GOVERNMENT ACTUARY'S DEPARTMENT

ACTUARIAL ANALYSIS
FOR THE PUBLIC SECTOR — FROM THE PUBLIC SECTOR

A DECISION-MAKER'S GUIDE TO LONG-TERM FINANCIAL MODELLING

USES

ABUSES

HOW TO IMPROVE

HOW TO REVIEW

December 2011

01

INTRODUCTION

Financial models are increasingly used to help guide decisions and are growing in complexity. As a result there are increasing risks that:

> so few people actually understand what the model does that it may miss out on key features and not be 'fit for purpose'
> there is insufficient challenge of the assumptions underlying the model (or none at all), with the delivery of results from a complex model causing a 'rabbit in the headlights' reaction of 'it must be right', despite the fact that the assumptions used are a key issue for any model, and
> the model does not do the calculations correctly

which can result in inappropriate decisions.

So this guide has been prepared for users/recipients/sponsors of models[1] to help them get the best out of their models and thereby reduce the risks to their organisations of wrong decisions. It is based on GAD's increasing experience of giving assurance on models, and how the results are presented and used, in Government. That said, we believe this guide will be of benefit not just in Government but also in other organisations making use of financial models.

For those interested in some of the various techniques and tools and models used in risk analysis, we include a summary list in the Appendix.

This guide includes:

> an overview of financial models
> hints, tips and points to watch with:
    - complex models
    - models that look into the costs of changes that affect the whole population
    - economic and Investment models
    - very long term models (over 30 years)
    - models designed to determine Capital Adequacy, and
> a checklist for assurance of models/results.

Note: This paper is about long-term financial modelling. On the whole, a lot of short-term modelling is conducted by accountants and rightly so. Actuaries come into their own over longer time periods when long-term relationships between different variables become significant. Whilst there is no 'black or white' demarcation, I am treating over 15 years as long-term, under 5 years as short-term and anything in between on a 'horses for courses' basis where both skill-sets are probably useful. That said, there are always exceptions, such as insurance models, where actuaries are involved both long and short term. For further information please contact me at trevor.llanwarne@gad.gov.uk or 020 7211 2620 or any of my GAD colleagues.

Trevor Llanwarne, Government Actuary

[1] There are particular technical considerations that apply to stochastic or 'Monte Carlo' models where many random scenarios are considered. However, in this guide we have concentrated mainly on issues which apply equally to both deterministic and stochastic models.

02

OVERVIEW OF FINANCIAL MODELS

Essence of models

In essence a model is a mechanism for demonstrating some aspect of the real word. A model can be an extremely simple representation that seeks to broadly mirror that mechanism or it may be extremely complex (as will frequently be the case with financial models). When presented with such a model or the results of some modelling, the first (and most fundamental) question to ask is whether it is clear what it has been designed to do – and whether or not it does it. Moreover, as a model is just that, it is not the real world and hence will always have some limitations no matter how sophisticated it becomes – it is just as important to understand the possible impact of these limitations as it is to understand the fundamental purpose of the model.

Typically there are three processes in relation to any financial model:

> inputs (i.e. data and assumptions)

> calculations

> outputs (numbers, words and graphs).

Each is considered below.

Inputs

Initial data can be critical. This might comprise asset values, annual expenditure, formulae for benefit payments, current percentages unemployed etc. Small changes in initial conditions can magnify into major changes in long-term results: the proverbial butterfly flapping its wings in the Amazon rain forest causing a tornado in Alabama. So getting initial data correct (and looking at possible ranges if there is doubt) is absolutely critical for long-term projection models in particular.

The other key issue is the assumptions that are input. Are they neutral or do they exhibit bias? Are there implicit assumptions (i.e. ones that are not input)? How does the model cope with scenarios or ranges for different assumptions (or indeed can it handle a multitude of runs with the input varying with some form of likelihood assumption – 'stochastic modelling')?

Calculations

Obviously it is critical that the model delivers the correct answers using the intended underlying mathematics. But there are two other key aspects:

> to what extent are there any built-in approximations and simplifications?

> do the users understand such built-in limitations?

Outputs

In many ways, the outputs are more critical than anything else. It is vital that users are given sufficient information such that they understand what the answer(s) is/are, the range of answers under different scenarios, where the risks and 'tipping points' may be and the limitations - but not too much information so that confusion arises or 'the wood can't be seen for the trees'.

