Collective Pensions with Investment Choice:

Making CDC work for the UK

November 2025

About this project

The Project

Collective Pensions with Investment Choice: Making CDC work for the UK is a collaborative project between The Pensions Policy Institute (PPI) and King's College London (KCL) which has been funded over two years by The Nuffield Foundation. The research undertaken investigates the implications of how Collective Defined Contribution (CDC) is envisioned to work in the UK.

CDC has recently moved from theory to practice in the UK, with Royal Mail launching the country's first single-employer CDC scheme in late 2024. At a time when Defined Benefit (DB) provision continues to decline and concerns persist about the adequacy of Defined Contribution (DC) pensions, CDC offers a potential third way: combining the prospect of higher returns and protection against longevity risk for members, while remaining manageable for employers.

The groundwork for CDC has already been established through existing and proposed legislation, giving a strong sense of how such schemes must operate. Yet, the current framework for single-employer CDC leaves significant design choices in the hands of scheme architects, and many anticipate that the longer-term future of CDC in the UK is more likely to lie in multi-employer models, an area where legislation has not yet been developed.

This project explores the implications of the UK's approach to CDC, modelling outcomes for both single- and multi-employer schemes, and examining the consequences of different design decisions. Key issues such as fairness, cross-subsidy, and investment choice have been considered, alongside potential solutions for delivering sustainable CDC schemes.

This report brings together the findings of the research project. All publications in the series can be found here.

About King's College London (KCL)

King's College London is a leading UK research university, founded by Royal Charter in 1829.

About the Pensions Policy Institute (PPI)

The Pensions Policy Institute (PPI) is the UK's leading independent authority on pensions and retirement policy. We conduct rigorous, impartial research to inform major policy decisions affecting millions of people's retirement security. Our evidence-based analysis is used by government and across Westminster – as well as industry and consumer groups - with extensive media coverage bolstering understanding of complex pension issues. Our work ensures that policymakers have the unbiased analysis needed to deliver better outcomes for those they serve.

While PPI analysis has informed this research, its role here is to highlight the trade-offs inherent in different policy choices, not to advocate for specific outcomes. The recommendations presented in this paper, while based on PPI analysis, do not represent the views of the Pensions Policy Institute (PPI).

About The Nuffield Foundation

The Nuffield Foundation is an independent charitable trust with a mission to advance social well-being. It funds research that informs social policy, primarily in Education, Welfare, and Justice. The Nuffield Foundation is the founder and co-funder of the Nuffield Council on Bioethics, the Ada Lovelace Institute and the Nuffield Family Justice Observatory. The Foundation has funded this project, but the views expressed are those of the authors and not necessarily the Foundation.

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Executive Summary

This report examines the effectiveness of collective pension scheme approaches that have been designed to meet the needs of UK pension savers. Underpinning this report, we have conducted quantitative analysis of the effectiveness of different approaches, qualitative research on the appetite for new products and barriers to implementation, as well as fundamental mathematical research into the economic principles underpinning collective investment.

An optimal CDC scheme design can deliver significantly better benefit outcomes than a conventional DC arrangement

Our key finding is that one collective pension design, which we call *collective drawdown*, can provide benefit outcomes approximately equivalent to investing 75% more money into a traditional Defined Contribution (DC) scheme followed by full annuitisation at retirement. This figure should be seen as indicative. Pension investments take place over long time horizons, and a difference of only 0.5% in returns can compound to a 22% difference over 40 years, which means that any projections will be highly sensitive to the investment assumptions. This estimate includes a penalty for risk and assumes that both the schemes are pursuing their optimal investment strategies. A precise description of how we adjusted for risk is given in Chapter 4 of the report.

A member of a DC scheme does not have to spend all their pension pot on an annuity at retirement. A more sophisticated strategy is a "*flex-then-fix*" strategy where one combines drawdown and gradual annuitisation in tranches. In our simulations, collective drawdown outperforms an optimised *flex-then-fix* design by 22%. Again the figure 22% should be seen as indicative. However, we have also shown mathematically why the collective drawdown design should be expected to outperform any other collective pension design, so this aspect of our findings is robust under a broad range of modelling assumptions.

In addition to these quantitative benefits, collective drawdown enjoys several other advantages over alternative Collective Defined Contribution (CDC) approaches. It allows scheme designers to give members some choice over the investment strategy. This improves the performance of the scheme by better meeting member's risk preferences and would also allow for different investments based on members' ethical views. In addition, the collective drawdown design is simpler than competing approaches, making it easier for members to understand, easier to calculate transfer values and it is potentially simpler to regulate.

Legislation and regulation would need to be adapted to enable optimal designs

The collective-drawdown design is new and so is not directly supported by existing UK regulation. This leads to our first and principal recommendations.

> **Recommendation 1:** Policy makers should encourage the development of collective drawdown schemes and should be prepared to update legislation to allow schemes operating on this design.

> **Recommendation 2:** Pension providers and employers considering different collective scheme designs should consider benchmarking their designs against a collective-drawdown approach.

Many potential benefits of collective pension schemes have been understood by UK policy makers for some time. There have been various legal and regulatory reforms to encourage the development of such pension products, notably the CDC provisions of the Pension Schemes Act 2021.

The key to the success of any collective pension design is effective risk management

All the collective designs we consider seek to address the flaws in the risk-management strategies of traditional decumulation approaches.

Historically, members investing in a DC scheme were required to purchase an annuity on retirement. However, this presents a mismatch to the approach to risk before and after retirement. During the accumulation phase, DC scheme members normally accept considerable exposure to market risk, but purchasing an index-linked annuity at retirement is an extremely risk-averse position. The payments structure of Defined Benefit (DB) similarly assumes members are unprepared to tolerate any risk. All the CDC schemes we look at seek to improve on this by taking a less extreme position in retirement. Since retirement may last two or more decades, even quite modest investment in riskier assets can yield significant rewards.

The other option open to DC investors is to pursue a drawdown strategy, where they can invest as they wish and gradually spend their savings to fund their retirement. This approach makes no attempt to insure against longevity risk. Since one's time of death is unpredictable, it is hard to know how much to drawdown each year. CDC schemes address this problem by providing all members with a form of longevity insurance. Members who live longer than expected receive additional payments which can be funded using the assets left by members who do not live as long as expected.

These two approaches can also be combined in a flex-then-fix strategy, and this can help mitigate the concerns. Collective schemes have the potential to provide even greater flexibility.

CDC schemes could be lower cost than currently available products

One could also consider buying longevity insurance from an insurer rather than through a CDC scheme. Indeed, this is what happens if you purchase an annuity. Our research shows how CDC can provide longevity insurance at a lower cost than an insurer. In essence, this is because in a CDC scheme all members are both buyers and sellers of insurance. This means that any errors in pricing longevity insurance only have a small effect because all members experience both the upside and downside of these errors. A third party on the other hand is only selling insurance. They need to charge a significant margin to cover the pricing errors that will inevitably arise given the uncertainty in future life-expectancy.

These considerations explain the potential of collective pension designs. All these issues have been understood for some time and have motivated the changes in legislation and regulation on collective pensions. What this report adds, is to study the alternative CDC design, collective drawdown, and to explain how it achieves a better distribution of pension outcomes than existing CDC designs.

Collective schemes can be designed to allow members to choose between investment strategies

In the collective-drawdown approach, each member has an associated pension pot and an associated investment strategy. The pension pot of each member grows according to the success of their investments. In this sense, a collective-drawdown design is very like a DC scheme. The difference between a collective-drawdown scheme and a DC + drawdown scheme is simply that in collective drawdown members enjoy the benefits of longevity insurance.

Within the existing UK framework, CDC scheme designs must operate very differently. All assets are pooled and invested collectively. Members' eventual benefits are calculated using mathematical formulae set out in the scheme's operating principles based on the initial contributions they made and the overall fund performance.

A key advantage of collective drawdown is that it allows the investment strategy to be chosen to match the needs of each member. Other designs must solve the challenging problem of finding an investment strategy and a set of fixed operating rules that will provide an appropriate compromise between different members' needs.

The collective-drawdown design makes it possible to search for an optimal strategy for every member. We have done this in practice using machine learning. Other CDC designs have very rigid designs which have not been developed through a process of optimisation. From this perspective, it is unsurprising that collective drawdown can outperform them. Indeed, in any scheme design that provides no opportunity to take account of different members' risk preferences, the result must inevitably be suboptimal.

Collective funds can benefit members by sharing longevity risk, but not investment risk

The ambition of existing CDC designs that motivates pooling members assets is to share investment risks across generations. In the collective-drawdown design, some generations will be lucky, and their assets will grow more than those of unlucky generations. The hope in other collective pension designs is that they might be able to improve outcomes by risk-sharing between lucky and unlucky generations.

The central result of the mathematical research underpinning this report states, in essence, that it is impossible to improve all member outcomes by sharing investment risk in this way. This is an abstract theoretical result but is borne out by quantitative results which confirms that the CDC designs which attempt this form of investment pooling lead to appreciably worse outcomes for members.

Mimicking a DB structure in a CDC scheme generates inter-age cross-subsidies and reduces efficiency

We identify two key causes of this under-performance. The first of these is inter-age unfairness. This affects CDC designs which attempt to mimic the flat-accrual structure of DB schemes. In flat-accrual schemes, you accrue the same benefit entitlement in proportion to your contribution whatever your age. However, the longer you invest the better returns one should get. This means that flat-accrual designs give better value-for-money to the old than the young. Our modelling found that a flat-accrual CDC scheme gave the oldest members a pension worth 9 times that of the youngest member. In a flat-accrual DB scheme, the equivalent ratio is 2.5.

Such cross-subsidies are undesirable to members because members who leave a scheme before retirement may feel that they have been unfairly treated. They will have to make up any shortfall in their expected pension themselves. However, as flat-accrual DB schemes already contain some cross subsidy, members who were in a DB scheme at the start of their career will have been subsidising older members and will be expecting to be benefit from cross subsidies at the end of their career. For this reason, a CDC scheme that is designed to replace a DB scheme may wish to replicate the levels of cross-subsidy in that DB scheme.

Large cross-subsidies will reduce the benefits members receive in the long term. This is because the first members of a scheme will receive benefits in excess of their and their employers' contributions and future generations in effect must pay interest on these overpayments. We call this effect drag.

> **Recommendation 3:** Flat-accrual CDC schemes may contain unacceptably high cross-subsidies by age. Policy makers should explicitly consider what level of cross subsidy is acceptable and how cross-subsidies should be measured.

Recommendation 4: Policy makers should consider how members are informed about employer contributions to ensure they are not misled. If members will not benefit from payments to overcome drag or that subsidise other members, employers should not suggest that these payments form part of their total remuneration package.

Mispricing in a CDC scheme can reduce efficiency

The second cause of under-performance in the existing CDC designs we have studied comes from mispricing. This affects what we call dynamic-accrual schemes which aim to avoid the inter-age cross-subsidies of flat-accrual schemes. CDC regulations specify how a scheme's pension liabilities should be valued, but this valuation methodology requires an assumption that will normally not hold. This can lead to valuation errors of up to 50%. These pricing errors tend to cancel out on average, but they add an unnecessary risk on top of market risk, making the scheme less efficient.

The cause of this mispricing is that collective pensions are derivative products and so one cannot simply use the same formulae in valuing collective pensions that one uses when valuing DB pensions. A financial derivative is any financial product where the final payout is determined in a non-linear way from asset prices. In dynamic-accrual pensions, pension benefits are computed using complex formulae given in the scheme rules, so these products are financial derivatives. As a result, they must be valued using a methodology appropriate for derivative pricing. The central-estimate approach required by regulations is inappropriate for this task.

Recommendation 5: CDC pensions that attempt investment-risk pooling are derivative products and benefits should be valued accordingly. Schemes offering such pensions should be required to seek advice on derivative pricing and regulators may also need to develop appropriate expertise in this area.

The collective-drawdown design is not a derivative product and it results in no cross-subsidies. This means it does not experience the same issues as existing UK CDC designs.

The concerns we have just identified with older CDC designs can all be detected by using simulations to assess the value of benefits and to quantify the risk. Similarly, any machine-learning strategies used in collective drawdown should be carefully validated.

Recommendation 6: Regulators should require schemes to quantify the risk of any collective design in published simulation studies. Investment strategies should be validated using simulations as part of the routine assessment of a scheme's performance.

Member communications are a crucial part of scheme design

There is no point in a pension scheme that members find unattractive. One issue that we have not addressed in this report is whether members would find a collective-drawdown design appealing.

Research in behavioural economics tells us that member views will depend heavily upon how the scheme is presented. The comparative simplicity of collective drawdown may help in explaining the design to members, but it may also have unwanted negative effects.

For example, all the collective designs we have modelled require members to forgo leaving a bequest in exchange for receiving longevity insurance, but this may be more obvious in the collective-drawdown design. If this proves to be a concern, this might be addressed by better framing. For example, one could point out that longevity insurance can give members the confidence to give money to their children while they are still alive rather than leaving an uncertain bequest on an uncertain date.

> **Recommendation 7:** Research should be conducted to understand to what extent members can understand how different scheme designs operate, how this impacts upon their benefits, and how schemes might be presented to encourage the adoption of designs that most benefit members.

Even without conducting such research, it is possible to identify some flaws in how existing CDC designs are currently presented to members. There are advantages in selecting a framing that encourages members to invest in a pension, but member communications should still provide sufficient information for members to make informed decisions, and communications should not cross the line into being misleading.

