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Financial Modeling Applications

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Topics to be covered

- Financial modeling by actuaries and the Actuarial Control Cycle
- Application 1: Pricing a Life Insurance Product
- Application 2: Asset Liability Matching
- Application 3: Value at Risk

Model

Definitions from the web:

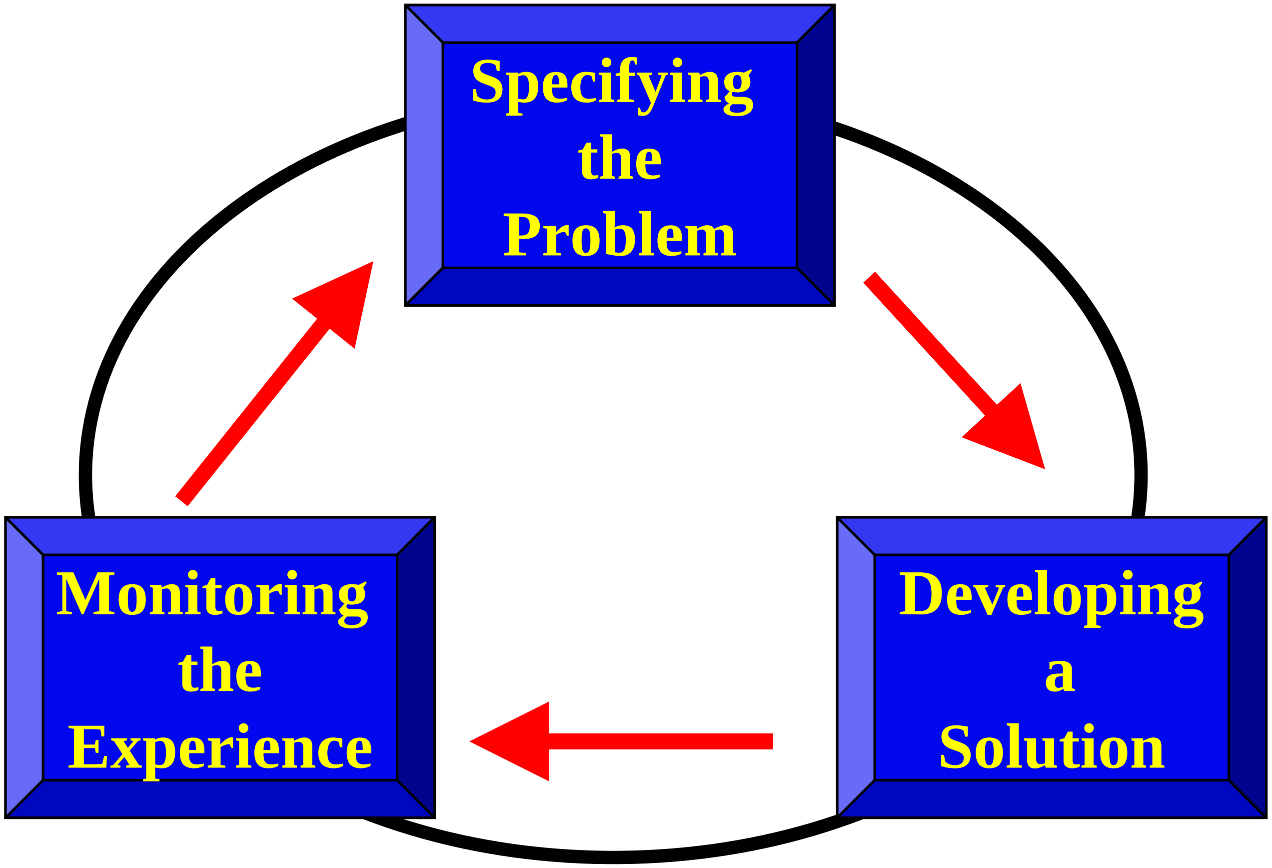
- Mathematical use of data to project experimental results.

- This is a simplified description of reality. They are used for prediction and control purposes and help us to improve our understanding of the behavioral characteristics of reality.

- A prototype or surrogate of a complex situation. It can be a physical model, such as an architectural model of urban design, or a mathematical model of interactions of many variables. It is used in simulations for relating various components together or can be a stand alone tool to evaluate different approaches using different assumptions.

