveProcess[initialReserve_, premiumRate_, years_] :=
 Module[{claimSizes, numClaims, reserveTrajectory, time}, SeedRandom[42];
   (*For reproducibility*) claimSizes =
    claimSizeFunction[#, 1] & /@ RandomVariate[magnitudeDist, 1000];
   numClaims = RandomVariate[PoissonDistribution[poissonRate * years]];
   reserveTrajectory =
    Table[initialReserve + premiumRate * t - Total[Take[claimSizes, UpTo[Min[Count[
           Accumulate[claimSizes] ≤ t, True], Length[claimSizes]]]]], {t, 0, years}];
   reserveTrajectory];
(*Generate claim size data*) magnitudeRange = Range[1.4, 7.4, 0.1];
claimSizeData = claimSizeFunction[#, propertyValue] & /@ magnitudeRange;
Grid[{{Labeled[ListLinePlot[{Thread[{Range[0, years], premiumsData}],
       Thread[{Range[0, years], paymentsData}]}, Axes → False, Filling → 0, Frame → True,
      ImageSize → is, PlotMarkers → {Automatic, 4}, PlotRange → All, ImagePadding → ip,
      PlotRangePadding → {{Automatic, Scaled[0.1]}, {Automatic, Scaled[0.05]}},
      AspectRatio → 1 / 2, FrameLabel → {"Years from inception", "Payment $"},
      PlotStyle → {{Blue}, {Red}}], Text["Insurer Payments"]],
    Labeled[ListLinePlot[Thread[{Range[1.4, 7.4, 0.1], claimSizeData}],
      Axes → False, Filling → 0, Frame → True, ImageSize → is,
      PlotMarkers → {Automatic, 4}, PlotRange → All, ImagePadding → ip,
      PlotRangePadding → {{Automatic, Scaled[0.1]}, {Automatic, Scaled[0.05]}},
      AspectRatio → 1 / 2, FrameLabel → {"Magnitude", "Claim Size"},
      PlotStyle → {Purple}], Text["Claim Size Distribution"]]},
   {TextGrid[{{"Present Value of Expected Claims",
       Row[{"$", NumberForm[expectedClaimSize[propertyValue]]}]},
      {"Present Value of Expected Premium", Row[{"$", NumberForm[premium, {9, 2}]}]},
      {"Annual Premium Needed to Break Even",
       Row[{"$", NumberForm[annualPremium, {9, 2}]}]}}, Frame → All,
     ItemSize → {14, 1}, Dividers → All, Background → Lighter[Green, 0.8]]}}]],
(*Sliders and Controls*){{propertyValue, 100000,
  "Property Value"},
 10000, 1000000, 10000,
 Appearance →
  "Labeled", ImageSize →
  Medium},
{{years, 10, "Coverage Period (Years)"},
 1,
 30,
 1,
```

```
  Appearance → "Labeled",
  ImageSize → Medium},
 {{safetyLoading, 0.2, "Safety Loading"},
  0.1,
  0.5,
  0.05,
  Appearance → "Labeled",
  ImageSize → Medium},
 {{deductible, 0.05, "Deductible"},
  0.01,
  0.20, 0.01,
  Appearance → "Labeled",
  ImageSize → Medium},
 {{a, 0.01, "Damage Coefficient (a)"},
  0.001, 0.1, 0.001,
  Appearance → "Labeled",
  ImageSize → Medium},
 {{b, 0.5, "Growth Rate (b)"}, 0.1, 1, 0.05,
  Appearance → "Labeled",
  ImageSize → Medium}]
```

Out[*]=

In[*]:=

```
(*Clear any existing definitions*)
Clear[expectedClaimSize, claimSizeFunction, calculatePremium,
  calculateBreakEven, simulateReserveProcess];

(*Constants*)
meanMagnitude = 4.30784;
```

```
stdDevMagnitude = 1.54993;
poissonRate = 1 / 0.04842;
magnitudeDist = NormalDistribution[meanMagnitude, stdDevMagnitude];

(*Define claim size function*)
claimSizeFunction[magnitude_, propertyValue_, damage_, growthRate_] :=
  propertyValue * (damage * E^(growthRate * magnitude));

(*Define expected claim size using discrete sum*)
expectedClaimSize[propertyValue_, damage_, growthRate_] := Module[
   {magnitudeRange, probabilities, claims, total}, magnitudeRange = Range[1.4, 7.4, 0.1];
   probabilities = PDF[magnitudeDist, #] & /@ magnitudeRange;
   claims = claimSizeFunction[#, propertyValue, damage, growthRate] & /@ magnitudeRange;
   total = Sum[claims[[i]] * probabilities[[i]], {i, 1, Length[magnitudeRange]}] * 0.1;
   total];

calculatePremium[propertyValue_, years_, safetyLoading_,
   deductible_, damage_, growthRate_] := Module[{expectedLoss}, expectedLoss =
    expectedClaimSize[propertyValue, damage, growthRate] * poissonRate * years;
   expectedLoss * (1 + safetyLoading) * (1 - deductible)];

calculateBreakEven[propertyValue_, annualPremium_] := propertyValue / annualPremium;