When communicating to members, one principle that is generally accepted is that it is unwise for members to focus on the value of their pension, rather than the benefits they will receive in retirement. This is partly because members tend to underestimate their longevity and so tend to underestimate the size of pension pot they need. It is also because gilt prices can fluctuate, so a member focussing on the value of their pension will incorrectly perceive an essentially riskless pension invested in index-linked gilts as frequently rising and falling in value. This leads to the following recommendation:

> **Recommendation 8:** Members of collective scheme should be informed of their projected real-terms benefit in retirement together with a quantitative assessment of the uncertainty, and there should be greater clarity on how these computations may be performed.

The UK's pensions dashboard project already requires CDC schemes to provide projected benefit figures[1], but it would be beneficial if there was greater clarity on how this is computed for CDC designs. In shared-indexation schemes, there is a danger that members may confuse a quantity we call their "nominal benefit amount" with their projected benefit and it is important that this confusion does not occur. There is currently no requirement to quantify risk for the pensions dashboard, but DC schemes are required to show alternative growth scenarios, and consistency across different scheme designs would seem desirable.

The primary focus in this report is all-life pension schemes, but we also study decumulation-only designs. Our findings there are broadly similar. They suggest that collective-drawdown schemes might be an appropriate default for DC schemes at retirement that would outperform annuitisation.

> **Recommendation 9:** Research should be conducted on using collective-drawdown designs as a default approach at retirement within DC schemes.

Current CDC designs can outperform both DB and DC propositions

Despite the issues we have raised with older CDC designs, we do find that they can outperform a DC + full annuitisation approach, assuming that a member is in the scheme for their entire career. The last assumption is important because, in the flat-accrual CDC design, members who are only in the scheme early in their career would be substantially better off in a DC + Annuity approach.

The older CDC designs will be outperformed by a DC scheme in accumulation followed by a decumulation-only collective-drawdown scheme, assuming the DC scheme provides access to sufficiently leveraged investments.

In summary, our research has confirmed that collective pensions have the potential to deliver substantial benefits to members over both DC and DB approaches. Our research has identified potential pitfalls in existing CDC approaches but has also shown that these can be overcome using the collective-drawdown design.

The quantitative benefits of collective drawdown come entirely from improved risk-management. In addition to improving retirement outcomes, better risk-management enables greater investment in productive assets and so can also bring benefits to the wider economy.

[1] https://www.legislation.gov.uk/uksi/2022/1220/schedule/3/made.

Structure of this report

Chapter 1 – Introduction

Chapter 1 studies the history of CDC developments that define the context of this project. The project approach and methodology are described as a reference for the report.

Chapter 2 – Flat Accrual: CDC in the UK Today

Chapter 2 studies flat-accrual CDC pensions. This is the only form of CDC scheme that currently exists in the UK. It can be broadly understood as a design that is intended to take over from a traditional flat-accrual DB scheme. This chapter contains a detailed numerical study of a hypothetical flat-accrual scheme.

Chapter 3 – Dynamic accrual: multi-employer and drawdown-only schemes

Chapter 3 studies dynamic-accrual CDC pensions. This design can be used for decumulation only CDC schemes and multi-employer schemes. The Department for Work and Pensions (DWP) held a consultation on multi-employer CDC in 2024 and the design we consider is aligned with that consultation.

Chapter 4 – Collective drawdown: collective pensions with investment choice

Chapter 4 studies collective-drawdown CDC pensions. The term "collective drawdown" has been introduced in this project. It describes a scheme which provides longevity insurance without requiring all the scheme's assets be pooled in a way that separates investment-risk from longevity-risk.

Chapter 5 – Summary of recommendations

Chapter 5 summarises the recommendations developed in response to the findings of the research.

Chapter 1

Introduction

The chapter studies the history of CDC developments that define the context of this project. The project approach and methodology are described as a reference for the report.

Background

Collective Defined Contribution (CDC) pension schemes are a new approach to pensions which aim to allow members to achieve better pension outcomes through risk-sharing, but without relying on an employer guarantee.

The primary UK approaches to pensions are Defined Benefit (DB) and Defined Contribution (DC) schemes. However, the majority of private sector DB schemes have closed to new members, future accruals or been wound up entirely. As of March 2024, there are 4,974 private sector DB schemes, just 4% of which are open to new members; a further 19% are closed to new members but open to new benefit accrual for existing members, while 74% are closed to both new members and new accruals, and 3% in the process of winding up.[2] DC membership has proliferated as a result of the introduction of automatic enrolment, however DC schemes are an accumulation-only vehicle without risk-sharing, and there remains a challenge of how best to manage these investments during drawdown.

CDC schemes have been tried internationally, but the UK market is fundamentally different. Pension choice is a central pillar of UK pension policy: any scheme must allow investors to opt out. International CDC schemes have been supported by legislation mandating membership and so have been able to take a one-size-fits-all approach. The central goal of this report is to examine an alternative paradigm designed for the UK centred on pension choice.

Nevertheless, there are lessons to be learned from the international experience. The impact of investment volatility to risk sharing outcomes, most particularly in the wake of the 2008 financial crisis, has led to cuts to pension entitlement in the Netherlands. This has raised debates around the long-term sustainability of these CDC models, and the differential impact of cuts across generations has led some to question the cross-subsidies that occur in these designs. Another theme of this report, therefore, will be to consider how cross-subsidies in CDC designs can be measured, and how they may be reduced.

The potential for CDC or similar collective arrangements has been explored in the UK context from as early as 2008. The Pension Schemes Act 2015 introduced the possibility of further legislation to enable collective schemes, such as CDC, although the legislation set out a framework for broader Defined Ambition schemes rather than CDC specifically. However, in 2015, the introduction of such collective schemes was considered a 'niche interest', and therefore not a policy which would impact a large proportion of savers, unlike automatic enrolment and pension freedoms which would have more immediate implications for millions of people. As a result, the Work and Pensions Committee recommended that the Department for Work and Pensions (DWP) ensure resources were not diverted towards the development of risk-sharing schemes until automatic enrolment was fully rolled out and the pension freedoms properly established.[3]

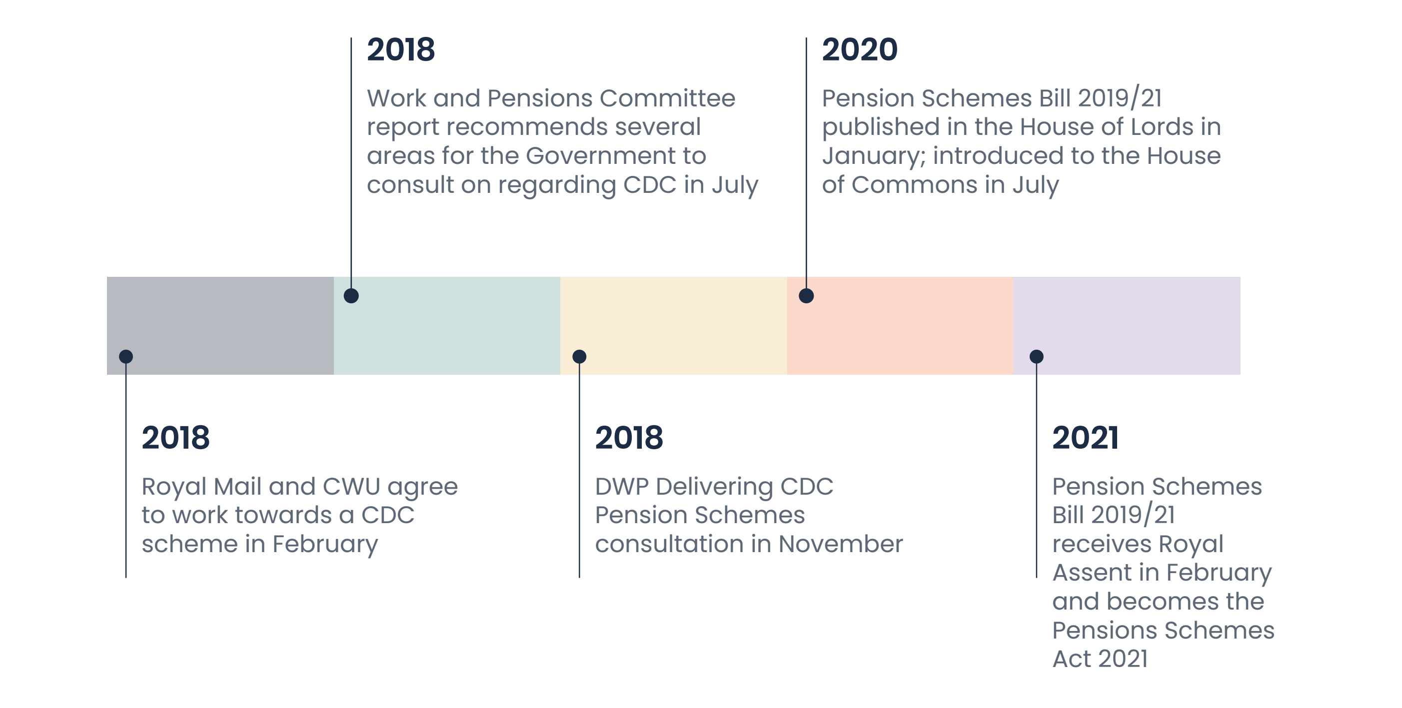
[2] Pension Protection Fund (2024)
[3] Work and Pensions Committee (2015)

In 2018, Royal Mail and the Communication Workers Union (CWU) agreed to pursue a CDC scheme as a replacement for Royal Mail's DB scheme, which was becoming unaffordable. This brought CDC back to the forefront of policy discussions. In November 2018, DWP published a consultation on "Delivering Collective Defined Contribution Pension Schemes", which highlighted several key issues to be considered in relation to CDC.

The introduction of primary legislation, in the form of the Pension Schemes Bill 2019-21, followed from the 2018 consultation. Uncertainty and prioritisation of more immediately pressing policy concerns resulting from the pandemic delayed the progression of the Bill. The Bill received Royal Assent in February 2021, becoming the Pensions Schemes Act 2021 [Figure 1.1].

The regulations have been designed initially for single-employer schemes, but the act also includes provision to extend CDC regulations in future beyond the single-employer schemes currently allowed by the legislation.

Figure 1.1: **UK CDC legislation pathway 2018-2021**



Royal Mail's Career Average DB scheme was closed to future accrual In March 2018. After detailed discussions with the CWU about future pension arrangements, it was agreed that a CDC scheme could best meet objectives going forward by providing better expected outcomes and more predictable costs for employees and employers.

A transitional DB cash balance scheme (in which the defined benefit promised to members is not an income but a lump sum, which most members could use as their 25% tax free lump sum) was put in place as an interim measure while Royal Mail and the CWU worked together with Government to introduce the necessary legislation to enable CDC in the UK. The Royal Mail Collective Pension Plan received authorisation from The Pensions Regulator (TPR) in April 2023 and opened to members in 2024.

Appetite for single-employer CDC schemes is currently limited. The Royal Mail scheme is the only CDC scheme at present, although some schemes, employers, and providers are investigating the potential of further single-employer designs. There may be greater appetite for CDC schemes with alternative designs to the current single-employer model, including multi-employer and decumulation-only CDC schemes. The Church of England and TPT Retirement solutions both have expressed an interest in developing CDC pensions.[4]

The Government consulted on regulation for multi-employer schemes in October 2024[5], and published their response in October 2025.[6] This consultation was in response to government engagement with a range of industry stakeholders to finalise the legislative framework needed to accommodate whole-life CDC schemes with multiple unconnected employers, including Master Trusts. Regulations have been updated to accommodate the Government's response to the consultation and laid before parliament. This indicates that there is desire within the pensions industry to push forward with multi-employer CDC in a suitable regulatory and legislative framework. For a more detailed account of the development of CDC in the UK and the legislative framework, see our previous Briefing Note (Wilkinson 2024).

The Government has also launched a consultation into the use of CDC schemes as decumulation only vehicles.[7] This will define the opportunity to develop and implement such schemes, including commercial considerations and member communications.

A common feature of the existing single-employer regulation and the expected multi-employer regulation is that all the assets of members are pooled together. The benefit entitlements of each member are then adjusted each year in response to the fund's performance. It is required that all members receive the same percentage increase or decrease in their benefits each year. For this reason, we call these designs *shared-indexation schemes*.

One downside of the shared-indexation design is that it does not allow for member choice. If all members must receive the same indexation, they cannot each choose their own preferred investment strategy. This project will examine an alternative design for collective pensions where assets are not pooled centrally. Instead, the collective benefits are obtained through a system of mutual insurance between members. As we will see, this allows member choice and also results in better pension outcomes.

[4] DWP (2024a)
[5] DWP (2024b)
[6] DWP (2025a)
[7] DWP (2025b)

Objectives

The aim of this research is to determine how CDC funds could operate within the UK pension environment in a way that maximises member choice, and to determine the potential benefits. The research had a number of strands.

Mathematical objectives: Define what it means to run a collective scheme optimally when members may all have different views and preferences. Develop the mathematical tools to understand the optimal strategy for such collectives.

Modelling objectives: Build realistic models to evaluate the performance of CDC schemes. Evaluate the performance of the UK industry state-of-the art approaches to CDC and compare this with the performance of schemes derived from the mathematical approach.