- A woman who wears clothes to display fashions

Actuarial Control Cycle



Actuarial Control Cycle

- Actuarial Control Cycle is a process based on a scientific approach to problem solving
  - first, specify the problem,
  - second design and implement a solution,
  - third monitor the effectiveness of the solution
  - But it does not end here…
  - Typically, revision is necessary – hence the loop or cycle.
- The Actuarial Control Cycle must of course be considered in the context of the economic and commercial environment (e.g. legislation, taxation, business ethics).
- Also, as professionals, actuaries must adhere to requirements of professionalism.

Specifying the problem

- This stage of the control cycle will give an assessment of the risks faced and how they can be handled. It also provides an analysis of the options for the design of plans to provide various benefits and the prices of the plans that will result. It also considers the strategic courses of action that could be used to handle the particular risks in question.

Developing a Solution

- An examination of the major (actuarial) models currently in use and how they may be adjusted for the particular problem to be solved.
- Selection of the most appropriate model to use for the problem, or construction of a new model.
- Consideration and selection of the parameters to be used in the model.
  - The parameters used in a model are critical and it is necessary to have a good understanding of their sensitivities.
- Interpretation of the results of the modeling process.
  - Consideration of the implications of the model results on the overall problem. Consideration of the implications of the results for all stakeholders.
- Determining a proposed solution to the problem.
- Consideration of alternative solutions and their effects on the problem.
- Formalizing a proposal.

Monitoring the experience

- It is critical that the models are updated to reflect current experience.
- This stage deals with the monitoring of experience and its feedback into the problem specification and solution development stages of the control cycle, i.e. updating the investigation.
- An important part of this monitoring will be the identification of the causes of any systemic departure from the targeted outcome from the model and a consideration as to whether such departures are likely to recur.
- Hence identify new problem and around the cycle again.

Pricing - Specify the problem

- Pricing a long term life insurance savings plan
- Risks faced: mortality, lapse rates, expenses, interest rates, inflation, sales distribution and volume, average policy size
- How will the risk be handled: underwriting guidelines, cost control mechanisms, sales incentives and compensation, sales force training, systems, reinsurance, asset liability management, customer relationship management , market research
- Do we differentiate prices by policy size, smoker/non-smoker status, distribution channels, individual/group segments

Pricing - Developing a Solution

- When pricing a product assumptions are more important than the model used: garbage in and garbage out
- The future is impossible to predict. We can develop a range of assumptions that encompass the most plausible possibilities
- By testing such a range of assumptions and designing the product to future outcomes, financial risk of the product can be reduced
- Assumption sources: economic data, life insurance industry data, reinsurer, company's own experience
- Concentrate on assumptions that are most critical and carry out sensitivity testing
- Most important assumptions for a life insurance product: mortality, lapse rates, interest rates, expenses, average size, sales distribution and volume.
- For each assumption you should know: why the assumption varies, source of data, general variations, variations by product, trends, how does it tie in with you risk control mechanisms
- Decide profit measures to be used: embedded values, ROI, PV of profits as % of PV of premium,
- Develop pricing model: cash flows over the life of the product..\Actuarial factors-tables\Pricing - SVP 2004.XLS
- Interpret and present results

Pricing - Monitor the Experience

- Actual versus expected: mortality, expenses, interest rates, sales volumes, average policy size
- Mortality studies
- Expense analysis reports
- Business reports
- Lapse reports
- Source of profits analysis
- Appointed Actuary's Financial Condition Report
- Identify reasons
- Take corrective actions: re-price product, make product changes, introduce new product, withdraw product, set aside reserves

Asset Liability Matching

- By matching assets and liabilities, a company can reduce the financial effect of changes in interest rates
- Also referred to as "immunization" because it immunizes a company from changes in interest rates
- More than a few financial institutions could have been saved from insolvency had they employed an asset/liability matching strategy
- This process brings together asset and liability models
- Two basic methods: exact matching, duration matching

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ALM - Exact Matching

- To create an exact matching of assets and liabilities, begin by matching the final liability and then work backward to the present time
- Once the longest liabilities have been matched with non-callable assets, proceed to matching the next longest liabilities
- This process continues until all future cash outflows have been matched

ALM - Exact Matching Case Study

Liability Cash Flows

t	Liability Cash Flow
0.25	(35.00)
0.50	(30.00)
0.75	(35.00)
1.00	(30.00)
1.25	(25.00)
1.50	(55.00)
1.75	(65.00)
2.00	(75.00)
2.25	(85.00)
2.50	(100.00)

