Report on USS Pension Valuation

Working party on pension valuation

November 20, 2014

1 Executive summary

In response to a request from central College, a working group, containing expertise in Mathematical Finance, Statistics, Actuarial science and experience in decision making for large external pension funds, was drawn together from the Departments of Mathematics and Physics [1]. We have analysed the available data, created and investigated modelling scenarios and extracted historical data from College accounts.

The broad conclusions, that we shall justify within the main text and back up with detail in appendices, are that:

1. We are witnessing sensitivity of the actuarial model to basic key assumptions and not volatility of the deficit itself. We explore this by creating a model that contains the essential details and then demonstrate the sensitivity of actuarial valuations of (any) defined benefit scheme to assumptions about future discount rates driving assets performance and future liabilities variables (investment returns, salary increases, CPI, RPI). Any defined benefit pension scheme, not just the USS one, will behave similarly given the USS assumptions.

2. This sensitivity to actuarial assumptions then drives one to query whether the USS assumption are reasonable or overly pessimistic? Looking at past investment returns and past salary increases gives an indication of this. Some quite controversial assumptions have been made and we will go into detail regarding assumptions about gilts reversion on the asset side and general salary increases (without promotions) being RPI +1% on the liabilities side [1] page 26. The conclusion is that more scenarios should have been presented and a sensitivity analysis presented; crudely speaking one would expect confidence intervals, variance or error bars to give an indication of the range of estimates: Giving a single value as *the* deficit with a few alternatives based on past reports is insufficient to form an informed opinion. Indeed with a slightly different set of assumptions it is not difficult to produce a scheme in surplus. In Appendix B we show anonymised sensitivity studies taken from a different large pension scheme and the College must request similar data and studies.

3. Not enough evidence is shown about the actuarial models being applied in conjunction to key Macroeconomic and Mathematical Finance concepts. We would like to see a discussion on the possible effects of yields reversion on gilts and on the impact of current economic factors, such as Quantitative Easing (QE), on current assumptions. One further point worth more discussion is the consistency of the assumptions between the asset and liability sides. To have both assets growing slowly and liabilities growing rapidly requires evidence and justification based on fundamental factors of the economy to ensure that the stress tests are consistent and not biased.

2 Methodology and analyses undertaken

We shall be necessarily brief, and not turn this into an academic tome, where we feel detailed elaboration is necessary we put detail in appendices.

2.1 The model

We consider a basic model of a defined benefit pension fund (such as the USS) where we have stripped the model down to its essential and bare details. It is possible to add many layers of complexity, but that will simply obfuscate the messages.

We assume that fixed inflation adjusted yearly payments have to be made over 50 years from an asset base, which we assume to be £41.6bn as in the 2014 USS valuation. There are two parameters in this model: the rate