Policy objectives: Examine the appetite for collective pensions within the UK pension market. Understand the potential benefits of CDC within the UK and the potential pitfalls. Identify any regulatory changes needed to allow new forms of CDC or to improve the regulation of existing CDC. Evaluate how CDC designs might be communicated to members.

Methodology

Stakeholder engagement

The impact of the project is predicated upon engagement with key stakeholders who form the critical audience for this work. This has included:

- **Government / policymakers:** setting out the evidence for CDC as a way of ensuring that policy can be more effective, better targeted and help Government aims of ensuring that people have adequate incomes in retirement.
- **Pensions Industry:** offering accessible evidence to those who have an interest in innovation in the provision of pensions savings and the policies to deliver better outcomes.
- **Other stakeholders:** other stakeholders, such as Age UK, and the Money and Pensions Service, who have an interest in pursuing better retirement outcomes, will be able to use the project findings in their own work and as evidence to support calls for better policymaking.

We have engaged with an Advisory Group to canvass expert views and seek their input. The advisory group has allowed a panel of interested parties with different views to have a debate about the project plans and emerging findings so that some of the potential conflicts may be ironed out during the research process. Those on the advisory group will have a sense of having participated, having been listened to, and of the level of balance and rigour which has gone into the project.

Interviews

The project has engaged a mixed methods approach. This has included qualitative interviews with experts from across the pensions industry. Interviewees have been drawn from: Government; regulators; trustees; pension providers; employers; advisers; schemes; consumer groups; and other industry groups such as trade bodies and associations.

These interviews followed a structured questionnaire covering: barriers to implementation; appetite for change; relevance and applicability to existing DB and DC schemes; member attitudes towards CDC, including trust; benefits for industry stakeholders and members, and how these may be realised; and potential future innovation.

Quantitative modelling

Modelling scheme designs

In the numerical modelling in this report we consider a number of different pension scheme designs. They are all similar in that they only provide a single-life pension with no lump sum at retirement. All the designs we consider could be modified to provide spousal benefits or a lump sum, but as the purpose of this report is to focus on the distinctive features of collective pensions, it would be a distraction to model these details.

Table 1.1: Classification of scheme designs considered in this report.

Optimised?	Collective?	Shared-indexation	Design	Chapter
Fixed strategy	Collective	Y	Flat-accrual	Chapter 2
			Dynamic-accrual	Chapter 3
	Individual	N	DC + Annuity	
Optimised strategy	Collective	N	Collective drawdown	Chapter 4
		Y	Optimised flat-accrual	
			Optimised dynamic-accrual	
			Optimised statistically-calibrated	
	Individual	N	Optimised DC + Annuity	
			Optimised DC + Flex-then-fix	

Table 1.1 provides a summary of the different scheme designs we look at in this report. We have classified the designs on a number of axes.

Firstly, all designs can be classified as either a fixed-strategy design or an optimised strategy. Fixed-strategy designs have an investment strategy that is selected based on our industry consultation. Optimised designs have an investment strategy which has been adjusted to meet the preferences of a chosen representative investor as best as possible. For example, in the “DC + Annuity” design, a member’s assets are invested in equities until 10 years before retirement and then gradually de-risked until, at retirement, they are invested entirely in index-linked gilts. In the “Optimised DC + Annuity” design, the investment strategy is chosen dynamically and varies with market conditions to achieve the best result. At retirement, all assets are used to purchase an index-linked annuity.

Secondly, we have classified the designs by whether or not they are collective designs. The non-collective designs' are chosen as benchmarks to assess the collective designs performance. The "DC + Annuity" design and the "Optimised DC + Annuity" design both assume that the member will purchase an annuity at retirement. The "Optimised DC + flex-then-fix" design is more flexible as the member can choose to gradually annuities while drawing down on their assets. This represents the most flexible approach that is possible using conventional pension products.

Collective schemes are then classified as either shared indexation or collective drawdown. The only CDC design that exists in the UK is a shared-indexation scheme, and the schemes proposed in the recent DWP multi-employer CDC consultation would also be shared-indexation schemes. The shared-indexation design represents the current UK industry standard for collective pensions. To understand this design we have drawn upon current regulations, existing scheme documentation, the DWP consultation documents, as well as our own industry consultation.

The three different shared-indexation designs, modelled in this report are flat accrual, dynamic accrual, and statistically-calibrated accrual. The flat-accrual design is similar to that used in the Royal Mail Collective Pension Plan. The dynamic-accrual design is similar to that envisaged in the DWP's multi-employer CDC consultation. The statistically-calibrated design is our own proposal for a shared-indexation design, which tries to correct for some of the weaknesses in the flat-accrual and dynamic-accrual designs.

Chapter 2 describes how shared-indexation designs operate, and illustrates this with the example of flat-accrual scheme.

Chapter 3 looks at dynamic-accrual designs. Both of these strategies look at fixed strategies.

Chapter 4 looks at collective drawdown and, in order to make sure the comparison with other scheme designs is as fair as possible, we optimise all the scheme designs used in our benchmarks.

Economic modelling

We have used three different approaches to modelling economic scenarios in this report.

A constant economic model. In this model all rates such as stock returns and inflation are known in advance. We have used to this to give simple numerical examples without the need for simulations.

A Black-Scholes model. In this model all rates are deterministic except for stock returns which follow a log-normal distribution. We have used this model when we need to be able to compute the current value of pension payments in a mathematically rigorous fashion.

The PPI economic model. This is a rich model where wages, inflation, bond prices, and stock returns are all unpredictable. We have used this model when we wish to assess the overall long-term benefit of different pension schemes.

Whenever we give a numerical example or a figure in this report we have indicated in a footnote which model was used.

Figures in the Executive Summary

The headline figure of a 75% risk-adjusted improvement of collective drawdown over DC + full annuitisation given in the Executive Summary was computed using the PPI economic model and the optimised strategies. We explain the precise meaning of this figure in Chapter 4 in the section on "Risk-adjusted comparison of schemes" which summarises the main quantative results of this report.

Further details

See Appendix A for more details on how the schemes were modelled. Full details are available in the mathematical papers listed below.

Relationship with our other reports

This report summarises the key findings of our research, but we have written a number of Briefing Notes and academic papers, which provide more detail.

For a policy audience, we have written three Briefing Notes. Our first Briefing Note (Wilkinson 2024) examines how CDC is expected to develop in the UK. Our second (Upton 2024) analyses the difference between flat-accrual and dynamic-accrual schemes. In that report we used the term "single-employer" to refer to the design we now call flat-accrual and "multi-employer" for the design we now call dynamic accrual. Our third Briefing Note (Upton 2025) describes the collective drawdown scheme and compares it to shared-indexation schemes.

For a mathematical or actuarial audience we have written four academic papers. Armstrong et al. (2025b) provides detail on our modelling of shared-indexation schemes. Armstrong et al. (2025c) describes how to find a collective-drawdown strategy in the Black-Scholes model. Armstrong et al (2025a) is a mathematical account of the effectiveness of collective drawdown using simplified score functions. Armstrong and Dalby (2024) describes the mathematical principle of mutual insurance in collective schemes. A forthcoming paper will describe how we developed the collective-drawdown strategy in this report which is optimised for the PPI Economic Model.

This report contains a number of new results to draw everything together. It quantifies the benefits of different scheme designs using a single risk-adjusted certainty-equivalent figure. It quantifies the errors in the standard pricing formula for shared-indexation when applied to flat-accrual schemes. It considers how CDC schemes could be used in drawdown only plans. It finds an optimal collective drawdown strategy in the PPI's economic model.

Terminology

Career-Average Revalued Earnings (CARE)

Accrual structure for DB pension schemes whereby accrued rights are linked to pensionable salary in the year of accrual and revalued till retirement.

Collective Defined Contribution (CDC) Pension Scheme

A type of pension scheme in which some risks are shared collectively between scheme members rather than individually, and contribution rates are defined in advance, with no ongoing liability for employers to pay more in the future to cover potential deficits.

Collective-Drawdown Pension Scheme

A type of CDC pension scheme in which longevity but not investment risks are shared collectively between scheme members rather than individually, and contribution rates are defined in advance, with no ongoing liability for employers to pay more in the future to cover potential deficits.

Dynamic Accrual

This is a type of CDC scheme where the rate of benefit accrual from paying contributions is priced individually (e.g. based upon age and medical underwriting) and also depends upon the funding level of the scheme. This is the approach most likely to be used for multi-employer CDC schemes.

Flat Accrual

This is a type of CDC scheme where the rate of benefit accrual from paying contributions is common across the active membership and does not vary with the funding level of the scheme.

Investment Risk

The risk that market fluctuations or poor investment strategies will deplete a fund's capital.

Longevity Risk

Individual longevity risk is the risk that you run out of money before death. Systematic longevity risk is the risk arising from uncertainty in future mortality rates.

Market Price of Risk

This is a measure of the additional return or risk premium that a member would be expected to receive in return for bearing risk.

Nominal Annual Benefit Amount

This is the annual benefit accrued by a member of a CDC scheme which will be revalued until coming into payment according to scheme performance.

Overfunded / Underfunded

This refers to a mismatch between assets and projected outgoings when computed using a fully accurate pricing formula. It is a design feature of shared-indexation schemes that sometimes there will be a surplus which will be used to help other generations and sometimes there will be a deficit which will be made up by other generations. This transfer happens through future changes to the prevailing level of indexation.

Replacement Ratio

The ratio between real-terms pension benefits in a given year to real-terms final salary.

Shared Indexation

This is a form of CDC pension where nominal benefits are all revalued and indexed using with the same factor for future benefit increases.

Time Value of Money

There is normally a greater value to receiving a fixed sum of money sooner rather than later. This is reflected in the potential investment return that the sum of money may generate over the period of time.

Chapter 2

Flat accrual: CDC in the UK today

This chapter studies flat-accrual CDC pensions. This is the only form of CDC scheme that currently exists in the UK. It can be broadly understood as a design that is intended to take over from a traditional flat-accrual DB scheme. This chapter contains a detailed numerical study of a hypothetical flat-accrual scheme.

The only existing CDC scheme in the UK is the Royal Mail Collective Pension Plan.

It is an example of what we call a *shared-indexation* CDC scheme with *flat accrual*. The term “shared indexation” refers to how the benefits a member has already accrued are adjusted to account for the investment performance of the scheme. The term “flat accrual” refers to how a member accrues new benefits in the scheme.

We have not developed a model to replicate the Royal Mail scheme in all features, but instead have modelled a hypothetical shared-indexation scheme with flat-accrual that works on similar general principles. In particular, we have not applied workplace demographics and employment patterns which are consistent with the Royal Mail Collective Pension Plan membership. Therefore, the results presented should not be considered a prediction for member outcomes within that scheme.

Shared-indexation schemes

During the time that a member contributes to a shared-indexation scheme, they gradually build up an entitlement that is recorded as their *nominal annual benefit amount.*

Unlike the guaranteed real-terms annual benefit amount provided by a DB scheme, the nominal annual benefit amount in a CDC scheme does not represent the actual amount that a member will receive in retirement, as it is subject to investment performance until the benefit is paid. The scheme is valued each year, and all members’ nominal benefit amounts are adjusted to take into account the performance of the fund’s investments over the previous year. The same proportionate adjustment is made to all members’ benefits which is why this is called a shared-indexation scheme. The level of future benefit increase required to balance the value of future liabilities with the scheme assets is called the *prevailing level of indexation*.

Setting the rate of increase to the nominal annual benefit amount

The level of adjustment is chosen to ensure that the current value of the fund’s assets will match the projected outgoings in future years if the same level of adjustment is applied in future years. In this computation, future outgoings are discounted by a factor equal to the expected growth of the fund’s investments.

Example 2.1:

At the beginning of the year, a shared-indexation scheme's prevailing level of indexation is 2%. At the beginning of the year Alice has accrued a nominal annual benefit amount of £10,000.

Scenario 1: The scheme's investments perform as expected. Alice's annual nominal benefit amount increases by 2% to £10,200.

Scenario 2: The scheme's investments outperform expectations. The prevailing level of indexation must be increased. A new prevailing level of indexation of 3% is chosen. Alice's nominal annual benefit amount increases to £10,300.

Scenario 3: The scheme's investments underperform expectations. The prevailing level of indexation must be decreased. A new prevailing level of indexation of 1% is chosen. Alice's nominal annual benefit amount increases to £10,100.

In all of these examples, the nominal benefit increases each year even if the fund's investments underperform. If the investments perform particularly poorly, the prevailing level of indexation has a floor at 0%, and an immediate benefit cut is applied to all members to ensure that assets match projected outgoings when indexation is set at 0%.

Example 2.2:

Scenario 4: A stock market crash occurs. Alice's nominal annual benefit is cut to £9,000 and the prevailing level of indexation is set at 0%.

Within the UK, CDC regulations nominal cuts to benefits can be phased in over a few years to prevent quite such a large shock. The Royal Mail scheme takes advantage of this flexibility, but in our models we have made the simplification that benefit cuts are applied immediately and in full. It is also possible to set a cap on the prevailing level of indexation in a similar way, with members awarded an immediate bonus whenever this bound is reached.

When a member retires, each year they remain alive they receive a pension equal to their current nominal benefit entitlement. This nominal benefit is still adjusted each year in retirement with the shared indexation of the fund.