BondUnits(2.5) [Coupon(2.5)+ParValue(2.5)]
= LiabilityCashFlow(2.5)

BondUnits (2.0) [Coupon(2.0)+ParValue(2.0)]
+ BondUnits(2.5)Coupon(2.5)
= LiabilityCashFlow(2.0)

ALM - Exact Matching Case Study

t	Liability Cash Flow	Coupon Rate	Bond Units X Par Value	Asset Cash Flow
0.25	(35.00)	4.00%	27.81	35.00
0.50	(30.00)	4.50%	20.79	30.00
0.75	(35.00)	5.00%	28.36	35.00
1.00	(30.00)	5.50%	21.25	30.00
1.25	(25.00)	6.00%	19.07	25.00
1.50	(55.00)	6.50%	46.84	55.00
1.75	(65.00)	7.00%	59.64	65.00
2.00	(75.00)	7.50%	68.36	75.00
2.25	(85.00)	8.00%	81.73	85.00
2.50	(100.00)	8.50%	95.92	100.00

Duration Matching

- It is not usually practical or even possible to exactly match all future asset and liability cash flows
- A more common approach is to match the duration of assets to the duration of liabilities
- If asset and liability durations have been matched, then small changes in interest rates will have an equal effect on assets and liabilities
- The effect on assets and liabilities will be offsetting, thereby immunizing the company from the risk associated with small changes in interest rates
- The company will have to rebalance its asset portfolio from time to time in order to maintain the matching
- When matching asset and liability durations, it is crucial that both durations be calculated using the same interest rates.
- With duration matching there is no exact matching of cash flows. These mismatches are important.

Duration Matching

Liability Cash Flows

t	Liability Cash Flow	Present Value	t X Present Value
	i	=	7%
0.25	(35.00)	(34.41)	(8.60)
0.50	(30.00)	(29.00)	(14.50)
0.75	(35.00)	(33.27)	(24.95)
1.00	(30.00)	(28.04)	(28.04)
1.25	(25.00)	(22.97)	(28.72)
1.50	(55.00)	(49.69)	(74.54)
1.75	(65.00)	(57.74)	(101.05)
2.00	(75.00)	(65.51)	(131.02)
2.25	(85.00)	(73.00)	(164.24)
2.50	(100.00)	(84.44)	(211.10)
	Sum	(478.07)	(786.75)
	Duration		1.5380

ALM - Horizon Matching

- Hybrid between exact matching and duration matching
- Assets are matched as closely as possible to the liability cash flows for first several years. In general the cash flows in the early durations are more predictable and easier to match
- The remaining liability cash flows are then matched using duration matching
- As these later cash flows become nearer term cash flows, the matching process is gradually adjusted to cover these cash flows on an exact matching basis

Value at Risk

- VaR is a single number summarizing the total risk in a portfolio of financial assets
- Used by senior management of financial institutions, corporate treasurers, fund managers and central bank regulators
- Regulators base the capital they require banks to keep on VaR
- The question being asked in VaR is: "What loss level is such that we are X% confident it will not be exceeded in N business days?"

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VaR - Time Horizon

- Regulators require the market-risk capital to be *k* times the 10-day 99% VaR where *k* is at least 3.0
- Instead of calculating the 10-day, 99% VaR directly analysts usually calculate a 1-day 99% VaR and assume

$$\text{10-day VaR} = \sqrt{10} \times \text{1-day VaR}$$

- This is exactly true when portfolio changes on successive days come from independent identically distributed normal distributions with mean zero

VaR - Historical Simulation Method

- Create a database of the daily movements in all market variables.
- The first simulation trial assumes that the percentage changes in all market variables are as on the first day
- The second simulation trial assumes that the percentage changes in all market variables are as on the second day
- and so on
- For each scenario we calculate the change in value of the portfolio between today and tomorrow
- This defines a probability distribution for daily changes in the value of the portfolio
- With 500 scenarios, the 5th worst daily change is the first percentile of the distribution. In other words, we are 99% certain that we will not take a loss greater than our VaR estimate