[1] See section 3.1 for membership

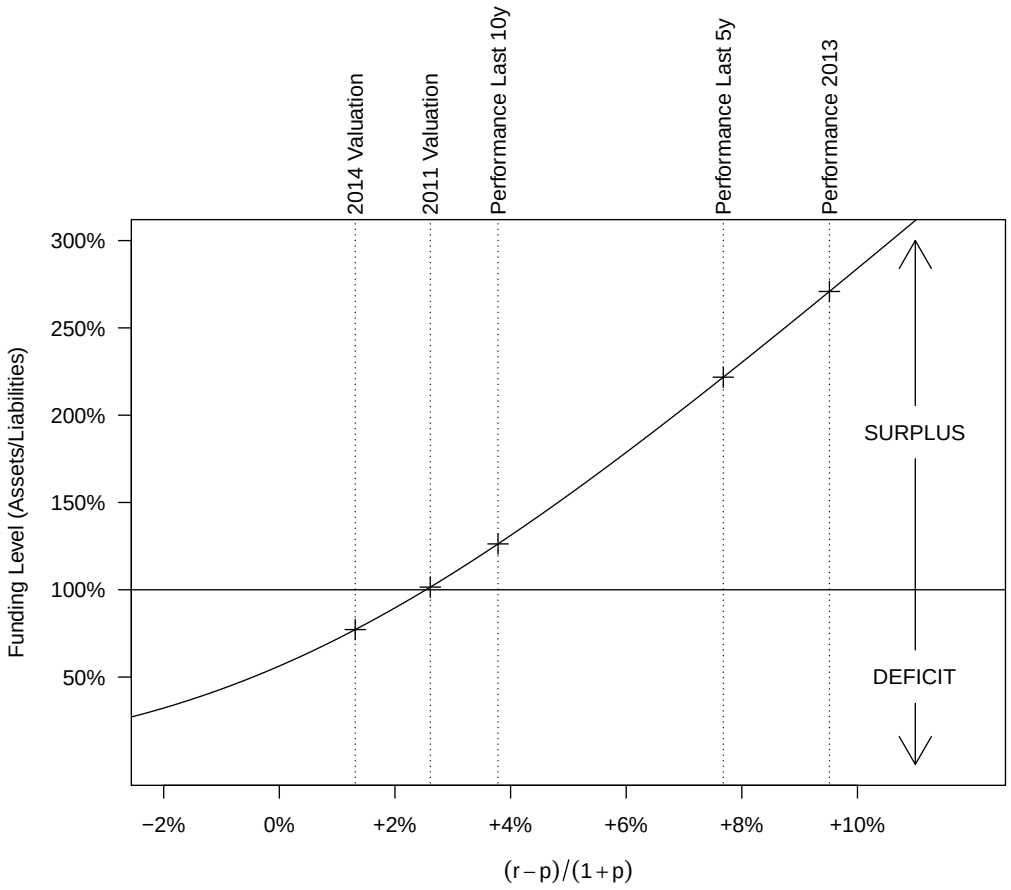


Figure 1: Funding levels under various inflation/return assumptions. Roughly speaking, if the investment returns outperform the RPI increases by at least 2.7 percentage points then the scheme is fully funded.

of inflation (p) and the investment returns (r). In the following we assume that the rate of inflation is given solely by RPI. Given this model we can then compute various scenarios and then compare them graphically: we do so, and the results are in Figure 1.

A key scenario, of course, is that of the 2014 USS valuation from [1]. The 2014 valuation assumes that returns in year 1 are 5.2% and then linearly decrease to 4.6% over 20 years and it assumes that RPI is 3.4% initially and then linearly increases to 3.5%.

The yearly payments of the model pension fund are set such that under the assumptions of the 2014 USS actuarial valuation the liabilities of the actuarial valuation (£53.9bn) are matched exactly. This results in yearly inflation adjusted payments of £1.477bn for the model pension fund.

Figure 1 shows funding levels of the model pension funds under several different scenarios concerning the inflation and investment returns. The scenarios are as follows.

- Assumptions of the 2011 USS actuarial valuation (r=6.1%, p=3.4%).
- Investment performance / inflation in 2004-2013 (r=7%, p=3.1%).
- Investment performance / inflation in 2009-2013 (r=11.2%, p=3.27%).
- Investment performance / inflation in 2013 (r=12.8%, p=2.3%).

Figure 1 shows that the model pension fund would be fully funded if the 2011 USS actuarial valuations had been used. If the investment performance over the last 10 years continued then the model pension fund would be over-funded (roughly by a similar amount as the 2014 USS actuarial valuation assumption would make it underfunded). If the performance over the last 5 years was to be assumed for future evaluations then the assets of the model would outstrip the liabilities by more than a factor of 2.

To validate our model we have investigated how the model reacts to sensitivities given in the 2014 USS actuarial valuation (using Table C.18, C.16 and C.5 from [1]) and our model matches these sensitivities closely; this is naturally reassuring in terms of our model. Therefore we are confident that the funding level of USS exhibits a similar sensitivity of the funding level to the inflation and investment return assumptions.