(*Simulate Reserve Process with Poisson Claim Arrivals*)
simulateReserveProcess[initialReserve_,
   premiumRate_, years_, propertyValue_, damage_, growthRate_] :=
  Module[{totalTime, claimTimes, claimSizes, reserveTrajectory, premiumAccrued},
   totalTime = years * 365;
   claimTimes =
    Accumulate[RandomVariate[ExponentialDistribution[poissonRate], totalTime]];
   claimTimes = Select[claimTimes, # ≤ totalTime &];
   claimSizes = claimSizeFunction[#, propertyValue, damage, growthRate] & /@
     RandomVariate[magnitudeDist, Length[claimTimes]];
   reserveTrajectory = {};
   premiumAccrued = 0;
   For[t = 1, t ≤ totalTime, t++, premiumAccrued += premiumRate / 365;
    If[MemberQ[Round[claimTimes], t], premiumAccrued -= claimSizes[[1]];
     claimSizes = Rest[claimSizes]];
    AppendTo[reserveTrajectory, initialReserve + premiumAccrued];];
   reserveTrajectory];

(*Main visualization*)
DynamicModule[{lastPropertyValue = 100000, lastYears = 10, lastSafetyLoading = 0.2,
  lastDeductible = 0.05, lastDamage = 0.01, lastGrowthRate = 0.5},
 Manipulate[Module[{is, ip, premium, annualPremium, breakEvenYears,
    paymentsData, premiumsData, reserveData, claimSizePlot}, is = {280, 140};
   ip = {{50, 2}, {40, 2}};
```

```
  premium = calculatePremium[propertyValue,
    years, safetyLoading, deductible, damage, growthRate];
  annualPremium = premium / years;
  breakEvenYears = calculateBreakEven[propertyValue, annualPremium];
  paymentsData = Table[expectedClaimSize[propertyValue, damage, growthRate] *
     poissonRate * t, {t, 0, years}];
  premiumsData = Table[annualPremium * t, {t, 0, years}];
  reserveData = simulateReserveProcess[initialReserve,
    annualPremium, years, propertyValue, damage, growthRate];
  claimSizePlot = Plot[claimSizeFunction[x, propertyValue, damage, growthRate] *
     PDF[magnitudeDist, x], {x, 1.4, 7.4}, Axes → False, Frame → True,
    ImageSize → is, FrameLabel → {"Magnitude", "Claim Size Density"},
    PlotStyle → Blue, Filling → Axis, AspectRatio → 1 / 2, PlotRange → All,
    PlotLabel → Row[{"Claim Size Distribution (Damage: ", NumberForm[damage, {2, 2}],
       ", Growth Rate: ", NumberForm[growthRate, {2, 2}], ")"}]];
  Grid[{{Labeled[ListLinePlot[{Thread[{Range[0, years], premiumsData}],
        Thread[{Range[0, years], paymentsData}]}, Axes → False, Filling → 0, Frame → True,
       ImageSize → is, PlotMarkers → {Automatic, 4}, PlotRange → All, ImagePadding → ip,
       PlotRangePadding → {{Automatic, Scaled[0.1]}, {Automatic, Scaled[0.05]}},
       AspectRatio → 1 / 2, FrameLabel → {"Years from inception", "Payment $"},
       PlotStyle → {{Blue}, {Red}}], Text@"Insurer Payments"],
     Labeled[ListLinePlot[Thread[{Range[Length[reserveData]], reserveData}],
       Axes → False, Filling → Axis, Frame → True, ImageSize → is, PlotStyle → Green,
       PlotRange → All, AspectRatio → 1 / 2, FrameLabel → {"Days", "Reserve Amount"},
       PlotLabel → "Cramer-Lundberg Reserve Process"],
      Text@"Reserve Process"]}, {claimSizePlot}}]],
 {{propertyValue, 100000, "Property Value"}, 10000,
  1000000,
  10000,
  Appearance → "Labeled",
  ImageSize → Medium},
 {{years, 10, "Coverage Period (Years)"},
  1, 30, 1,
  Appearance → "Labeled",
  ImageSize → Medium},
 {{safetyLoading, 0.2, "Safety Loading"}, 0.1, 0.5,
  0.05, Appearance → "Labeled",
  ImageSize → Medium},
 {{deductible, 0.05, "Deductible"}, 0.01, 0.20, 0.01,
  Appearance → "Labeled", ImageSize → Medium},
 {{damage, 0.01, "Damage"}, 0.005, 0.05, 0.005,
  Appearance → "Labeled", ImageSize → Medium},
 {{growthRate, 0.5, "Growth Rate"}, 0.1, 1, 0.1,
  Appearance → "Labeled", ImageSize → Medium},
 {{initialReserve, 100000, "Initial Reserve"}, 10000, 1000000,
  10000, Appearance → "Labeled", ImageSize → Medium},
 Initialization :→ (lastPropertyValue = propertyValue;
```

```
lastYears = years; lastSafetyLoading = safetyLoading;
lastDeductible = deductible; lastDamage = damage;
lastGrowthRate = growthRate), SaveDefinitions → True]]
```

Out[•]=