The nominal annual benefit is not a prediction of income to be paid by the scheme to a member in retirement

While it is simple to understand the nominal benefit amount during retirement, it is important to emphasise that before retirement nominal annual benefit is not a prediction of the benefit that will be received when the member does retire. We have called it a "nominal" benefit because it is best thought of as simply the name given to a variable used to represent accrued rights relative to other current scheme members that one should not try to interpret in isolation.

To predict a member's benefit in retirement, knowing their nominal benefit amount is not enough. You also need to know the benefit entitlements of all the other members, the prevailing level of indexation, the expected return on assets, how many members are likely to join in future years, and how much they will contribute.

Warning:

Before retirement, the nominal benefit amount does not provide an estimate of future retirement income.

Flat-accrual schemes

There are different ways to design shared-indexation schemes according to how you increase members' nominal benefit entitlements when they make a contribution.

The Royal Mail Collective Pension Plan is called a *flat-accrual* scheme, because the benefit a member receives in exchange for their contribution is directly proportional to their contribution, and does not depend on their age or the prevailing level of indexation. This replicates the accrual of a prototypical CARE DB scheme.

Example 2.3:

Alice is 27 and will retire at 65. She contributes £1000 to a flat-accrual scheme and the employer adds a contribution of £2000. In return for this payment her nominal annual benefit amount increases by £500.

Bob is 64 and will retire at 65. He contributes £1000 to a flat-accrual scheme and the employer adds a contribution of £2000. In return for this payment his nominal annual benefit amount also increases by £500.

This is intended to mimic the benefit accrual within DB schemes where members receive a guaranteed benefit entitlement proportional to their contribution each year. Flat-accrual schemes, such as the Royal Mail Collective Pension Plan, will normally be designed for use by employers that have previously offered DB pensions, and the intention of the design is to provide a similar benefit structure within a CDC framework.

A flat-accrual CDC scheme, indeed any CDC pension scheme, cannot give a guaranteed index-linked income, but they are designed so that at least on average, pensions should increase by a given target level of indexation each year. This can be done by choosing an appropriate ratio between the level of contributions and the level of nominal benefit received. This will determine how much the fund's assets and liabilities will grow on average and so will determine the average level of indexation.

Although all members receive the same nominal benefit entitlement for the same level of pensionable pay and all members receive the same level of indexation, the actual payments they receive in retirement will normally be very different. This is because changes to the level of indexation will also affect the level of indexation in future years.

Example 2.4:

Alice is 27 and accrues a nominal annual benefit of £500 in return for her pension contribution. She contributes £1000 to a flat-accrual scheme and the employer adds a contribution of £2000. In return for this payment her nominal benefit increases by £500.

Bob is 64 and accrues a nominal annual benefit of £500 in return for his pension contribution. He contributes £2000 to a flat-accrual scheme and the employer adds a contribution of £2000. In return for this payment his nominal benefit also increases by £500.

Scenario 1: The average level of indexation over all future years is 0.5% above inflation. Alice will receive a pension benefit of £604 in real terms when she is 65. Bob will receive a real-terms pension benefit of £503 when he is 65.

Scenario 2: The average level of indexation over all future years is 0.5% below inflation. Alice will receive a pension benefit of £413 in real terms when she is 65. Bob will receive a real-terms pension benefit of £498 when he is 65.

The value of the same nominal annual benefit may vary by a factor of up to nine depending on the age of a scheme member

As the uncertainty in the level of indexation is compounded over time, Alice's pension benefits are much more uncertain than Bob's. This will make Alice's future pension worth less than Bob's as she is not being compensated for the risk she is bearing. This effect is called *the market price of risk*. In addition, the promise of receiving money in 38 years is worth less than the promise of receiving the same amount in a year. Since Alice has to wait 38 years for her pension, this will further reduce the market value of her pension compared to Bob's. This effect is called *the time-value of money*. The difference in value between Alice and Bob's £500 of nominal annual benefit is a factor of about 8 and rises to about 9 for the youngest members of the scheme.

Example 2.5:[8]

Alice is 27. To increase her annual nominal benefit amount by £500 Alice and the employer must contribute £3000, but the market value of her total future pension will only increase by about £1000.

Bob is 64. To increase his annual nominal benefit amount by £500 Bob and the employer must contribute £3000, but the market value of his total future pension income will increase by about £8000.

When this is viewed across all the membership, this will approximately balance. The discrepancies that occur cause the level of indexation to tend to its long-term target.

In this example, the employer's contributions are sufficiently high to ensure that Alice doesn't lose out from paying into the scheme. The legislation for CDC funds requires this. However, Alice herself does not benefit from the employer's additional contributions. This means that flat-accrual CDC schemes contain very high levels of inter-age cross-subsidy.

The payments of a member and the payments made by the employer all enter the pooled funds of the scheme. The payments made the employer are a fixed proportion of the payments made by members, so in this sense there is an employer contribution associated to each member. However, the value of the benefits received by a member do not correspond directly to these contributions.

If a member is in the scheme for the whole of their life they will sometimes benefit from these cross-subsidies and will sometimes lose out. These effects do not exactly cancel over members' lifetimes, and this leads to intergenerational cross-subsidies.

[8] Values computed in the Black-Scholes model

Suppose that Alice and Bob joined the scheme in its first year. Bob will receive a pension worth more than the total value of his and the employer's total lifetime contribution. To finance this, when Alice retires her pension will be worth an amount that is less than her and the employer's total lifetime contribution. In the long-term, members who are in the scheme for the whole of their lives can expect to receive a pension that is worth less than the value of their contributions and the matching employer contributions. In effect, the fund must pay interest in perpetuity on the initial overpayments, reducing the income of later generations. We call this effect "drag".

As a result of the drag effect, flat-accrual schemes give lower average benefits than the other CDC schemes as well as lower risk-adjusted benefits. Both proponents and opponents of CDC schemes[9][10] have argued that, in the long term, the performance of a CDC scheme must match the growth of the assets they invest in. The phenomenon of drag shows that this need not be the case and that decisions on how assets are allocated to different generations can significantly affect fund performance.

These concerns about cross-subsidies lead to the following recommendations.

> **Recommendation 3:** Flat-accrual CDC schemes may contain unacceptably high cross-subsidies by age. Policy makers should explicitly consider what level of cross subsidy is acceptable and how cross-subsidies should be measured.

> **Recommendation 4:** Policy makers should consider how members are informed about employer contributions to ensure they are not misled. If members will not benefit from payments to overcome drag or that subsidise other members, employers should not suggest that these payments form part of their total remuneration package.

The Equality Act 2010 contains provisions describing the exceptions to rules on age discrimination that apply to pension schemes. For example, it is acceptable to reward long service with higher pension benefits even though this favours older members. However, this would only justify different benefits based on length of service, not based directly on age.

There are specific provisions in the Act on money purchase schemes and DB schemes. Cross subsidies are allowed in these schemes to the extent that they equalise pay in retirement, but it is unclear how to understand how these provisions should be applied to CDC schemes where the level of risk in future pension payments is an important factor in determining their value and in determining whether payments can reasonably be considered equal.

[9] Ralfe (2024)
[10] WTW (2021)

Schemes are already required not to mislead members about the extent to which they benefit from employer contributions, but we have seen evidence of existing DB schemes incorrectly suggesting that a member's contributions are used to benefit that member, rather than to support the scheme as a whole. While this should already be a concern in DB schemes, it is arguably mitigated by the fact that these schemes have a clear contract that says what benefits a member will receive and this is independent of employer contributions. There is no such mitigation in CDC schemes. The situation is further exacerbated by the drag effect, as it is not true that a member who is in the scheme for the whole of their working life will receive a pension equal in value to the sum of their and their employer's combined contribution.

There are various approaches one could take to accurately inform members of their remuneration, for example, they could be told the percentage of their pensionable pay they must contribute and the value of the additional benefit they will receive at different ages also expressed in percentage terms. As the pricing of derivatives is complex, thought should be given to what methodologies are acceptable for determining this value.

Cross subsidies in DB schemes[11]

In a DB scheme, where all members receive the same additional benefit for a given level of contribution, there are also inter-age cross-subsidies due to the time-value of money. However, as DB schemes give guaranteed payments, there is no effect due to the market price of risk. The scale of cross-subsidies in DB schemes is much lower than in flat-accrual CDC schemes. Using the same assumptions for a DB scheme and CDC scheme, we found the oldest generation received benefits worth 2.5 times that of the youngest generation in a DB scheme, compared to a factor of 9 for a flat-accrual CDC scheme.

In a DB scheme, initial overpayment of the earliest generation is much smaller than in a flat-accrual CDC scheme and is at a level which can be compensated for by the growing wages of each generation. This avoids the drag effect seen in flat-accrual CDC. The value of the pension received by a member of a DB scheme will not exactly match the value of their contributions together with the employer's contributions, but the discrepancy is small.

[11] Computed using a Black-Scholes model

Smoothing of benefit payments

The design of a shared-indexation scheme adds a delay before the full effect of market fluctuations is felt on benefit payments.

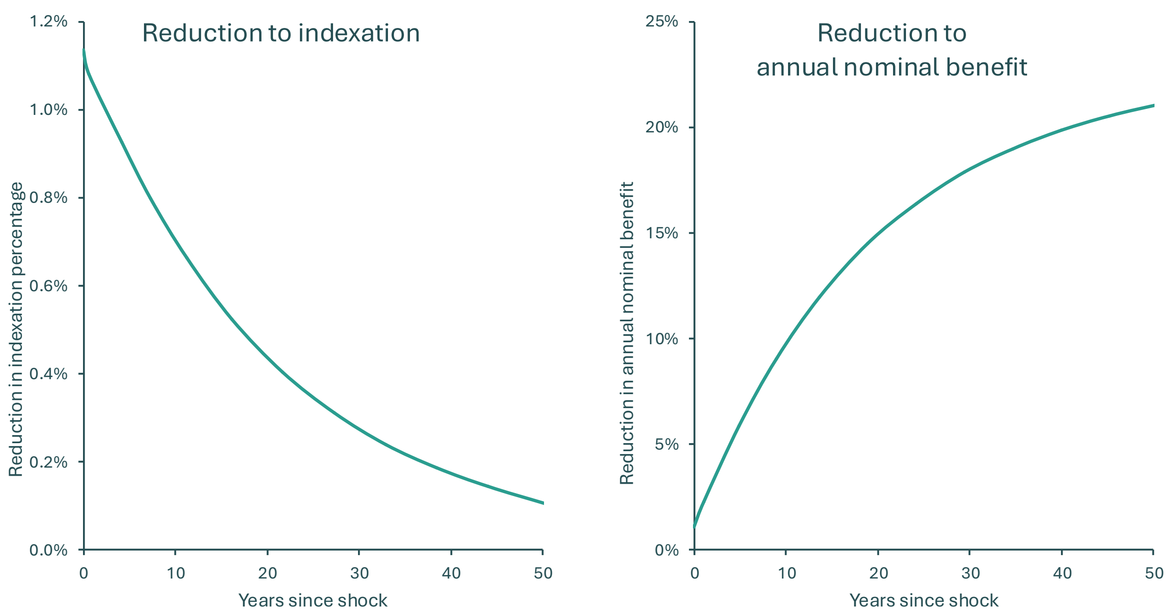
Example 2.6:[12]

A shared-indexation scheme is targeting a long-term rate of indexation that matches inflation. At the start of the year, it is currently achieving this target.

A stock market crash occurs, and the value of stocks falls over the year by 10%. In response, the prevailing level of indexation is set to 1.13% below inflation. In future years, the scheme can be expected to gradually return to a level of indexation equal to inflation. After 10 years the indexation is expected to be about 0.7% below inflation. After 50 years indexation is expected to be about 0.1% below inflation [Figure 2.1]. The expected level of indexation each year after the shock is shown on the left in [Figure 2.1].

As a result, benefits paid immediately after the crash will be 1.13% lower than previously expected. Since the effects of indexation are compounded, the expected benefits paid will be approximately 20% lower 40 years after the shock. The reduction in expected benefit each year after the shock is shown on the right in [Figure 2.1].

Figure 2.1 **The return to long term expectations after a shock means are compounded over the longer term**[13]



Following a 10% fall in stock prices: (left) the resulting expected reduction in the prevailing level of indexation for future years; (right) the resulting expected reduction in benefit payments for future years.

[12] Computed using a constant economic model
[13] Computed using a constant economic model

As the effect of market fluctuations is delayed in shared-indexation schemes, members whose remaining life expectancy is short will see relatively small changes in their expected future pension payments, compared to members who are a long way from retirement. This offers a higher degree of certainty of benefit payments to the pensioner members of CDC schemes.

Example 2.7:[14]

The stock market falls 10% over a year, so the prevailing level of indexation is cut to 1.13% below inflation.

Alice is aged 27. Her annual nominal benefit amount falls that year by 1.13% in real terms. The benefits she has accrued are expected to fall by 20% in real terms by the time she receives them.

Bob is aged 64. His annual nominal benefit amount falls that year by 1.13% in real terms. The total real-terms pension he expects to receive in retirement falls by 8.3% in real terms.