The detail of our model and further analysis is in Appendix A.

2.2 The need for sensitivity analysis

Given the outcomes from the stripped down model above it should be self-evident that the College should be provided with a far more comprehensive and coherent set of analyses.

To further emphasise this, reflection upon common practice in other related disciplines might be worthwhile. In oil and gas exploration analysis of sensitivity to a set of variables for multi-billion pound investments is common, and known as Probabilistic Prospect Evaluation. Here (typically 6 or more) variables are used, including reservoir volume, rock porosity, recovery factor etc. A Monte Carlo study is undertaken where, based on expert opinion or historical data, the variables are assigned distributions: e.g., probabilities constant over a range for some variables, triangular for others (defined by a most likely outcome and a possible range). The distributions are then sampled and the set of variable outcomes are used to calculate the resulting hydrocarbon volume. The process is repeated many times to produce a distribution of hydrocarbon volume, from which a median, confidence intervals, extremes etc are extracted for financial decision making.

Sensitivity analysis is also one of the cornerstones for risk analysis in finance. When analysing the risk of a trading book, one looks at the sensitivities of the book to a number of key risk factors to understand what drives the main risk for the portfolio. These may include equity prices, short and long term interest rates, credit spreads, volatility itself, commodity prices, foreign exchange rates, inflation, among many others. While sensitivity is not enough per se to provide a complete risk analysis, it is definitely an important component of the process. In finance one often combines sensitivity analysis with statistical analysis for the risk factors to come up with an overall risk measure for the potential portfolio losses over a future horizon. While such horizons are usually taken as shorter than in actuarial valuation, ranging from a few days to one year typically, sensitivity analysis remains an important component of the process that we feel should be more present in the risk assessment of the pension fund.

> *We submit that an exactly analogous procedure should be applied to the USS pension valuation based on variables such as investment returns, salary increases, CPI, RPI. The result would be much more informative than a single value based on just one possible scenario. Where, say two, variables are known to be correlated it would be a simple matter to use historical data to produce a joint distribution from which sampling can be carried out; this would prevent self-contradicting assumptions. This is, in fact, exactly what is done during a professional actuarial valuation and in Appendix B we show anonymised typical data projections of modelling taken from an actuarial report of a different large pension scheme and the College must request similar data and studies.*

2.3 Historical data regarding salaries

Some key pieces of information from [1] are reproduced below.

From page 9 of [1]: *The analysis of scheme experience over many years has been shared with Universities UK and University and College Union representatives to support the formation of a continuing long-term assumption for future increases. These data demonstrate that over the 20 year period to 2014, the general pay increase was equivalent to RPI. If we exclude the last three years, the general pay growth experience was RPI + 0.7% per annum. Annual analysis over the last few years indicates additional pay increases over and above the general pay growth assumption have been broadly in line with the age-related salary scale assumption used for the 2011 technical provisions basis.*

This is unfortunately "cherry-picking" the data. It is nonsensical to take a set of numbers, then throw away three particular ones that are disliked for some reason or other: this is exactly what we teach undergraduates not to do with a data set. Therefore the analysis based upon this opinion is open to challenge.

The report continues with *Having considered both the past and future outlook of salary increase data for USS members, and having engaged in substantial dialogue with stakeholder representatives, the trustee is minded to retain the 2011 salary increase assumption of RPI +1% per annum plus the age-related salary scale for this valuation.*

Clearly one could argue that inflating the salary estimate is fair given promotions etc, but later in the report it makes it very clear that the RPI +1% is actually the general increase and other salary escalation is taken into account separately. Thus this is being double counted. The extract from [1] page 26 elaborates upon this.

It has been assumed that general increases in salaries will be 1.0% per annum above the assumed RPI inflation assumption. In addition to the above general inflationary salary escalation allowance for further salary increases, over and above the sectors inflationary general pay growth, has been made by reference to an age-related scale.