This Goldilocks scenario of not too much, not too little presented in a simple way to maximise understanding is very difficult to achieve in practice and warrants just as much effort as the other two components.

03

COMPLEX MODELS: POINTS TO WATCH

1. Consider whether the model ‘does what it says on the tin’ - this may be particularly relevant if a model was originally constructed for another purpose and has been adapted for the present purpose. In order to do this, ensure there is adequate documentation to check that the model is understandable (and so are any conclusions reached).
2. How are the model and the outputs communicated to non-experts (limitations, applicability, risks etc.)? There is a risk that management use the results in a way they should not due to poor or inadequate communication. This is even more true for others such as the press, politicians etc.
3. Equally, there should be scope for feedback and challenge from management in order to drive ongoing improvement of the model.
4. A corollary of the above is that people often see ‘more complex’ models as ‘more right’. This should not follow. It has been said that all models are wrong but some are useful, and in particular they can help on direction of travel.
5. Consider any optimism bias in the assumptions. People often want models to prove their prejudices so if the results are out of line the assumptions get changed (often accompanied by a compelling justification).
6. It can be difficult to check complex models other than by results or outcomes using a parallel model or approach.
7. The use of too narrow a range of scenarios around the central projections can lead users to think all outcomes will appear in just a narrow band. On occasion some pressure can be applied to avoid the showing of any real more extreme scenarios. This should be resisted or appropriate warnings made clear.
8. If there are gaps in the specification of what is being modelled it follows there should normally be a wide range of potential outcomes. An exception may arise if the user in the real world has the ability to regularly re-steer events to keep on a certain track, in which case the range of outcomes can be made narrower. (The phrase ‘management actions’ is sometimes used to describe such possibilities.)
9. Models built for one purpose are often inappropriate for other purposes.
10. When presenting results, it is normally helpful to present:
    - > both absolute numbers (in the appropriate currency) and percentages for financial results
    - > base results (e.g. this year and next year) as well as results allowing for changes, and not just differences
    - > results for any new populations in isolation as well as total populations.
10. There are invariably implicit assumptions. Tease them out.
11. In some models, correlations in extreme conditions may be the same as the correlations that apply in more normal conditions. But this is not necessarily the real world and should be tested.
12. Work on absolute numbers as well as differences. Have a solid audit trail built up from a secure known base of absolute numbers.
13. Is the use of the model resilient to staff changes/departures and/or software changes?
14. Understand all the limitations.

04

MODELS THAT AFFECT THE POPULATION: POINTS TO WATCH

There are specific additional issues when looking at changes having an impact on people – be they about tax, fares, benefits (e.g. pensions, care), education etc. In particular, make sure you consider behavioural economics and model various possibilities – or have strong warnings.

For example, does the model allow for the following factors?

1. Big bang changes create more winners/losers (and relative losers) and wider disparities in size of change.
2. As a result big bang changes usually end up with more money thrown at the change than if a more gradual transition were to apply (partly because in the latter situation the relative losers disappear).
3. There is a cost to uncertainty, a value in flexibility and (if relevant) a price for removing risk. Build into the model accordingly.
4. For a Government initiative, be very careful to review examples of the population who would hit the headlines and see if this warrants any modelling refinements. This might include (a) the poor (b) a typical voter for each party (c) the high earners (accountants, lawyers, bankers, hedge-fund managers) (d) MPs etc.
5. Remember the popular 80/20 rule (sometimes referred to loosely as 'Pareto') – 20% of the population can cause 80% of the flak – and check whether the model allows for the consequences.
6. Don't leave transition to the last minute – pre-plan just as early as for the main design since transition can often be a source of sudden extra costs. Build transition into the modelling.
7. Beware legal risk e.g. falling foul of age discrimination, ECJ ruling etc. Does this warrant any change to the model?
8. Behaviours change when the rules/laws change. The effect is invariably higher cost than expected. This isn't just a tax point where it is inappropriate to calculate the extra tax yield on a tax change assuming no changes in behaviours' – there will always be people who respond to tax changes to minimise the tax payment. It's also a benefit point – if a more generous benefit (or less burdensome benefit) is provided by the State, the take-up rate and amounts taken up will invariably be higher than would be the case if behaviours remain unchanged. Does the model allow for this?
9. Models need to be run over a long-term period if decisions are to be based on the model. Typically this means 30+ years. This is because some key 'direction of travel' issues do not show up in early periods (e.g. the first 15 years), because of generational impacts, and these issues should often affect decisions.