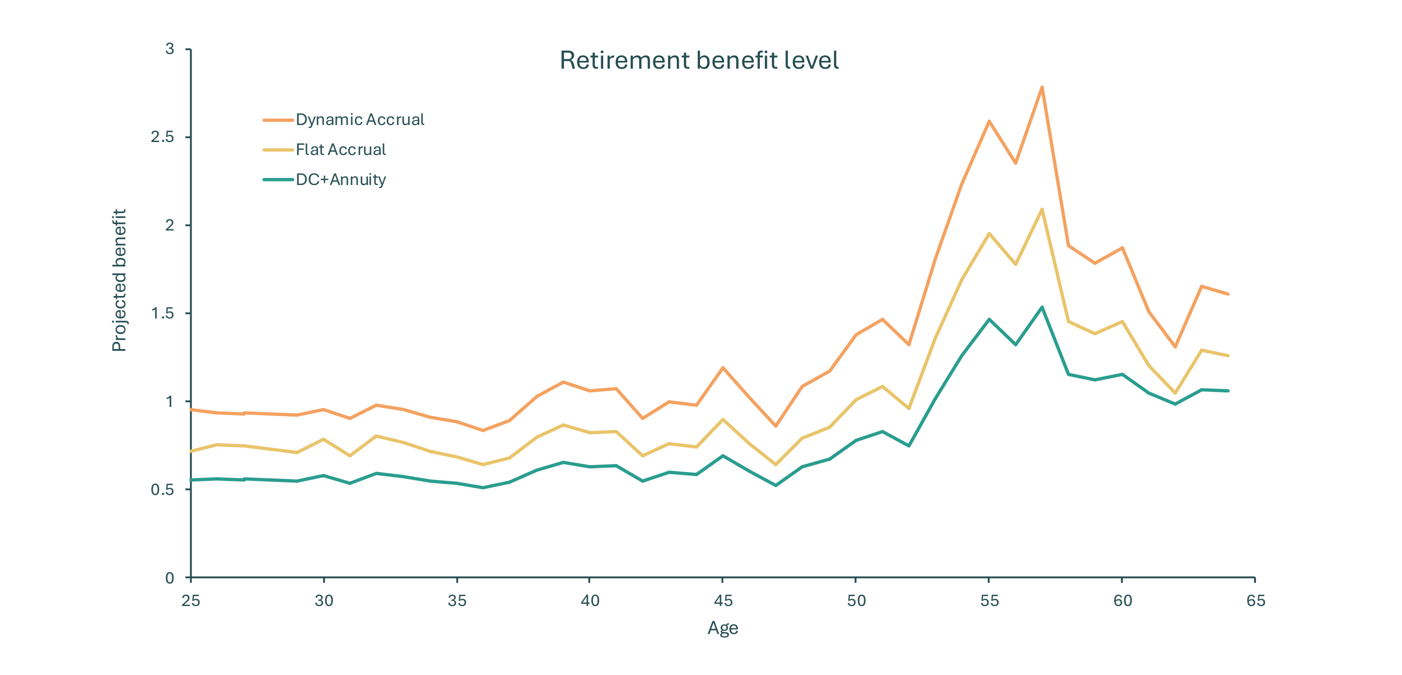
This example shows why we have emphasised that, before retirement, the annual nominal benefit amount should not be interpreted as a prediction of future pension payments. Predicted pension payments typically fluctuate by much more than a member's nominal benefit amount.

If members' annual pension statements only tell them their accrued nominal benefit amount, they may incorrectly believe this is a prediction of their future pension payments when in fact, these values differ significantly. They may also incorrectly believe that a 1% drop in their nominal benefit amount means that the value of their future pension has only dropped by 1%.

Asset values fluctuate constantly, and this should be taken into account when evaluating smoothing in response to an investment shock. Before retirement, predicted pension payments in DC and shared-indexation schemes fluctuate in a very similar fashion in response to investment risk [Figure 2.2]. This contradicts some of the strong claims that have been made on the predictability of pension benefits of shared-indexation and similar CDC schemes.[15][16]

[14] Computed using a constant economic model
[15] Aon (2020)
[16] Boulding (2024)

Figure 2.2 **The projected retirement benefit levels for DC and CDC respond similarly to economic circumstances**[17]



Projected benefit at retirement in one scenario for three scheme types. The Dynamic accrual scheme is described in the next chapter.

Why smoothing in shared-indexation CDC may have been over-estimated

There are a number of reasons why the smoothing properties of shared-indexation CDC schemes may have been over-estimated. Firstly, it is easy to confuse annual nominal benefit amounts with projected pension payments.[18] However, nominal benefits vary much more smoothly than projected benefits. Secondly, the behaviour of shared-indexation schemes is complex and time-consuming to model. As a result, some studies have estimated expected benefits from shared-indexation schemes without estimating risk.[19] We could not find any previous simulation studies of the smoothing achieved before retirement. Thirdly, much of the literature on shared-indexation schemes uses valuation formulae that do not take into account the fact that the prevailing level of indexation will tend to return to the target level.[20]

[17] Computed using the PPI economic model
[18] E.g. GAD (2009)
[19] E.g. WTW (2020)
[20] E.g. Donnelly (2022)

Transferring out of a flat-accrual CDC scheme

In the UK, members of a pension scheme have the right to transfer out of that scheme, and so one must consider how to value a member's future pension entitlements in a flat-accrual scheme. The calculation used to determine the prevailing level of indexation in a shared-indexation scheme ensures that the scheme's assets are sufficient to cover a centrally estimated projection of future outgoings, on the assumption that that the prevailing level of indexation will remain constant. UK regulations on CDC funds requires that assets and projected outgoings are matched in this way.

However, the design of a flat-accrual scheme ensures that indexation will tend to a long-term target level. This contradicts the assumption of constant indexation that is required when matching assets and outgoings in accordance with the regulations. The pricing errors that occur from incorrectly assuming constant indexation can be large.

Example 2.8:[21]

The prevailing level of indexation in a flat-accrual scheme is 1.83% below inflation.

Alice is aged 27. Assuming constant indexation undervalues her benefits by 41%.

Bob is aged 65. Assuming constant indexation undervalues his benefits by 4%.

When indexation is below the target level, benefits are undervalued, so the regulations will require the scheme to hold less assets than are needed to match the true projected outgoings. The scheme will, therefore, be underfunded. When indexation is above the target level, the scheme will tend to be overfunded. We are using the terms underfunded and overfunded to refer to the match between assets and projected outgoings when computed using a fully accurate pricing formula. It is a design feature of shared-indexation schemes that sometimes there will be a surplus which will be used to help other generations and sometimes there will be a deficit which will be made up by other generations.

Suppose members receive transfer values computed using a constant indexation assumption. When indexation is above the target level, members' benefits would be overvalued, so the transfer value would exceed the true value of the benefit. This would mean members would have an incentive to transfer out. This could endanger the viability of the scheme.

To avoid this issue, transfer values could be computed as the smaller of

- the value of their future benefits computed using the constant indexation assumption
- the value of their future benefits calculated accurately

[21] Computed using a constant economic model

This would mean that at times when the scheme was underfunded, members would receive a transfer value that was lower than the true value of their future pension entitlements. For young members of a scheme, our example shows that the transfer value could be as low as 41% below the value of their future pension entitlements. This may discourage members from transferring out of a scheme that is performing poorly.

In the instance of DB schemes being underfunded, members may also be offered transfer values below the value of their future pension payments.[22]

Benefits in retirement in a flat-accrual CDC scheme

To measure the performance of different schemes, we have simulated member benefits in a large number of economic scenarios. We computed the *replacement ratio* for each member of the scheme in retirement. The replacement ratio is the ratio between the member's final salary in real-terms and their pension benefit. In each economic scenario, we computed the average replacement ratio for each member.

We found that the flat-accrual scheme outperformed a DC + Annuity scheme in the sense that all the percentiles of the lifetime-mean replacement ratio from 1% upwards are higher in the flat-accrual scheme. We have shown the percentiles in Table 2.1.

Table 2.1 The flat-accrual scheme outperforms a DC + Annuity design.[23]

Percentile	**1%**	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**
Flat-accrual	14%	23%	30%	36%	42%	51%	61%	77%	102%	157%
DC + Annuity	11%	20%	26%	31%	36%	43%	50%	60%	74%	100%

Percentiles of the lifetime-mean replacement ratio.

It is important to note that Table 2.1 only applies to members who are in the scheme for their whole life and who join when the scheme has settled into a long-term steady state. Members who only contribute in the early part of their career would see much better results from a DC + annuity investment because of the large inter-age cross-subsidies in a flat-accrual scheme.

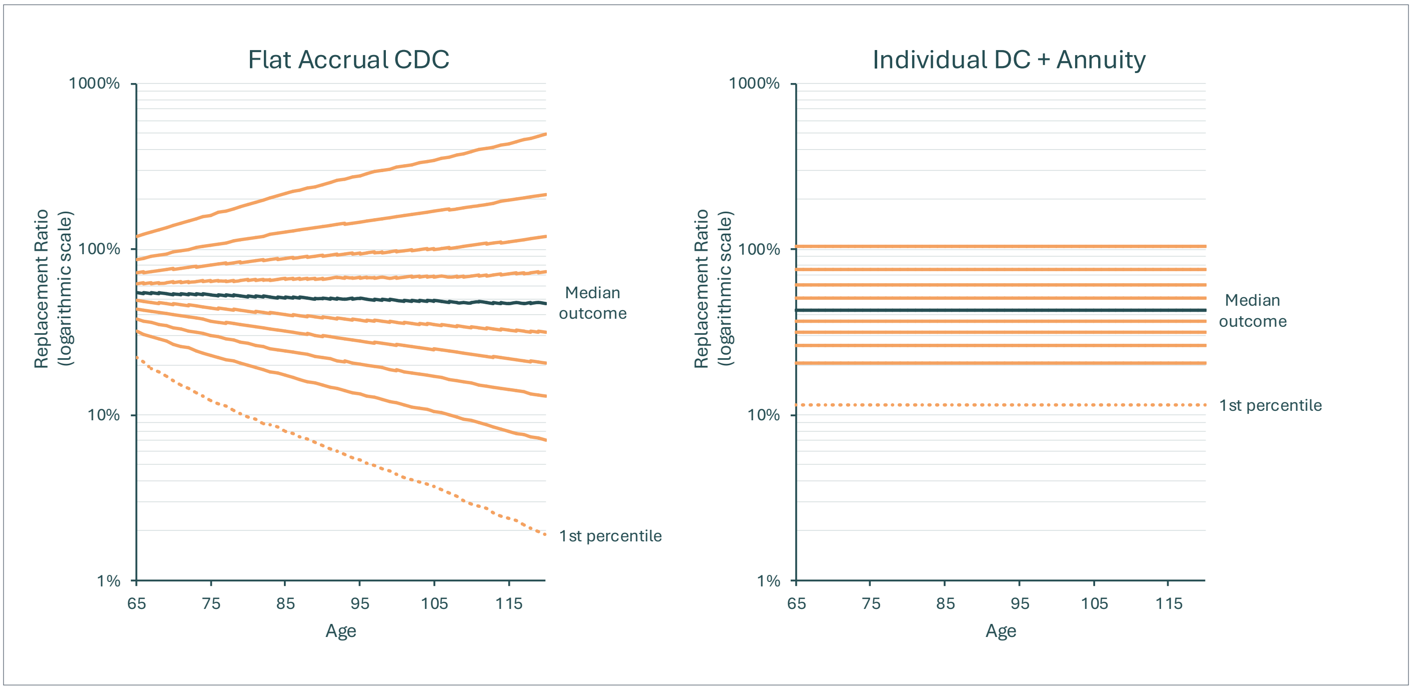
To understand how benefits vary in retirement, we have plotted in Figure 2.3 a diagram showing the range of pension benefits that might be achieved during retirement for a typical investor in a flat-accrual CDC fund.

[22] The Pensions Regulator (2008)
[23] Computed using the PPI economic model

This is a *fan diagram* which shows the deciles of a member's benefits in retirement. The deciles are the 10th, 20th, 30th percentiles and so on up to the 90th percentile. We have also shown a dotted line indicating the 1st percentile. The y-axis of the plot shows the replacement ratio achieved each year. Notice that we use a logarithmic scale so that the bottom percentile is easy to read.

For comparison, we have also shown the same percentiles for someone who invests the same total member and employer contributions in a DC + Annuity scheme.

Figure 2.3 flat-accrual CDC schemes increase in risk during retirement[24]



Fan diagrams of benefit in retirement in a flat-accrual scheme (left) and in DC + annuity scheme (right). Deciles of the replacement ratio, solid lines, the first percentiles are shown with dotted lines.

The flat-accrual scheme is able to provide a higher initial benefit on average than a DC scheme, but with increased risk for older members. The benefits received in a flat-accrual scheme may increase or decrease and the uncertainty in benefits increases into retirement. While the median income from a flat-accrual scheme keeps up with inflation, it is possible for a member's pension to fall quite significantly in real terms over the course of their retirement.

[24] Computed using the PPI economic model

Member communications

Considerable work has been done to consider how the design of shared-indexation CDC schemes can be communicated to members. However, the design is undeniably complex and contains a number of pitfalls.

The concept of nominal benefits is very abstract and easily misunderstood. It is easy to confuse nominal benefits with projected benefits, but it is important to differentiate these concepts.

It has been argued by some in the industry that it could be beneficial to hide some of the volatility of projected benefits from members in order to encourage pension saving, as members may overreact to the inevitable falls in asset values that will occur in some years. However, the UK pension dashboard project requires funds to provide a projected benefit amount where possible, and for consistency with other scheme designs this should not be smoothed.

