

Institution: King's College London		
Unit of Assessment: 10 Mathematical Sciences		
Title of case study: Stochastic modelling of pension assets and liabilities influences UK Government's pension policies, and the work of financial institutions and charities		
Period when the underpinning research was undertaken: 2012 - 2020		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s): Teemu Pennanen John Armstrong	Role(s) (e.g. job title): Professor of Financial Mathematics Senior Lecturer in Financial Mathematics	Period(s) employed by submitting HEI: From 24/10/2011 From 01/09/2012
Period when the claimed impact occurred: 2015 – 2020		
Is this case study continued from a case study submitted in 2014? N		
<p>1. Summary of the impact (indicative maximum 100 words)</p> <p>The Financial Mathematics (FM) group at King's College London has developed mathematical and computational simulation tools to quantify the financial risks associated with long-term pensions liabilities. Building on this research, the Pensions Policy Institute (PPI, an independent research charity) has collaborated with the FM group to develop statistical simulation models for risk analysis of UK pensions schemes. The models have been used by PPI in their research and publications, and have been central to pensions policy debate and development in the UK. Most significantly, these models have been used by the UK Government's Department of Work and Pensions to further develop and rollout the auto-enrolment pension scheme, which has been highly successful in increasing the uptake of workplace pensions in the UK. Further impacts have included strengthening the campaigning work of the charity network Age UK, and raising the profile of global asset management group Columbia Threadneedle Investments. This modelling has also contributed to the preservation of the auto-enrolment scheme through the COVID-19 pandemic.</p>		
<p>2. Underpinning research (indicative maximum 500 words)</p> <p>The most important task of a pension fund or a scheme is to manage their investments so that the future returns cover the pension liabilities as well as possible according to a given measure of risk. This is a challenging task as both assets and liabilities are subject to significant uncertainties that affect the financial position of the schemes in the long run. The King's Financial Mathematics group, led by Teemu Pennanen, has developed mathematical and computational techniques for asset liability management (ALM) and liability valuation applicable to such settings. As opposed to the commonly used actuarial techniques, the ALM-approach puts asset allocation and liability valuations under a single risk management framework that describes the whole balance sheet of a fund and takes into account all the relevant risks. The mathematical foundations underpinning the techniques are described in a general illiquid market setting in [R2]. Numerical study of how to adapt investment strategies to pension liabilities are presented in [R4].</p> <p>Stochastic modelling of pension assets and liabilities Mathematical ALM-models build on a probabilistic description of the relevant financial risk factors that affect future liability cashflows and investment returns in different asset classes. In a typical pension fund, one can easily identify thousands of such risk factors, which poses a challenge for quantitative analysis. Pennanen and co-authors have developed models that allow for significant reductions in the number of risk factors while still capturing the main distributional properties of asset returns and liability payments.</p> <p>Longevity and the economy On the liability side, the most important sources of uncertainty are longevity, and price and wage inflation that are often used in indexation (adjustment) of defined benefit pensions. There</p>		

are also other macroeconomic risk factors, such as the gross domestic product (GDP), that may affect investment returns or liabilities indirectly. Indeed, it was found in [R5] that GDP has an effect on old age mortality over longer periods of time. GDP affects pension liabilities also through inflation which is often used in indexation of the benefits. GDP has statistically significant connections not only with inflation but also with many other factors that affect investment returns [R1].

Investment returns on large bond portfolios

Bond portfolios are subject to a large number of risk factors. Even in the case of fixed-rate government bonds, portfolio returns depend, in general, on the whole yield curve. Bond returns can also be described in terms of yield to maturity, which reduces return uncertainty to a single portfolio-specific factor. Such simple descriptions are easy to analyse statistically and they are particularly convenient in the asset liability management of complex pension funds. Pennanen and Koivu [R3] extended the approach to more general classes of bonds including inflation-linked bonds and corporate bonds that are extensively used by pension funds to hedge the inflation risk inherent in most pension liabilities and to take advantage of the higher return expectations of corporate bonds.