Table 1: This is salary data drawn from a single representative Imperial College Department. It gives key historical data for the last 4 years normalised against 2010.

Year	Pay/FTE relative to 2010	CPI July	CPI relative to July 2010
13-14	1.057	125.8	1.1006
12-13	1.03	122.5	1.0717
11-12	1.008	119.4	1.045
10-11	1	114.3	1

In Table 1 we give actual historical data drawn from a single College Department showing that actually the salaries have risen, roughly, in line with CPI over the last four years. This table is open to criticism as it is just 4 years, and just a single Department, but given the timescales and the data involved we felt this real data was worth presenting.

To get historical depth we then collected together the annual pay awards versus RPI, CPI. Again this data can be criticised as actual staff pay rises can include, for instance, promotion. Nonetheless it is instructive to see the data and that assuming salary rises continually above RPI would seem somewhat inaccurate when one reflects upon this historically. It is notable that the College has consistently recognised the local increased costs of London and has always matched or exceeded the National award. This is not a report on salary rises and the purpose is not to tangentially approach this topic, simply to point out that stating implicitly that RPI +1% historically is dubious and dangerous as a precedent for the future.

Table 2: This table captures useful background historical data of relevance regarding pay (source Office of National Statistics & Imperial College HR). Some pay data is complicated by awards that involved fixed amounts or percentages and those years are indicated by $*$ and we omitted the fixed amount.

Year	2001	2002	2003	2004	2005	2006	2007
IC Award	3.0	1.0/3.2	3.44	3.5	3.4	3.0*	1.2/3.0
UK Award	3.0	1.0/3.2	3.44	3.0	3.0	3.0*	1.0/3.0
RPI	0.7	2.9	2.8	3.5	2.2	4.4	4.0
CPI	1.1	1.7	1.2	1.6	1.9	3.0	2.1
Year	2008	2009	2010	2011	2012	2013	2014
IC Award	3.0/5.0	0.5	0.5	2.0*	1.0*	2.0	2.0
UK Award	3.0*/ 5.0	0.5	0.4	£150	1.0	1.0	2.0
RPI	0.9	2.4	4.8	4.8	3.1	2.7	(2.3)
CPI	3.1	2.8	3.7	4.2	2.7	2.0	(1.3)

We conclude that the salary assumptions of RPI +1% within the USS valuation must be vigorously challenged. Accepting this as an implicit assumption within the model will lead to never-ending industrial discord as every future wage negotiation will have this as the starting position of Union and staff negotiators. The argument will go that the employers cannot have it both ways: An assumption of RPI +1% for the pension, and then make offers of RPI or less. It should clearly be consistent between real salaries and pension assumptions and so it is dangerous to accept this assumption.

2.4 Macroeconomic details and Financial assets

Probably the most important issue in the valuation is related to the discount rate as it has the most power to drastically alter the value of liabilities with small changes in its value. In effect we can see this through the model presented earlier.

Usually one discounts liabilities at the assets return rate, and this is common practice in pension funds. The 2014 Actuarial report [1] states that

In particular the initial discount rate for the proposed technical provisions basis is assumed to be gilts +1.7% compared to the best estimate return from the current investment strategy of gilts +2.75% per annum. Over a 20 year period the trustee will reduce investment risk, and there will be a corresponding reduction in the discount

rate, it is therefore appropriate to allow for the same reduction in investment risk in the neutral assumptions. The schemes actuary has therefore assumed that, for the current benefit structure, the neutral assumptions use a discount rate of gilts +2.75% in year one declining linearly to gilts +1.75% per annum over a 20 year period.