The risk of CDC investments is an integral part of the design. If members are not prepared in advance for fluctuations in their projected benefits they are likely to react adversely when they fall. For this reason, it would seem advisable to provide some quantification of the volatility of projected benefits. There are standard rules for DC funds describing how benefits should be projected and how the uncertainty of investments should be presented to members. It would be beneficial to provide similar clarity for shared-indexation schemes, especially since the complexities of the shared-indexation design make it quite easy to miscalculate these figures.

> **Recommendation 8:** Members of collective scheme should be informed of their projected real-terms benefit in retirement together with a quantitative assessment of the uncertainty and there should be greater clarity on how these computations may be performed.

Age-related accrual

Rather than use a flat-accrual structure, it is possible to design a scheme where different age groups receive different benefit amounts for the same level of contribution. This could be used to reduce the level of inter-age cross subsidies and the resulting drag effects.

If one wishes to design a shared-indexation scheme that is intended to mirror the behaviour of an existing DB scheme, one can tune the level of cross-subsidy to match the previous scheme. This would help ensure that members received broadly similar benefits according to their age in each scheme. For an example of such a design see the paper Armstrong et al (2025b).

It is possible for such a design to give the earliest generations pension benefits which have a lower value than their contributions. This results in a situation where later generations may receive higher pensions than their contributions, essentially the opposite effect to drag. While this would be beneficial to later generations, it seems unlikely that the first members of the scheme would want to subsidise future members in this way.

Summary

- The only CDC scheme in the UK is the Royal Mail scheme, which is a shared indexation, flat-accrual scheme.
- The modelled flat-accrual scheme outperformed an individual DC + Annuity scheme resulting in higher lifetime-mean replacement ratios at all percentile points in the results distribution.
- Flat-accrual CDC schemes can contain very large inter-age cross-subsides.
- Flat-accrual CDC schemes can experience drag effects resulting in lower performance compared to the other types of collective pension scheme we considered.
- The smoothing of pension payments within flat-accrual CDC schemes is more effective after retirement than before retirement.
- In flat-accrual CDC schemes the probability of having an inadequate pension increases throughout retirement and is higher than in the other collective pension schemes we considered.
- Members may receive considerably less than the value of their accrued benefits if they choose to transfer out of a flat-accrual scheme.

Chapter 3

Dynamic accrual: multi-employer and drawdown-only schemes

This chapter studies dynamic-accrual CDC pensions. This design can be used for decumulation only CDC schemes and multi-employer schemes. The Department for Work and Pensions (DWP) held a consultation on multi-employer CDC in 2024 and the design we consider is aligned with that consultation.

Dynamic-accrual CDC

Dynamic-accrual shared-indexation CDC schemes work very much like the flat-accrual schemes discussed in the last chapter, except that the amount a member pays to accrue additional nominal benefits depends upon:

- the prevailing level of indexation
- underwriting of the member by factors, including age.

This is called dynamic-accrual because the prevailing level of indexation will change from year to year, so the price of benefits will also vary from year-to-year and member-to-member. Flat accrual, on the other hand, is both fixed over time and independent of a member's age.

Members are charged an amount equal to the value of their benefits as calculated using the central-estimate methodology described in current UK CDC regulations. This formula includes terms which take into account both the time-value of money and the increased risk of longer-term investments. As a result, members do not need to pay as much for benefits they will only receive a long time in the future. This is designed to prevent dynamic-accrual schemes containing the inter-age cross-subsidies seen in flat-accrual schemes.

Example 3.1:

Alice is 27. She contributes £2000 to a dynamic-accrual scheme. Her additional annual nominal benefit amount depends upon the prevailing level of indexation. When indexation is 1% below the long-term target level, she receives £3442 additional annual nominal benefit amount. When indexation is 1% above the long-term target she receives £1389 additional annual nominal benefit amount.

Bob is 64. He contributes £2000 to a dynamic-accrual scheme. When indexation is 1% below the long-term target level he receives £204 additional annual nominal benefit. When indexation is 1% below the long-term target level he receives £171 additional annual nominal benefit.

Dynamic-accrual schemes have limited capacity to target a desired rate of long-term indexation

In a dynamic-accrual scheme, the cost of additional benefits is determined by the prevailing level of indexation. In a flat-accrual scheme, the scheme designer gets to choose the relationship between costs and benefits. This gives a flat-accrual scheme designer one more parameter they can adjust than the designer of a dynamic-accrual scheme, and this allows the designer of a flat-accrual scheme to target a long-term level of indexation by tuning this parameter.

To target a given level of indexation in a dynamic-accrual scheme, all the scheme designer can change is how risky the investments should be and the upper and lower bounds on indexation. However, changing the risk of investments will change the overall risk of the scheme and this is undesirable. On the other hand, if the level of indexation is allowed to drift too far from inflation, this may make the scheme unattractive either because pensions don't keep up with prices or because benefits become too expensive. This makes it harder to hit a given indexation target in dynamic-accrual schemes.

Deterministic pricing leads to errors in dynamic-accrual CDC

From our industry consultation, we found providers who were considering dynamic-accrual schemes intended to price benefits using a central-estimate methodology, where indexation is assumed to remain constant.

If prices are calculated applying an assumption that indexation will remain constant, this will lead to pricing errors. While the assumption is not unreasonable over a short-term time horizon, over the long-term the fact that indexation is bounded above and below means that the long-term level of future indexation is primarily determined by these bounds rather than the current rate of indexation. These boundaries can be used as a mechanism to target a long-term level of indexation. As a result, in the long-term, the assumption of constant indexation is incorrect. This leads to similar pricing errors to those seen in flat-accrual CDC.

This highlights a flaw in the central-estimate methodology. This methodology approximates uncertain future changes by assuming that they were deterministic. In a deterministic model, the prevailing level of indexation remains constant, so the upper and lower boundaries of indexation are never hit. In a model with uncertainty, the indexation will fluctuate and will eventually hit either the upper or lower boundary. This leads to qualitatively different behaviour in an uncertain model to a deterministic model.

A financial derivative is any contract whose payments are determined in a non-linear fashion from the behaviour of assets. The pricing formulae used to compute the payoffs in a shared-indexation scheme are complex and non-linear. This means that to accurately compute the value of assets in a shared-indexation scheme one needs to use the methods of derivative pricing. We explain a little more about financial derivatives in Appendix B, where we will see how the concept of replication can be used to value complex contracts.

Computing the price of derivatives in realistic markets is challenging, and there is some subjectivity in which model to use. To avoid this, when we studied pricing in this project, we used a slightly simplified model called the Black-Scholes model where it is possible to price derivatives unambiguously.

Using this model, we found that dynamic-accrual schemes using deterministic pricing can over- or under-charge members by as much as 50%. When the prevailing-level of indexation is higher than its long-term median, the scheme will overcharge for benefits, because indexation will fall in the long-term. When the prevailing-level of indexation is lower than its long-term median, the scheme will undercharge for benefits, because indexation will rise in the long-term. The difference is more acute for the youngest members of a scheme.

Finding: Pricing benefits by assuming that indexation will remain constant can lead to large pricing errors of up to 50% in both flat- and dynamic-accrual designs.

One way to address these pricing errors is for an employer to make sufficiently large additional contributions. Doing this makes it possible to guarantee that it is always in a member's interests to pay into the scheme.

These pricing errors largely cancel out on average. The average net effect results in the youngest members receiving on average a value of approximately 12% less than they pay in. Thus, inter-age cross-subsidies still exist in dynamic-accrual CDC, but they are much less dramatic than in flat-accrual CDC and are dominated by the fluctuating pricing errors caused by changes in indexation.

Although these fluctuating pricing errors do not have a large adverse impact on the average benefits received by members, the uncertainty in these fluctuations may add to the risk that members face, potentially lowering the risk-adjusted performance of CDC schemes. This is another illustration of why it is incorrect to believe that the long-term performance of a CDC scheme will match the long-term performance of its assets.

The results described in this section explain why it is essential to think of shared-indexation CDC designs as derivative products and price them accordingly. This justifies the following recommendation.

Recommendation 5: CDC pensions which attempt investment-risk pooling are derivative products and benefits should be valued accordingly. Schemes offering such pensions should be required to seek advice on derivative pricing and regulators may also need to develop appropriate expertise in this area.

Pension outcomes in dynamic-accrual CDC

The dynamic-accrual CDC scheme we modelled outperformed the flat-accrual scheme when measured by the lifetime-mean replacement ratio at a 90% confidence level. The two schemes were designed to have similar investment strategies. By adjusting the dynamic-accrual's strategy to invest in less-risky assets, we were also able to find a dynamic-accrual design which outperforms the flat-accrual design at the 99% confidence level.

This outperformance is possible because the dynamic-accrual does not experience the drag effect seen in flat-accrual. This outperformance occurs on the assumption that the flat-accrual scheme follows the investment strategy that emerged from our industry consultation. We will see in Chapter 4 that there are situations where flat-accrual and dynamic-accrual perform equally.

Table 3.1 Dynamic-accrual outperforms flat-accrual at a 90% confidence level in the lifetime-mean replacement ratio when both invest in a similar asset mix.[25]

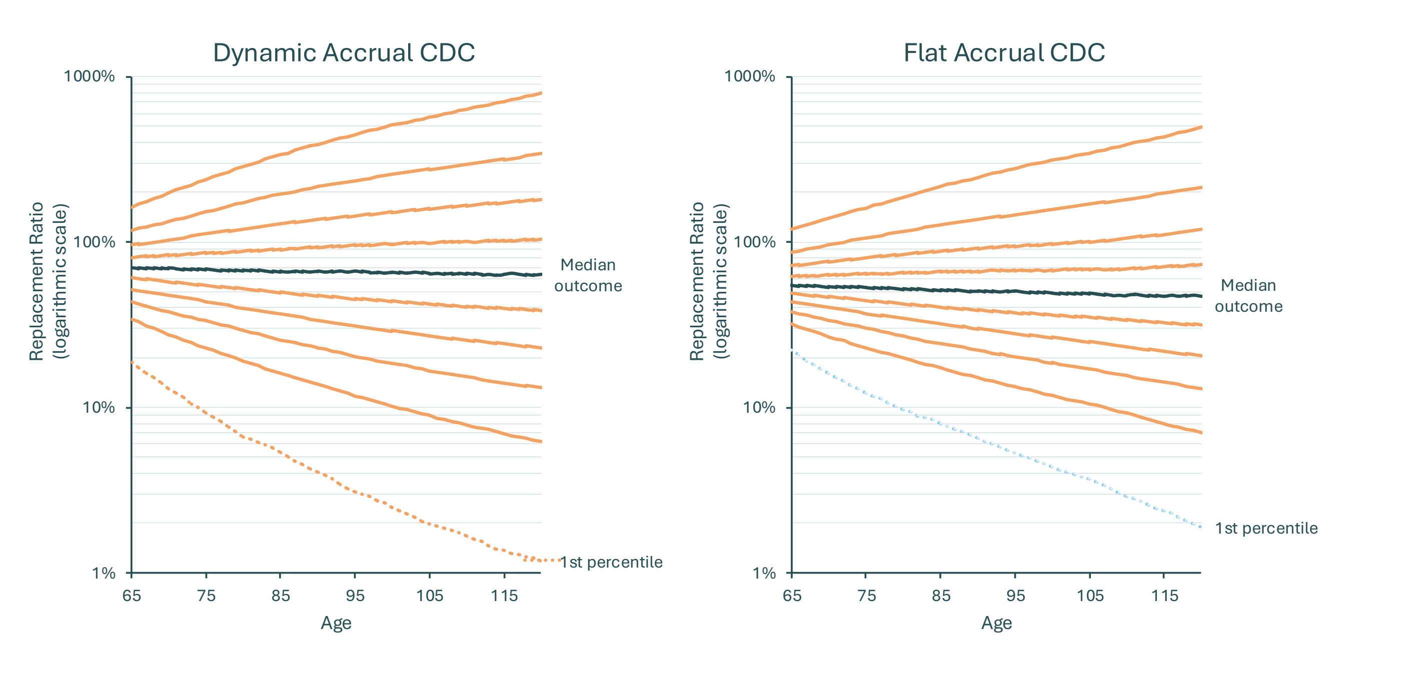
Percentile	1%	10%	20%	30%	40%	50%	60%	70%	80%	90%
Flat accrual	14%	23%	30%	36%	42%	51%	61%	77%	102%	157%
Dynamic accrual	10%	23%	31%	41%	53%	66%	83%	109%	151%	245%

Percentiles of the lifetime-mean replacement ratio for a flat-accrual scheme and a dynamic-accrual scheme both pursuing a similar investment strategy

We have shown how benefits vary with time in Figure 3.1. As with flat-accrual, risk increases with time since retirement.

[25] Computed using the PPI economic model

Figure 3.1: The benefits in dynamic-accrual and flat-accrual both increase with time since retirement.[26]



Deciles of the replacement ratio in retirement for a dynamic-accrual CDC fund (left, solid lines) compared with a flat-accrual CDC fund (right, solid lines). The first percentiles are shown with dotted lines. Both funds are invested in similarly risky assets.

We have shown the smoothing effects of dynamic-accrual schemes on projected benefits in Figure 2.2 in the previous chapter. They are comparable to those seen in flat-accrual schemes.

Multi-employer schemes

If two employers have employees with different age profiles or different mortality distributions, then it will not make sense for both employers to share a flat-accrual CDC scheme. This is because the large inter-age cross subsidies in flat-accrual will benefit one employer more than the other.

Within a dynamic-accrual scheme any difference in age profile is less important due to the reduced inter-age cross-subsidies. A difference in mortality distributions will still be important, unless additional underwriting is performed, otherwise the employer whose members have the longest life expectancy will benefit the most.