A grand unification

The development of comprehensive ALM-simulation models that describe investment and longevity risks is a nontrivial task that requires expertise in economics and statistics as well as numerical analysis and computer science. The recent article [R1] describes a general approach that combines the above reduced-form models for longevity and bonds into a stochastic simulation model. All the risk factors are modelled as a multivariate stochastic process that captures the dynamics and the dependencies across different risk factors. The model is easy to interpret and to calibrate to both historical data and to forecasts or expert views concerning the future. The simple structure of the model allows for efficient computations: a million scenarios can be constructed in a few minutes on a personal computer.

These models have been implemented in the R and Python programming languages into **Economic Scenario Generators (ESG)** that allow for efficient numerical analysis of financial risks. King's developed the first version of the ESG for PPI in 2013 and has since updated it with several new features based on further research. The latest updates to the ESG were done in July 2020 to account for the effects of the pandemic.

3. References to the research (indicative maximum of six references)

[R1] Stochastic modelling of assets and liabilities with mortality risk, Alvares Rodrigues Souza Maffra, S., Armstrong, J. & Pennanen, T., 8 Feb 2021, <https://arxiv.org/abs/2005.09974>; (Accepted/In press In: Scandinavian Actuarial Journal)

[R2] Optimal investment and contingent claim valuation in illiquid markets, Pennanen, T., 1 Aug 2014, In: Finance and Stochastics. 18, 4, p. 733-754; DOI:10.1007/s00780-014-0240-0

[R3] Return dynamics of index linked bond portfolios, Koivu, M. & Pennanen, T., 2014, In: Journal of Portfolio Management. 41, 1, p. 78-84; DOI:10.3905/jpm.2014.41.1.078

[R4] Liability-driven investment in longevity risk management, Aro, H. & Pennanen, T., 18 Oct 2016, International Series in Operations Research & Management Science. Vol. 245. p. 121-136 (International Series in Operations Research and Management Science; vol. 245); DOI:10.1007/978-3-319-41613-7_5

[R5] Stochastic modelling of mortality and financial markets, Aro, H. & Pennanen, T., 2012, In: Scandinavian Actuarial Journal. 3 Dec 2012, p. 483-509; DOI:10.1080/03461238.2012.724442

4. Details of the impact (indicative maximum 750 words)

The Financial Mathematics group at King's collaborates with the Pensions Policy Institute (PPI) on developing statistical simulation models for risk analysis of UK pensions schemes. The models have been used extensively by PPI in their research and publications. This in turn has informed and influenced other organisations. Key examples include impacts on financial firm Columbia Threadneedle Investments, whose thought leadership in the pensions landscape has

been enhanced by drawing on these models, and on campaigning charity Age UK, whose lobbying activities have been strengthened by the models. Most significantly, these models have been used in major policy development work by the UK government Department of Work and Pensions (DWP), including the highly successful auto-enrolment pensions scheme which has resulted in more than 10,000,000 new eligible employees participating in the workplace pension in the UK [S7].

Key impact pathway: the Pensions Policy Institute (PPI)

The PPI is an independent research charity that was established in 2001. PPI produces a large number of research reports on a variety of pension related topics which it uses to inform policy and policy debates by providing evidence-based research about the pensions landscape.

The Economic Scenario Generator (ESG), based on King's research [R1-R5], has been key component of PPI reports and modelling since it was first used in the Automatic Enrolment study published in 2013 [S8d]. It is used in the PPI's key models such as their Individual Model, which models the retirement income of individuals, and the Aggregate Model, which projects government expenditure on pensions [S2]. Over the last three years alone the PPI has used these pension models in 35% of its published research reports [S1, p.5]. In addition, there has been significant usage of the models in its production of briefing notes. Significant recent examples include the 2017 report that explores the role that behavioural techniques play alongside other policy levers to help people achieve better long-term saving outcomes [S9f], the 2019 report showing that women have around 28% lower pensions savings and income than men [S8a], and the September 2020 briefing note on proposed changes to the state pension scheme resulting from the Covid-19 pandemic [S8b].