The Gilts yield curve is one of the key risk drivers of the strategy. The actuarial report [1] states that, for prudence, the current yield is lowered from 2.75% to 1.7%. It also says that since there is a de-risking strategy in place where equity investments will be switched to bonds, a lowered return is expected and therefore the already lowered 1.7% is assumed to yet further lower to 1.1% in 20 years:

Based on the above approach, if the current benefit structure were to be maintained going forwards, the trustee would seek to gradually reduce the discount rate (and correspondingly the inflation risk premium) to a level which equates to gilts +1.1% per annum, over a 20 year period. For the 2014 formal valuation, based on the current benefit structure, this means the trustee will adopt: A discount rate of gilts +1.7% per annum in year one, reducing linearly (for the purposes of the valuation calculations) to gilts +1.1% per annum in year 20 and beyond

Crucially, there is evidence that the current Quantitative Easing plan that the Bank of England, and other developed nations, have embarked upon is keeping Gilt yields artificially low. See for example [3], that shows evidence on how even the mere announcement of QE has had an important impact on Gilts yields. The Bank of England report [4] states that

There is a broad range of evidence that suggests that QE did reduce gilt yields and boost other asset prices.

It is therefore to be expected that current Gilt yields may be artificially low compared to other asset classes involved in the de-risking strategy. If yields go back to higher levels once QE ends, as is expected, the discount factors will lower and the predicted deficit value can be reduced importantly, or even cured over time.

> *The assumption on Gilt yields needs to be supported by detailed economic analysis and must be discussed in far more depth before being accepted, especially in connection with current exceptional economic conditions. From the model presented earlier we see that a change in the discount rate (equivalently increases in the returns) has a dramatic effect. We invite a more in depth analysis on the above points and a related discussion before any decision is made.*

3 Recommendations

Our analysis leads us to conclude that the valuation of the deficit is potentially flawed and that certainly further work is required to answer the points made in the executive summary. To conclude:

1. What is required from the USS is that they present a range of scenarios, and carefully justify any key assumptions made, both in terms of macroeconomics and in modelling terms. We have discussed, of necessity briefly, specific scenarios within this report, and demonstrated sensitivity and precedent for the chosen scenarios, and we would expect a professional valuation to do likewise. At present the analysis seems crude at best, we would be interested (and surprised) to see analysis that refutes any of the points we have made. Appendix B shows some typical data projections of modelling taken from an actuarial report of a different large pension scheme, the USS must have undertaken similar modelling and the College must request access to the actual actuarial reports.

2. The salary assumptions of RPI +1% within the USS valuation must be vigorously challenged. Accepting this as an implicit assumption within the model will lead to never-ending industrial discord as every future wage negotiation will have this as the starting position of Union and staff negotiators. The argument will go that the employers cannot have it both ways: An assumption of RPI +1% for the pension, and then make offers of RPI or less. It should clearly be consistent between real salaries and pension assumptions and so it is dangerous to accept this assumption.

Much of this report, doubtless, has a negative tone. However, we conclude with a notable piece of good news: the pension fund is apparently being managed well with the assets growing above market averages. We show the asset change in table 3. One notable fact is that, in order to create the asset change value used for the USS valuation you need to go back to 2001 and 2002 to include those negative values in order to get the average down towards the 5.2%, dropping to 4.6 %, the value used within the valuation.

To conclude we summarise three possible scenarios:

- The USS scenario from the valuation which gives a deficit of £12.3 Bn.

Table 3: USS asset returns drawn from the annual USS valuations.

Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
% increase	-10.1	-16.7	18.2	8.9	24.0	9.9	7.5	-27.2	20.7	11.7	0.32	11.4	12.8

- A calculation using the 2011 assumptions which gives essentially a break-even position.
- A scenario that using the averages from the last 10 yrs for which the scheme is actually predicted in surplus by £8.7 Bn.

All are plausible and there is no need to rush into one scenario or another without further analysis.