VaR - Historical Simulation Method

Data for VaR Historical Simulation Calculation

Day	Market variable 1	% change daily	Market variable 2	% change daily	…	Market variable N	% change daily
0	20.33		0.11320		…	65.37	
1	20.78	1.0221	0.11590	1.0239	…	64.91	0.9930
2	21.44	1.0318	0.11620	1.0026	…	65.02	1.0017
3	20.97	0.9781	0.11840	1.0189	…	64.90	0.9982
:	:	:	:	:	:	:	:
498	25.72		0.13120			62.22	
499	25.75	1.0012	0.13230	1.0084	…	61.99	0.9963
500	25.85	1.0039	0.13430	1.0151	…	62.10	1.0018

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VaR - Historical Simulation Method

Scenarios generated for tomorrow (Day 501)

Scenario Number	Market variable 1	Factor used	Market variable 2	Factor used	…	Market variable N	Factor used	Portfolio value (millions)	Change in Value
Today	25.85		0.13430			62.10		23.5	
1	26.42	1.0221	0.13750	1.0239		61.66	0.9930	23.71	210,000
2	26.67	1.0318	0.13465	1.0026		62.21	1.0017	23.12	(380,000)
3	25.28	0.9781	0.13684	1.0189		61.99	0.9982	22.94	(560,000)
:									
499	25.88	1.0012	0.13543	1.0084		61.87	0.9963	23.63	130,000
500	25.95	1.0039	0.13633	1.0151		62.21	1.0018	22.87	(630,000)

VaR - Model-Building Approach

- The main alternative to historical simulation is to make assumptions about the probability distributions of return on the market variables and calculate the probability distribution of the change in the value of the portfolio analytically
- This is known as the model building approach or the variance-covariance approach
- In option pricing we measure volatility "per year". In VaR calculations we measure volatility "per day"

$$\sigma_{day} = \frac{\sigma_{year}}{\sqrt{252}}$$

Example

- We have a position worth 10 million in say OGDC shares
- The volatility of the share 2% per day (about 32% per year)
- We use N=10 and X=99
- The standard deviation of the change in the portfolio in 1 day is 200,000
- The standard deviation of the change in 10 days is
- $200{,}000\sqrt{10} = 632{,}456$

Example continued

- We assume that the expected change in the value of the portfolio is zero (This is OK for short time periods)
- We assume that the change in the value of the portfolio is normally distributed
- Since $N(-2.33)=0.01$, the VaR is
- 2.33 X 632,456 = 1,473,622

Another Example

- Consider a position of 5 million in PTCL
- The daily volatility of PTCL 1% (approx 16% per year)
- The S.D per 10 days is $50{,}000\sqrt{10} = 158{,}114$
- The VaR is 158,144 X 2.33 = 368,405

Portfolio

- Now consider a portfolio consisting of both OGDC and PTCL
- Suppose that the correlation between the returns is 0.3

S.D. of Portfolio

- A standard result in statistics states that

$$\sigma_{X+Y} = \sqrt{\sigma_X^2 + \sigma_Y^2 + 2\rho\sigma_X\sigma_Y}$$

- In this case $\sigma_X = 200{,}000$ and $\sigma_Y = 50{,}000$ and $\rho = 0.3$. The standard deviation of the change in the portfolio value in one day is therefore 220,227

VaR for Portfolio

- The 10-day 99% VaR for the portfolio is

$$220{,}227 \times \sqrt{10} \times 2.33 = 1{,}622{,}657$$

- The benefits of diversification are

(1,473,621+368,405)–1,622,657=219,369

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Cat models cannot replace common sense

15 May 2006

Jonathon Gray of Beazley has told the industry that "catastrophe models should not override underwriting common sense".

The insurance industry needs to get back to "common sense underwriting" when dealing with weather-related risks, an expert has warned.

Jonathan Gray, Head of Property at Beazley Group, said that last year's hurricane highlighted the dependance of some underwriters on catastrophe models.

"We need to get back to a world where there is common sense underwriting," he said. "Catastrophe models are useful tools but they should not override underwriting experience."

Gray was talking at a conference in London last week entitled 'Mastering Nature – Managing Exposure Post Katrina'. Industry experts were gathered to discuss the future of the insurance world following last year's record hurricane losses and the challenges underwriters now face covering catastrophe risk in an increasingly uncertain climate.

Professor Mark Saunders, lead scientist for the Tropical Storm Risk Consortium, painted an uncertain climatic picture for the decade.

References

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- Options, Futures and Other Derivatives, John C Hull