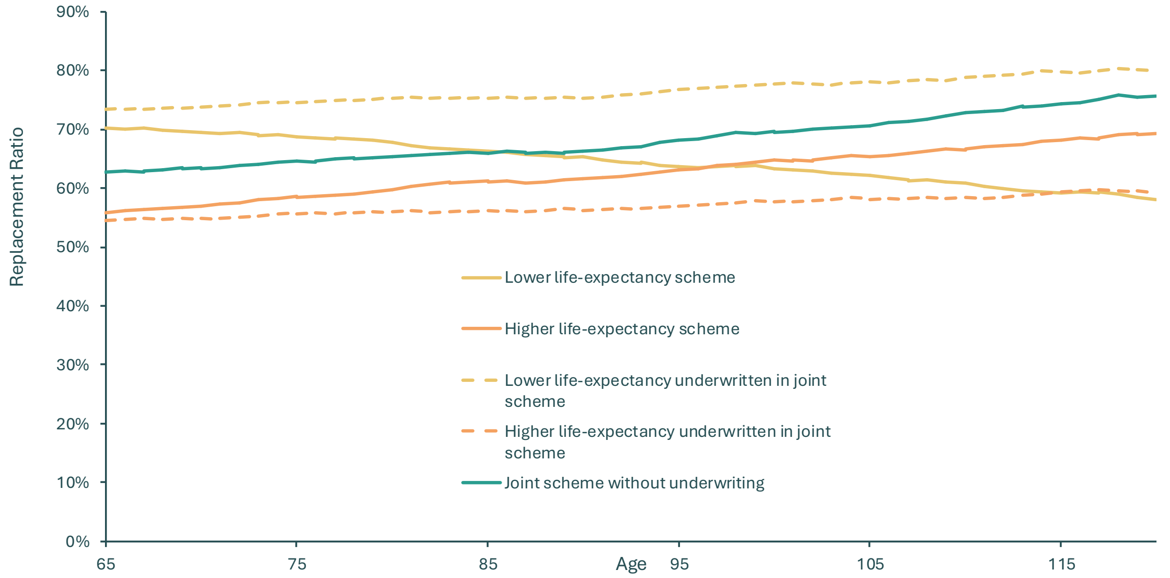
We assessed the impact of combining employers in a single scheme, when one employer has employees with a shorter life-expectancy.[27] The difference in life-expectancies was chosen to be the same as the difference between men and women in the population.

[26] Computed using the PPI economic model
[27] Upton, J, PPI (2024)

Underwriting does not have the same effect as sectionalisation of a scheme

In a mixed scheme with no underwriting, all members receive a 63% median replacement rate at retirement. In contrast, if members were sectionalised by life expectancy, the high life expectancy and the low life expectancy groups would receive replacement rates of 56% and 70% respectively. However, in a joint scheme with underwriting, they receive 54% and 73% respectively [Figure 3.2].

Figure 3.2 Underwriting does not fully mitigate the impact of heterogeneous life expectancy in a scheme[28]



The chart shows median incomes in retirement for low-life expectancy and high-life expectancy groups.

This demonstrates that underwriting could overcompensate and reduce the retirement outcome of the high life-expectancy group, by subsidising the low life-expectancy group. These results should not necessarily be taken to demonstrate that underwriting will always overcompensate in this way. When looking at the median replacement rate achieved over the lifetime, there are no clear trends that can be observed.

The modelling demonstrates that underwriting cannot always fully mitigate unfairness in a multi-employer scheme. There could be legitimate unfairness concerns for overly diverse scheme memberships. If these kinds of inequalities are permitted to exist, the scheme may become unfair, or at least, be perceived to be unfair. The consideration for multiemployer schemes might be whether there are life expectancy inequalities at the employer level. Even if no significant inequalities exist between employers, providers of multi-employer schemes may not have the same level of knowledge of their membership as a single-employer scheme might.

[28] Computed using the PPI economic model

While these results show that these two approaches can benefit some members more than others, it should be remembered that the overall benefits of the scheme (when compared to individual DC) may outweigh any disadvantage particular groups members may receive.

In addition, there are situations in which strict actuarial fairness is not perceived as the most equitable approach. For example, on a purely actuarial basis, the longevity difference between men and women should result in different prices for longevity products, but equal prices for men and women may still be perceived as more equitable. Other factors which may result in cross-subsidies include socio-economic status and occupation. Employers consciously choose to accept certain cross-subsidies and pursue outcomes on this basis. They may be especially likely to do this if they previously operated a DB scheme and wish to avoid a transition that may be perceived as unfair.

Our results suggest how sectionalising can mitigate the issue of unfairness that arises from differences between various socioeconomic groups. It should also be acknowledged that there are limits to the use of underwriting. Even if two groups have different life expectancies on average, many individuals from the low life expectancy group will outlive many individuals from the high life expectancy group. This will be down to individual factors, and these factors should not be underwritten against, as doing so would defeat the purpose of CDC, which is to pool longevity risk. These individual factors may contribute to a person's life expectancy more than any factors that could be practically underwritten against. Likewise, some factors such as sex may not legally be underwritten against. Even for factors for which it would be valid to underwrite against, there are practical limits to how much underwriting you can do and how accurate you can be.

An alternative approach which could be explored is to have sectionalised schemes, but to still share individual longevity risk between those schemes. We discuss briefly how this might be done in the next Chapter.

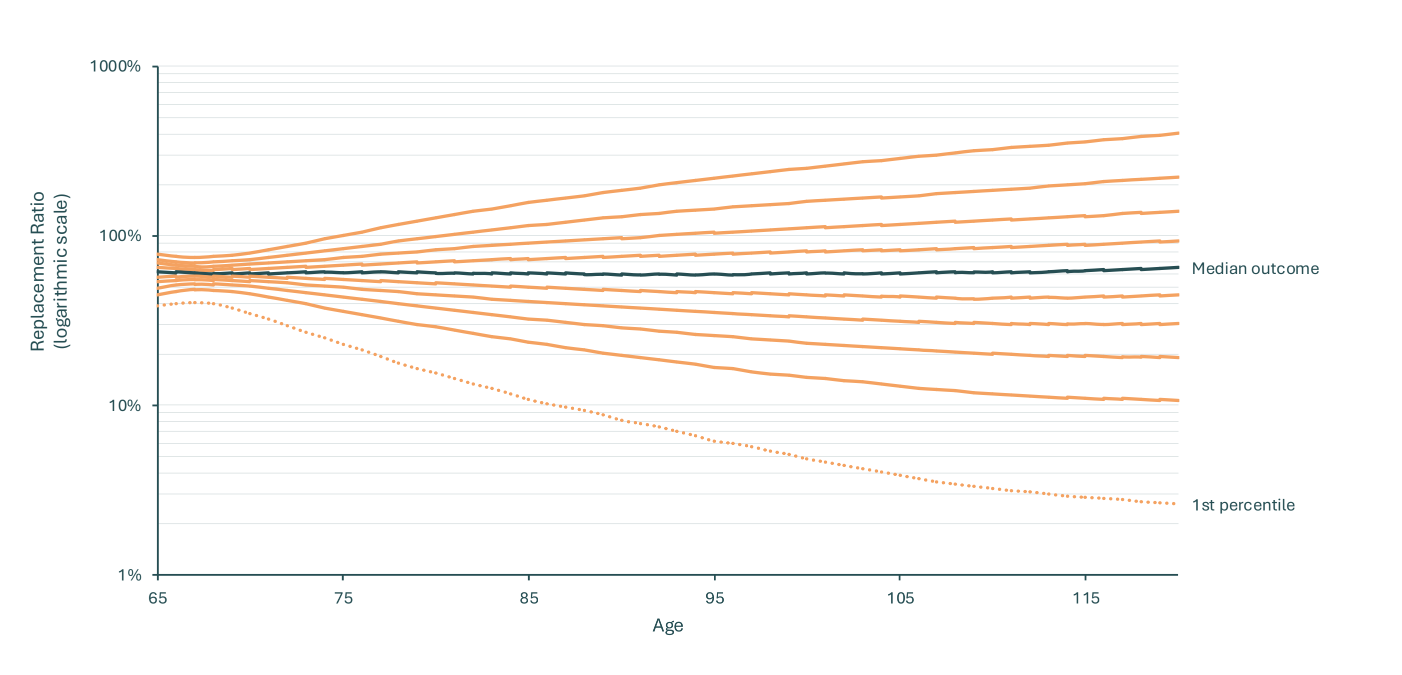
Decumulation-only schemes

A dynamic-accrual design could be used as the basis for a decumulation-only scheme. In return for a lump sum at retirement, members would receive an annual nominal benefit amount for the rest of their life.

Since there is a single lump-sum payment, it is essential in a decumulation-only scheme that the benefits a member receives are priced fairly. We have seen that the pricing errors for the oldest generations in dynamic-accrual schemes are much lower than those for the youngest generation, of the order of 5% [Example 2.8]. This is of the same order as the premium we have assumed one must pay to purchase an annuity to allow for systematic longevity risk, so this level of pricing error seems acceptable.

We have modelled a decumulation-only scheme using the same target level of indexation, life-styling strategy, and upper- and lower-bounds on indexation we used for the all-life scheme. The results are illustrated in Figure 3.3.

Figure 3.3: Deciles of the replacement-ratio in a decumulation-only dynamic-accrual scheme (solid lines), together with the first percentile (dotted).[29]



What one notices from Figure 3.3, is that even though we have assumed the pot-size at retirement is a fixed proportion of final salary, there is considerable variation in the replacement ratio at retirement. This presents a challenge for decumulation-only schemes, as the attractiveness of the scheme to new members will depend heavily upon the prevailing level of indexation. A member may not want to join a scheme that anticipates providing benefit increases below inflation. The bounds on indexation would need to be chosen very carefully to provide sufficient smoothing (which requires wider bounds to avoid benefit cuts and bonuses) while ensuring the expected growth rates and the price of benefits are all acceptable.

This challenge is, in a sense, also present in all-life schemes. If a member could transfer out at a fair price to another scheme at retirement, they might prefer one which had a different prevailing level of indexation. Thus, members of an all-life shared-indexation scheme are exposed to the risk of the prevailing level of indexation being unattractive at the point of retirement.

Statistically calibrated accrual: It is possible to improve the pricing formula to take into account the fact that indexation will tend to a long-term level. We did this by first computing the price of benefits accurately using rigorous financial mathematics techniques and then finding a simple, but more accurate, approximation formula using statistical techniques. We used this to create a statistically-calibrated version of dynamic-accrual which contains lower (but still non-trivial) pricing errors. We will see in Chapter 4 that this design is able to outperform the standard dynamic-accrual approach.

[29] Computed using the PPI economic model

Summary

- Dynamic-accrual CDC contains much lower inter-age cross-subsidies than flat-accrual schemes.
- Dynamic-accrual CDC schemes do not experience the drag effects seen in flat-accrual CDC.
- Assuming constant indexation when pricing dynamic-accrual schemes can lead to large pricing errors, especially for younger members. Either employer contributions must cover this, or a different pricing approach must be used.
- The dynamic-accrual scheme outperforms the flat-accrual scheme when we assume both invest in an asset mix that matches industry expectations.
- Dynamic-accrual CDC behaves similarly to flat-accrual CDC in terms of smoothing benefits. It smooths benefits after retirement but does not significantly smooth benefits before retirement.
- Dynamic accrual can be used for multi-employer schemes, but it may be preferable for different employers' funds to share only longevity risk rather than pooling their investments. See Chapter 4.
- Dynamic-accrual designs might be considered for decumulation only schemes, but fluctuating levels of indexation may result in fluctuating demand.

Chapter 4

Collective drawdown: Collective pensions with investment choice

This chapter studies collective-drawdown CDC pensions. The term "collective drawdown" has been introduced in this project. It describes a scheme which provides longevity insurance without requiring all the scheme's assets be pooled in a way that separates investment-risk from longevity-risk.

Collective drawdown

Let us now consider an alternative approach to shared-indexation schemes which we call a *collective-drawdown* scheme. This scheme operates very much like a DC scheme with drawdown in retirement because every member has their own investment pot which is used to fund their retirement income. The key additional features of a collective-drawdown scheme are:

- Members do not leave a bequest when they die, instead their assets are shared among survivors to provide a form of longevity insurance.
- The scheme designer chooses the investment strategies and the rate at which to drawdown in retirement so that members do not have to choose an optimal strategy.

We will also use the term “collective drawdown” to describe an extension of this idea, discussed in Appendix B, which allows members to provide other forms of mutual insurance.

Provider Architecture

The design of collective-drawdown schemes allows a pension provider to offer separate scheme designs for different employers. In Figure 4.1 we have drawn a schematic diagram of how these schemes would work together.

A pension provider would design schemes that meet the needs of different employers. As part of this process, they would conduct underwriting to estimate the mortality distribution of the employees. The pension provider could design more than one scheme for each employer if they have a diverse workforce, or if they wish to provide employees with choice between riskier and less risky investment approaches. The design of each scheme provides an overall strategy for how much to invest each year, how much risk to take and how much to pay in benefits. This is the “employer layer” in our schematic diagram.