3.1 Membership of the working group

This report was prepared for Imperial College London by an internal working party primarily drawn from the Mathematics Department:

Damiano Brigo: Professor of Mathematical Finance, co-Head of Mathematical Finance, and formerly Managing Director at Fitch Ratings (a global rating agency).
Richard Craster: Head of Mathematics Department and Professor of Applied Mathematics
Axel Gandy: Reader in Statistics with expertise in Statistics in Finance, Reliability and Computational Statistics
Jordan Nash: Head of Physics Department and Professor of Physics with experience of pension schemes elsewhere.
Andrew Walden: Professor of Statistics with expertise in Time Series and formerly with BP in a group advising upon predictive decision making.

3.2 Distribution list

This report is designed to provide key technical information and analysis to inform College opinion and strategy. It is currently not for open distribution.

Distribute to: Tony Lawrence (Director of Financial Management), Louise Lindsay (Head of HR), Muir Sanderson (CFO), James Stirling (Provost).

References

[1] Universities Superannuation Scheme 2014 Actuarial Valuation, October 2014

[2] Proposed changes to USS - Myths, Misconceptions and Misunderstandings, Employers Pensions Forum for Higher Education

[3] Jens H.E. Christensen, and Glenn D. Rudebusch (2012). The Response of Interest Rates to U.S. and U.K. Quantitative Easing, Federal Reserve Bank of San Francisco technical paper.

[4] Nick Butt, Rohan Churm, Michael McMahon, Arpad Morotz and Jochen Schanz (2014). QE and the bank lending channel in the United Kingdom. Working Paper No. 511, Bank of England.

Appendix A Illustration of sensititivies through a stripped-down model

The purpose of this annex is to illustrate the extreme sensitivity of the funding levels on the assumed discount factors (salary increases, returns on investments). This can be done using a basic model that is stripped back to incorporate the major essential components; this could be elaborated upon in many ways, but the point here is to illustrate key concepts. Indeed were we to have the actual data from the USS (which was requested but were told there were IP issues and issues regarding data sharing) regarding the pension scheme we could, given sufficient time, model it in-house.

A.1 The model

Suppose we have to pay $£x$ (adjusted by salary increases) every year for 50 years. Suppose that these payments get inflated every year by p% (through inflation adjustment, pay rises, etc). For simplicity, assume p is given by the retail price index (RPI). Then the payout needed in year $t = 1, \dots, 50$ is

$$£x(1 + p/100)^t$$

This has to be funded through the assets of the scheme which we assume to have a return of $r_i\%, i = 1, \dots, 50$ in year i. So, to cover the payment in year t we need

$$£x \prod_{i=1}^{t} \frac{1 + p/100}{1 + r_i/100}$$

of assets now. So the total liabilities at time 0 in this model are

$$L = £x \sum_{t=1}^{50} \prod_{i=1}^{t} \frac{1 + p/100}{1 + r_i/100}$$

The yearly payments $£x$ have been calibrated to match the 2014 actuarial valuation under its assumption (which calculated the liabilities to be £53.9bn). This results in $x = 1.477bn$.

Suppose that the available assets A are $41.6bn$ (as in the USS evaluaion). Then the funding level is

$$A/L.$$

A.2 Sensititivity of the model

Table 4 displays various combinations of the funding levels resulting from various assumptions about the salary increases and the returns of the investments.

	3.45%(2014)	3.35%	3.4%(2011)	3.1%(past 10y)	3.27%(past 5y)	2.3%(RPI)
Valuation 2014	77.2	78.9	78.3	83.6	80.6	98.9
Val 2014 Initial Increase 0.25%	78.8	80.5	79.9	85.3	82.2	100.8
Val 2014 20y Increase 0.25%	79.9	81.7	81.0	86.4	83.3	101.9
Neutral Valuation (2014)	91.5	93.5	92.7	98.6	95.2	115.5
6.1% (2011)	100.3	102.3	101.5	107.6	104.1	124.8
7% (past 10y)	118.4	120.6	119.7	126.3	122.5	144.7
11% (past 5y)	216.9	219.6	218.2	226.4	221.8	248.9
12.8% (2013 perforamnce)	258.1	261.0	259.4	268.0	263.1	291.3

Table 4: Funding levels of the toy model under various scenarios; rows: investment returns; columns: pay increments

Importantly, if the average investment performance of the USS over the last 5 or 10 years is used and if the average RPI increase in that period is used (see the USS investment report 2014) then the model would be significantly in surplus.