05

ECONOMIC & INVESTMENT MODELS: POINTS TO WATCH

1. A lot of these models depend critically on assumptions used, so all the messages elsewhere about optimism bias etc. apply with real impact.
2. These models often use concepts such as 'Value at Risk' or VaR which link to extreme events (perhaps the 2.5% worst case or 1 in 40 year event for example). As stated in section 3, watch out for the implied correlations at these extreme events, for example the relationships between equities and bonds or between prices and base rates. The point is that the correlations are not the same as in the main less extreme times and there is not enough data to fully know what happens in the extremes.
3. These models are often used to support decisions, e.g. on investment strategy, and so are vulnerable to optimism bias.
4. It is easy to arrive at wrong assumptions. For example, what is the gap between earnings growth (NAE) and inflation (CPI)? If you take the 20 years to 2009 as being representative you might assume 2%. If you take to 2010, you might get 2.5%. If you take 20 years to 1990 and try to adjust for the lack of CPI over that period, you might get 4%. So the empirical evidence is by no means clear and any attempt to use a theoretical model requires assumptions about the future rise of India/China which are impossible to predict. Be very careful with assumptions like this and show scenarios.
5. A similar issue can arise with many other assumptions. For example, does the Bank of England's targeting of 2% CPI mean 2% is the right long-term rate to use? Only if the effect of the Bank's targeting is a symmetric distribution around 2%. But it is difficult to see this will happen when a doubling of the rate of CPI is twice the difference (4% - 2% = 2%) that a halving is (2% - 1% = 1%).
6. Many models on investment combine asset classes and make some simplifying assumption such as to treat all return seeking investments the same (as equities for example). This may be appropriate depending on the purpose of the model, but it should be challenged and justified.
7. Be careful with models which mix assets with liabilities such as LDI (Liability Driven Investment) models. There are instances of such models being written by asset experts with very limited knowledge of liability issues. If in doubt bring in a liability expert to give an assurance.

06

VERY LONG-TERM MODELS: POINTS TO WATCH

1. Only very small changes to the initial conditions or to the assumptions can have a major impact on long-term results. For example just a 0.25% lower investment return each year can knock over 20% off the value beyond 50 years in a theoretical stable world. In an unstable world, with times of dynamic change, small changes can have bigger impacts (e.g. the proverbial ‘butterfly flapping its wings’ scenario described in section 2).
2. In long-term Government projections, there will invariably be policy changes over the period and it is not possible to allow fully for this.
3. On the other hand, some policy issues such as benefits are notoriously difficult to change in terms of accrued rights (it’s like turning a super tanker where small changes now can take many years before being noticed).
4. So the real benefit of long-term projections is to show direction of travel and the effects in the long term of a little re-steering now, in order to assist decision-making. The long-term results are only reliable to the extent that continual re-steering to maintain direction can be expected.
5. If re-steering will not work, then the position might be more akin to ‘we need a crisis to make any change’, in which case the model’s purpose should be considered as reviewing the circumstances of a crisis occurring and tested in that light.
6. As in all models, there is likely to be a need for expert judgment in choosing assumptions. Some of the techniques listed in the Appendix may be helpful in applying such judgment and we comment elsewhere on the importance of testing the sensitivity to alternative assumptions in such circumstances.
7. On long-term financial models in particular, there may be a need to use expert judgment in choosing an appropriate set of assumptions combining current financial or market conditions in the short term with possible ‘mean reversion’ to equilibrium conditions in the long term.

MODELS FOR CAPITAL ADEQUACY: POINTS TO WATCH

1. These models ('internal models' under Solvency II for insurance companies for example) are one approach (sometimes imposed by Regulators) to set a minimum level of capital to protect against rare events. In the case of Solvency II, it is not obligatory to use such a model – a standard formula can be used instead, although most insurers in the UK believe that the standard formula would deliver a higher level of capital than would be necessary for their particular business.
2. The rare events are often expressed as 1 in 200 year events. But there is not adequate data to know what an event like this really is – so real care is needed in terms of explaining to users and management what is really being delivered.
3. Where the model is used to determine capital adequacy under a regulatory regime, there is a danger that it becomes a box-ticking compliance issue without adequate thought. Note that in the case of Solvency II, the 'use test' is intended to avoid this risk.
4. Recipient boards, investors and other users may have little or no understanding of these very complex models, even though Board understanding is a requirement for the use of internal models under Solvency II. So there are very real risks that such recipients treat the results as absolutely correct and do not understand the limitations.
5. Because the models can be complex, it is very important for users not to give the models more status or meaning than the limited purpose they are intended for – and section 3 of this Guide is particularly relevant.
6. Notwithstanding the points made above, and despite its imperfections, nevertheless the approach to be used in Solvency II internal models is considered to be of a high standard which many other models should aspire to. For example, as well as the 'use test' there are required standards relating to:

   > model governance
   > statistical quality of data and assumptions
   > calibration
   > validation
   > documentation.

   This is also a requirement for 'profit and loss attribution' - essentially a comparison of actual financial outcomes over time with model outputs and assumptions.

CHECKLIST FOR ASSURANCE OF MODELS & RESULTS

1. Ensure there is clarity over what it is required to give assurance on.
2. It is easier for an external reviewer to review and give a form of assurance on fiscal/cost outcomes/projections from a complex model than on accuracy of any complex model in all circumstances, i.e. on the outputs from a model rather than the model itself. Therefore be clear which type of review/assurance is being given and conduct the review accordingly. If the former type, ensure you consider applicability and accuracy of data, input assumptions, possible ranges, outputs and degree of approximation.
3. It is easier to give assurance if discretions are built into the matter being modelled – for example, if there is a model of benefit costs which would normally increase with inflation but with an automatic provision not to increase in times of deficits, a stronger assurance can be provided over longer term viability than might otherwise be the case. Even so, any assurance must take into account the inherent uncertainty of any projections.
4. For projection models used by decision-makers who have a prior view as to their preferred outcome (and where results may get quoted in support of any decision), there is a danger of those running the model bowing to demands regarding the assumptions to be used throughout the life of any projection. So ensure there is a margin built in (or be clear that the projection may be worse than a best estimate).
5. Significant gaps in design of the matter being modelled make it difficult to give assurance on results. The bigger the gaps, the greater the qualifications needed. That said, over-complexity also has dangers – so review whether there are gaps and what their materiality is in order to understand the balance being struck and how acceptable this is.
6. It is important to see a full range of sensitivities and scenarios covering:
    a) Different variables (sensitivities) and
    b) Wide ranges for any key individual variable and
    c) Key combinations (to consider scenarios)

    Without this, recipients of results will not be able to gain a proper understanding of the issues and are vulnerable to taking wrong decisions.
7. Where the model is being used to consider changes which impact individuals (as per section 4), consider the impact of the political risk based on the type of transition being modelled – for example, it is often the case that ‘cliff-edge’ changes have high vulnerability to being changed under political pressure (e.g. 10p income tax in 2007/8). Adjust the assurance accordingly.
8. In terms of any presentation of model results for projects, there is usually a base scenario, or central scenario. Ensure it is clear what exactly this scenario represents, and then for other scenarios ensure it is clear how they differ from the base/central scenario. Be very careful as to what any base and comparator figures are. Are they valid or in need of adjustment?
9. Models invariably have implicit assumptions which need to be understood. Ensure they are determined.

10. Be careful over any assumed or stated independence (or lack thereof) of assumptions. In the investment and economic world, variables that are assumed to be independent can change to become more correlated (and therefore less independent) in the more extreme scenarios.
11. The Board for Actuarial Standards have produced a standard for models (TAS M) – check the provisions in the standard for applicability.
12. In Government departments, as in the private sector, there can often be implicit pressures to support the stated aims of the senior personnel. Any reviewer or provider of assurance should be free from conflicts that can otherwise arise by being sufficiently independent.
13. Always be on the lookout for optimism bias. This applies just as much to the style of presentation of results as it does to assumptions and data input. Really check the validity of empirical evidence (see for example section 5).
14. Extra care is needed in the review of models used for a different purpose to that originally intended, as it is for new untried models. Equally, don't get complacent with 'tried and tested' models where a new assumption set or style of data is being employed.
15. Be very careful if extremes are being modelled. Extremes often behave differently in terms of correlations (see point 10 above). Recurrence/combinations of extremes are more likely than intuition might suggest. Full historical data doesn't exist for 1 in 200 year events for example. This should not stop assumptions being made, in good faith, based on what does exist but it means the user should be aware of the real limitations on which the model is based.
16. Be cautious if outputs are expressed in terms of just differences or changes from an implied base or status quo. Outputs of just differences are often confusing and more liable to error and misunderstandings. Ensure that the absolutes (i.e. the base and the changed figures) are both also shown.
17. Check a range of outputs over multiple and extreme scenarios.
18. Check consistency between all elements of the model - inconsistency will often invalidate outputs.
19. Check comparability with previous runs of the model and understand how/why the outputs have changed.
20. Check that behavioural impacts caused by proposed changes for a population are modelled. It should always be assumed that a portion will act to reduce taxes/levies etc. and/or improve benefit take-up. Or add strong warnings if not modelled.
21. For models used to aid decisions on long-term benefit changes, ensure the projection does cover the long term – typically this requires at least one generation shift (i.e. 25-30 years) and often two generation shifts are needed to understand a real direction of travel.
22. A number of tools and techniques exist to assist risk analysis and modelling, for example, see the Appendix. Check which have been used and consider using some for validation.