Since 2013, the PPI has had regular interactions with DWP ministers and officials and share all their work with a range of politicians, civil servants and key policy stakeholders [S3]. Several PPI reports, underpinned by the ESG, were also sponsored by the DWP to look at how to best develop and roll out the Auto Enrolment pension scheme and to look at a potential CDC scheme under different assumptions to determine whether CDC produces better results compared to DC and in what circumstances [S2]. In conjunction with the release of research reports, PPI runs awareness-raising and information events (46 since 2015) which are well attended by the pensions industry [S1 p.27]. According to testimonial from a senior policy manager of Age UK, the PPI reports and events have been a key pathway to developing greater understanding of pensions issues among policymakers and other stakeholders in the UK [S5].

Informing the Department of Work and Pensions' policy development work

PPI's publications using the ESG has formed an integral part of the evidence base DWP used for developing the automatic enrolment pension policy. In particular, DWP's 2017 Automatic Enrolment Review [S10a] builds conclusions based on evidence from the PPI report *Consumer engagement: the role of policy through the life course (2017)* [S9f], the modelling in which uses the ESG. The DWP's 2019 Automatic Enrolment Review [S10c] also references another PPI report *Policies for increasing long-term saving of the self-employed (2017)* [S9g], which again uses the ESG for its modelling. [S3]

Other examples of PPI work based on the ESG shared and used by the DWP include: Automatic Enrolment Report 2: The benefits of automatic enrolment and workplace pensions for older workers (2014) [S9a]; Automatic Enrolment Report 3: How will automatic enrolment affect pension saving? (2014) [S9b]; Briefing note 105: The impact of the introduction of automatic enrolment on future generations (2018) [S9c]; Automatic enrolment in the gig economy: modelling for Zurich (2018) [S9d]; Increasing Savings in Automatic Enrolment: Analysis Sponsored by Which? (2019) [S9e]. [S3]

Between 2016 – 2019, several of the ESG based PPI reports were cited in Parliamentary debates as evidence [S3, p.2], and the 2015 report Modelling Collective Defined Contribution Schemes [S8c] was also referenced by the House of Commons Work and Pensions Committee in 2018 and fed into their recommendations [S10b]. The PPI models, underpinned by ESG, were also used by DWP when assessing pensions schemes for the self-employed [S1 p.9]. Information presented in the DC Future Book (an annual PPI publication) and the 2019

research report on Pension Charging Structures and Beyond, both of which used the ESG, has also been used by the DWP to inform their policy development [S4].

“The team at DWP have used the results from the King’s College financial mathematics department’s stochastic model for pensions and investments to inform policy development. [For example] the forecasts of Defined Contribution scheme assets up until 2039 have been especially useful for informing our evidence base and supporting longer term policy thinking. The Pensions Charges Survey for 2020 has been compiled with reference to the outputs from the models that were presented in the Pension Charging Structures and Beyond report on the median impact of various charging structures on fund values.” - Joint Heads of Private Pensions Analysis, Department of Work and Pensions [S4]

Strengthening pensions campaigning in the charity sector: Age UK

Age UK is a leading UK-wide charity network dedicated to helping people in later life. As well as helping older people directly, it also campaigns and lobbies the government and the pensions industry on various issues around the economic and social well-being of the elderly population in the UK. It regularly draws on PPI publications based on the King’s research: this has guided and informed Age UK’s campaigning work and policy decisions. [S5]

Age UK also commissioned research in 2019 from PPI, underpinned by the King’s models, with the goal of understanding the pensions landscape and forecasting its future, obtaining data and statistical backing for policy arguments and campaigning:

“This modelling project, like the previous Age-UK-commissioned modelling projects around the State Pension Age and Triple Lock, has delivered on its goal. As evidenced by the Triple Lock modelling, the findings of these analyses can be useful years after they are conducted. Age UK continues to use the State Pension Age related data for current arguments being put to the government. It also still considers the projections on how many pensioners will be left in poverty if the Triple Lock is removed while making policy decisions.

Such use of the PPI’s work also helps lay the foundations of an evidence-based way of making pensions policy. This has had significant demonstrable impact on protecting certain useful policies such as auto-enrolment in difficult times such as this present COVID-19 pandemic when businesses are leaning towards suspending auto-enrolment to save money.” - Senior Policy Manager, Age UK [S5]

These examples illustrate the centrality of the PPI’s modelling to pensions policy in the UK: modelling which is underpinned by the research of the King’s FM group.