A.3 Validation of the model

Several of the above scenarios correspond to scenarios of the 2014 USS actuarial valuation (see p.14, C.5, C.16, and C.18 of the Actuarial Valuation 2014). Table 5 compares these to the funding levels obtained through the model.

	3.45%(2014)	3.35%	3.4%(2011)
Valuation 2014	77.2 (77.2)	78.9 (79)	
Val 2014 Initial Increase 0.25%	78.8 (79)		
Val 2014 20y Increase 0.25%	79.9 (80.1)		
Neutral Valuation (2014)	91.5 (92.9)		
6.1% (2011)			101.5 (101.4)

Table 5: Validation of the Toy Model: Funding levels of toy model and, in brackets, funding levels of the corresponding USS actuarial valuation; rows: investment returns; columns: pay increments

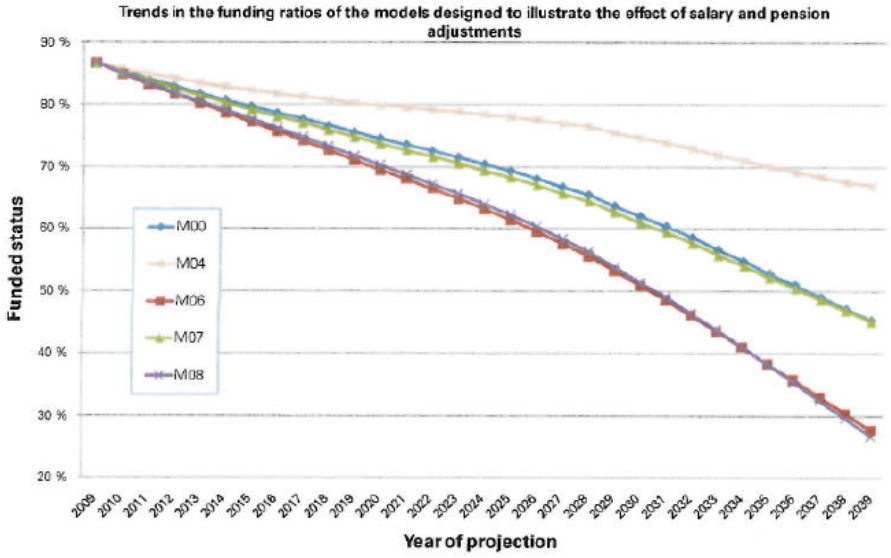
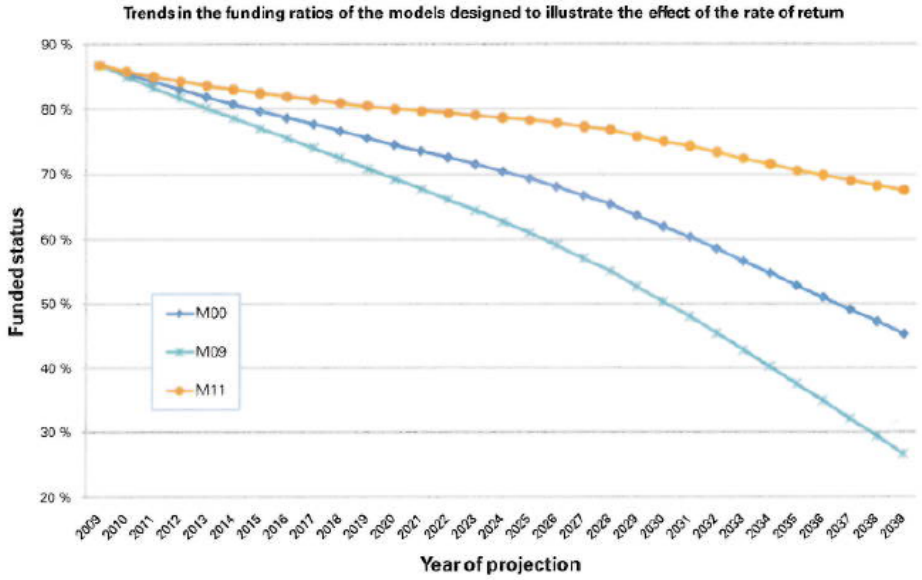