Some techniques and tools used in risk analysis

STRESS TEST – What is the consequence (in terms of success or failure) of applying certain adverse assumptions?

REVERSE STRESS TEST – What are the assumptions which could deliver failure and how realistic are they?

HEAT MAPS – One- or two-dimensional charts (likelihood or impact v likelihood) to assist prioritisation and action

DEEP DIVE – Random selection of key issues to discuss at risk committee with thorough challenge

ERM (NARROW SENSE) – For financial institutions, target a metric such as economic value

'LESSONS LEARNED' – To ensure that potential failure events are fed back into risk analysis to ensure better future management and control

HORIZON SCANNING – Systematic mechanism to become aware of potential known and unknown unknowns which may start to create risks or hidden pressures

VAR (VALUE AT RISK) – A common technique in financial entities to look at losses at the unlikely end of the spectrum

RISK OPTIMISATION MODELS – To show which risks deliver acceptable value and which do not

'DELPHI' PROCESS – Use of 'collective intelligence', e.g. to derive overall risk exposure using copulas and fat-tailed distributions

PATTERN RECOGNITION – Systematic tracking of events to pinpoint emerging risks using pattern recognition techniques (including fuzzy pattern identification)

CONCEPT MAPPING* – Considers links between cause and effect through a single-page diagram of boxes and arrows to assist focus on where to manage/control

COGNITIVE MAPPING* – Similar to concept mapping with a more theoretical and detailed analysis

BAYESIAN NETWORKS* – A diagrammatical approach to cause and effect using experience-based probabilities on each element to identify distribution effects on risk outcomes

EVOLUTION/CLADISTICS* – Use of DNA/biometric techniques along with information theory to identify which variables/metrics to monitor and assign linkages to

PROJECTION MODELLING – To do scenario testing (for example)

ASSURANCE OF MODELS – To test against good practice on both outputs and communication

*NOTE – All of these enable proper assessments of risk dashboards – what should be shown and what combinations cause danger, relative to tipping position

ABOUT GAD

GAD provides actuarial analysis to the public sector from the public sector. Our aim is to be a highly valued principal provider of actuarial analysis and advice to all parts of the UK government and other relevant UK and overseas public bodies.

GAD is a Top Ten employer, coming 8th in the Sunday Times 'Best Places to Work in the Public Sector' in 2010.

Our services

Policy advice

- Pensions
- Demography
- Social Security
- Investment and risk
- Healthcare
- Long-term care

International

- Pensions
- Social Security
- Insurance

Public Sector Pension Schemes include

- Teachers
- Police/Fire
- Local Government
- Armed Forces
- Coal pensions
- UK Atomic Energy
- Staff transfers
- NHS
- MPs

Insurance

- Regulatory support
- Life and general

Contact details

Trevor Llanwarne Government Actuary	020 7211 2620
George Russell Deputy Government Actuary	020 7211 2666
Colin Wilson Technical Services Director	020 7211 2672

e-mail: firstname.lastname@gad.gov.uk

London office
Finlaison House
15-17 Furnival Street
London EC4A 1AB
Switchboard: + 44 (0)20 7211 2601
Email enquiries: enquiries@gad.gov.uk

Edinburgh office (from 4 January 2012)
Room T18
44 Drumsheugh Gardens
Edinburgh EH3 7SW
Email enquiries: enquiries@gad.gov.uk