Raising the profile of Columbia Threadneedle Investments

The DC Future Book, underpinned by the ESG model, is an annual statistical compendium and review which has been published by the PPI since 2015. The focus is on the Direct Contribution (DC) pensions market. The latest edition was published in September 2019 and was sponsored by Columbia Threadneedle Investments (CTI), a global asset management group which manages investments totalling GBP385,000,000 for individual investors, financial advisers and wealth managers, as well as insurance firms, pension funds and other institutions. The aim of the publication is to promote a better understanding of the DC pensions market in the UK.

The Future Book uses the ESG pension model to forecast the DC pensions landscape. This analysis is complemented by the publication of articles and thought pieces which aim to increase stakeholder engagement from policy makers, regulators, activists, and pension scheme trustees. [S1 p.9]

“The profile of CTI has risen dramatically as a consequence of its association with The DC Future Book - CTI now being recognised as a genuine thought leader in the DC space. Moreover, The DC Future Book continues to influence and assist CTI’s thinking around how DC pension savers and investors might achieve better outcomes and has

allowed us to gain traction with both policymakers and regulators. The models are a dominant feature of The DC Future Book and they will continue to be so.

“Without exaggeration, The DC Future Book itself has been a catalyst for change in the pensions industry and remains a unique publication. Crucially, the independence of the PPI has driven much of the success of the publication. Although The DC Future Book has a significantly higher profile than the models themselves, it is important to state that the pensions models are integral to the publication and everything that it seeks to achieve.” - Head of Pensions and Investment Education, Columbia Threadneedle Investments [S6]

5. Sources to corroborate the impact (indicative maximum of 10 references)

[S1] Evaluation report: [Stochastic Modelling of Pension Assets and Liabilities \(Impact Science, 2020\)](#)

[S2] Testimonial from Director, Pensions Policy Institute

[S3] Testimonial from Head of Policy research, Pensions Policy Institute

[S4] Testimonial from Joint Heads of Private Pensions Analysis, Department of Work and Pensions

[S5] Testimonial from Senior Policy Manager, Age UK

[S6] Testimonial from Head of Pensions and Investment Education, Columbia Threadneedle Investments

[S7] [The Guardian – Watchdog hails success of auto-enrolment pensions](#) (24 October 2019)

[S8] PPI reports using ESG:

[a] [PPI Briefing Note 114: The gender pensions gap – Can it be closed?](#) (6 June 2019)

[b] [PPI Briefing Note 123: What does COVID-19 mean for the triple lock and State Pension inflation?](#) (8 September 2020)

[c] [PPI Report - Modelling Collective Defined Contribution Schemes](#) (1 November 2015)

[d] [PPI Report - Automatic Enrolment Report 1: What level of pension contribution is needed to obtain an adequate retirement income?](#) (22 October 2013)

[S9] PPI reports based on the ESG and used by the DWP for developing the auto-enrolment pension policy:

[a] [PPI Report - Automatic Enrolment Report 2: The benefits of automatic enrolment and workplace pensions for older workers](#) (20 May 2014)

[b] [PPI Report - Automatic Enrolment Report 3: How will automatic enrolment affect pension saving?](#) (17 July 2014)

[c] [PPI Briefing Note 105: The impact of the introduction of automatic enrolment on future generations](#) (8 February 2018)

[d] [PPI Report - Automatic enrolment in the gig economy: modelling for Zurich](#) (21 February 2018)

[e] [PPI Report - Increasing savings in automatic enrolment: analysis sponsored by Which?](#) (3 June 2019)

[f] [PPI Report - Consumer engagement: the role of policy through the lifecycle](#) (19 July 2017)

[g] [PPI Report - Policies for increasing long-term saving of the self-employed](#) (2 October 2017)

[S10] DWP publications and auto-enrolment reviews citing PPI's work based on the ESG:

[a] [Automatic Enrolment Review 2017: Analytical Report](#) (December 2017)

[b] [House of Commons, Work and Pensions Committee - Collective defined contribution pensions, Sixteenth Report of Session 2017–19](#) (11 July 2018)

[c] [Automatic Enrolment evaluation report 2019](#) (12 May 2020)