Figure 2: Funding predictions of the external pension fund for several models for varying values for salary and pension liabilities

The funding level of the 2014 valuation is of course identical to the corresponding funding level in Table 4 due to calibration. In the other scenarios, the model comes up with almost exactly the same funding level as the actuarial valuation. The neutral valuation also includes other more favourable assumptions than the default 2014 valuation (which we do not take into account in the model) - so it is not surprising that the model comes up with a worse funding level than the actuarial evaluation.

Appendix B Examples of sensitivity analysis from another pension fund actuarial report

It is best practice for actuarial reports on pension funds to contain the projections for a variety of models and discussion of the sensitivity of the projections for each of the assumptions. We assume that the USS trustees should have seen such models, and suggest that the college try and obtain these for a more complete understanding of the sensitivity of the fund to more than the one set of assumptions given in the report. We present a couple of examples of such projections taken from the actuarial analysis of a large international pension fund in figures 2, 3. The report these are taken from contains the analysis of more than 30 different models varying the major input parameters, and a discussion of the sensitivities of the projections to the assumptions. These are then used by the pension fund's governing body to establish what actions to take on the fund.



The above graph reveals that the return on assets is a decisive factor in the trend in the funding ratio of the Fund. Its impact is much greater than that of the contribution rate, as can be seen in the graph below.

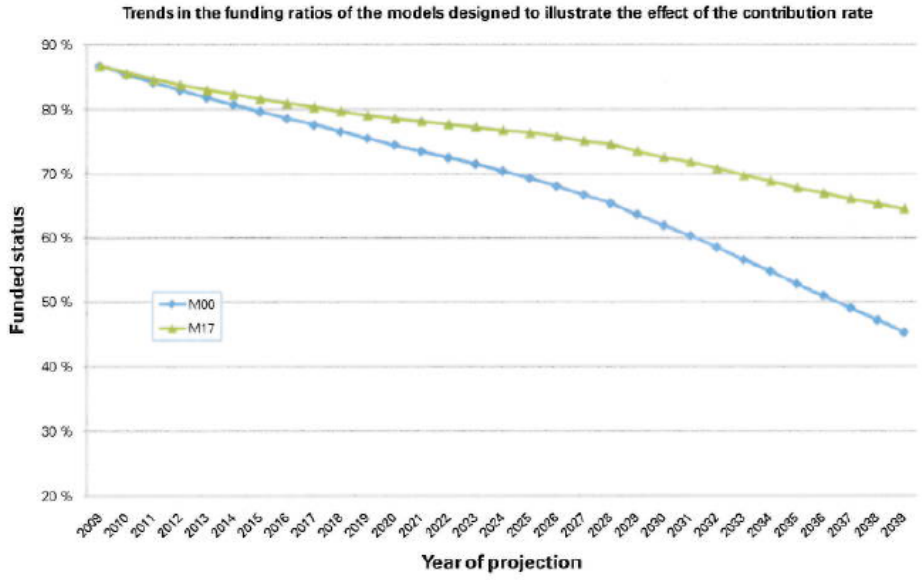


Figure 3: Example of graphs showing the actuarial predictions for the external fund with varying assumptions on the fund return and the employee contribution rate