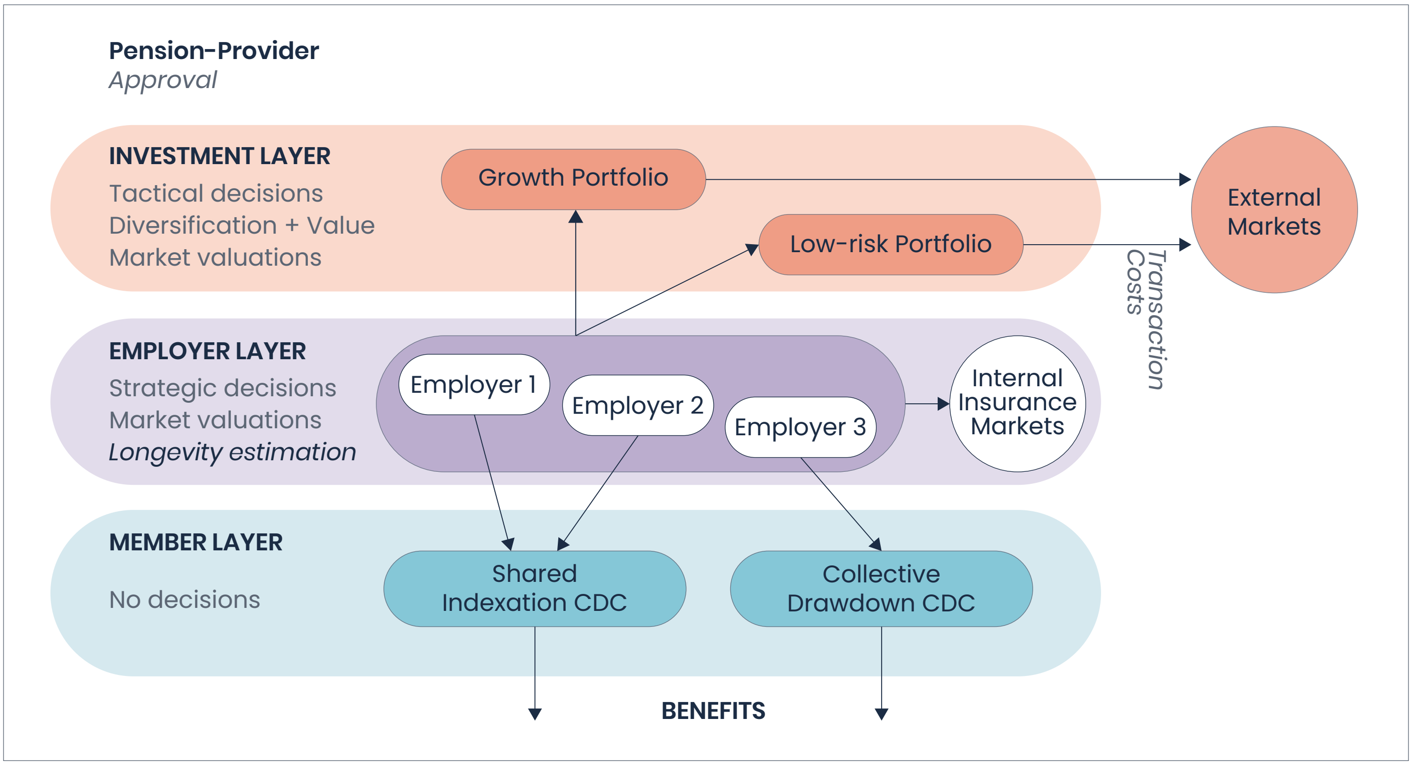
A pension provider must then put these strategies into practice. To do this they can manage a number of internal investment funds. For example, they could maintain a fund of higher-risk investments in emerging technologies, a lower-risk fund tracking a stock index and a low-risk fund investing in bonds. The details about how to invest can be performed at the level of these internal investment funds. The trades needed to maintain the funds according to the needs of each scheme can then be netted together, reducing the transaction costs which occur when trading with external markets. This is the investment layer in our diagram.

As the strategy is chosen at the employee layer, individual members do not have to make complex investment decisions. They make contributions and in retirement they will receive an income from their investments. This is the member layer in our diagram.

The final ingredient is an internal market which is used to provide longevity insurance. We will explain how this internal market operates in the next section.

Figure 4.1: Schematic diagram of the proposed provider architecture.

Key areas where costs are incurred are highlighted in italics.



This architecture is intended to reduce the costs of the scheme while maximising the benefit that can be achieved from the internal insurance market. This architecture could be used for both collective-drawdown schemes and shared-indexation schemes. A single provider could offer both pension products if they wished.

At present, UK CDC regulations require that shared-indexation schemes for members with divergent demographic characteristics are kept separate. This makes it hard to create schemes for small employers, as the fund needs to be reasonably large for longevity pooling to operate effectively.

If providers were able to share longevity risks as indicated in this architecture, one would only need the total number of members across all employers to be sufficiently large for longevity pooling to operate efficiently. Thus, our proposed architecture makes it possible to offer small bespoke schemes for many different employers without damaging the efficiency of the design.

Operation of the internal insurance market

The internal insurance market operates by allocating the funds left behind by deceased members to the survivors. This is done in proportion to how much each member would have contributed to the fund themselves had they died during the year. In this calculation, the contribution is estimated by multiplying the probability of a member dying during the year by the value of their fund at the end of the year.

Example 4.2:

Alice is aged 70 and has a probability of dying over the next year of 2%. The value of her pension pot at the beginning of the year is £200,000. Her assets are invested in a conservative fund which grows by 4% over the year. Alice's contribution is equal to 2% x (1.04) x £200,000 = £4160

Bob is aged 80 and has a probability of dying over the next year of 6%. The value of his pension pot at the beginning of the year is £150,000. His assets are invested in a risky fund which falls by 2% over the year. Bobs's contribution is equal to 6% x (0.98) x £150,000 = £8820

Cyril is aged 100 and has a probability of dying over the next year of 36%. The value of his pension pot at the beginning of the year is £10,000. His assets are invested in a very conservative fund which grows by 2% over the year.

Alice and Bob both survive the year, but Cyril dies, leaving £10,200. This is distributed in accordance with Alice and Bob's contribution, so Alice receives 32% of Cyril's pot, giving her £3,265. Bob receives 68% of Cyril's pot, giving him £6,935.

The important feature of this design is that it shields members from the investment decisions made by other members. It is a fair trade based on the investment returns each member has made. It is this aspect of the design that makes it possible for very different members following very different investment strategies to insure each other in a fair way. This makes it possible to combine many different employers and age groups in a single internal insurance market.[30]

In a collective drawdown scheme every member has an individual investment fund from which they drawdown in retirement. The only pooling that occurs is through the internal insurance market and through the netting of trades in the investment layer. In a shared-indexation scheme, longevity pooling also occurs, but the design of the scheme does not separate longevity pooling from investment pooling.

[30] Similar forms of longevity insurance have been used for centuries. The basic principle of a survivor fund is sometimes called a tontine. See Milevsky (2015) for a historical account of their development. A very similar method of separating investment risk and longevity risk to the one we use is described in Donnelly et al. (2014). Our approach simplifies this to work in discrete-time, and we then compute optimal investment strategies within such a scheme. See Armstrong et al. (2025c) for a more extensive literature review.

A shared-indexation scheme can also benefit from a longevity insurance market using the same principles. At the end of each year the scheme pays into the pool an amount equal to the fund value of its deceased investors and receives payments in proportion to the contributions of the survivors. This allows longevity risk to be pooled across shared-indexation schemes. This could be used to eliminate the difficulties we saw in the previous chapter when members with different demographic characteristics are placed in the same dynamic-accrual scheme.

The larger the number of members in the internal insurance market, the more effective it will be. We have performed numerical simulations that indicate that once a fund has about 100 members it already achieves about 98% of the maximum potential benefit (when measured in cash terms[31]). As a result, we will assume in all our calculations below that the fund is sufficiently large to achieve the maximum possible benefit from investment pooling.

Choice in collective-drawdown schemes

In a collective-drawdown scheme, each member has an associated pension pot, which must be invested and from which they drawdown their pension. There are many possible strategies for deciding how to do this.

It is very challenging for an individual member to choose this strategy. Instead, we envisage the strategy being designed by the pension provider in consultation with the employer. They may identify a small number of strategies that might be appropriate, with members then being presented with a simpler choice between a small number of options. For example, the pension provider might offer members three strategies: a default strategy; a low-risk, low-return strategy; a higher-risk, higher-return strategy.

There is no universal "best" investment strategy. Some members may prefer more risk; some may prefer less. The ability to provide members with some degree of choice in their pension allows them to tailor their pension to their own preferences, and doing so will help ensure that the pension meets their needs.

It would be possible to go further and to allow members to choose their investments and rate of drawdown themselves while still benefiting from the internal insurance market. This would be a form of self-invested pension (SIP) that still enjoys the benefits of a collective scheme. The central issue this would raise is how and when to perform sufficiently accurate underwriting for an individual member for them to be able to participate in the internal insurance market. We won't consider the possibility of such a collective SIP further in this report as we expect it would only appeal to a small number of pension investors.

[31] see Armstrong et al. (2025a)

Designing investment and drawdown strategies

It is the job of the pension provider to design investment and drawdown strategies for their members. In our modelling, we have assumed that the pension provider will use a mathematical approach to identify optimal strategies when judged according to appropriate criteria.

In this approach, each strategy is given a numerical score according to how well it performs in simulations, and the best strategy can be found by maximising this numerical score. In the past, finding the best strategy was very difficult, but advances in machine learning have made this type of problem reasonably straightforward to solve once you have decided how to assign the numerical scores.

There is no single correct way of assigning a score to a strategy. The best pension plan will always be a matter of personal opinion. To design our score functions we included three different parameters which can be customised to match a member's preferences.

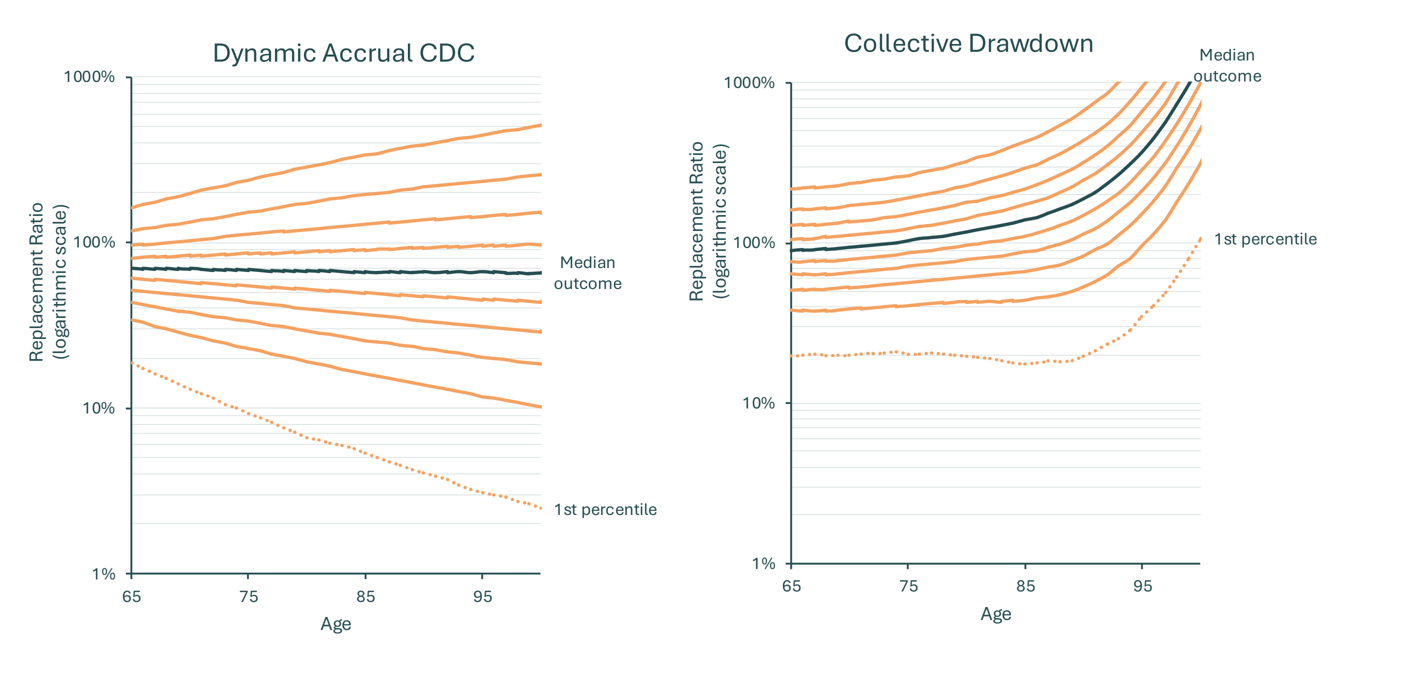
- The score should consider pension adequacy. This is the level of pension needed to satisfy a member's basic needs.
- The score should consider satiation. Some members may be happy if their pension is adequate and not see the need for having a much greater income, others may strongly value being able to afford many additional luxuries.
- The score should consider risk-appetite. Some members may want greater certainty over their income in retirement; others may be willing to take more substantial risks to obtain a better income.

To understand one's own preferences, one can look at the optimal pension outcomes achieved for different score functions. Once you have identified the pension outcomes that looks best for you, you will then have identified your own personal score function.

We assumed that a typical member might want to see pension outcomes that were similar to those achieved by a dynamic-accrual scheme. We made this assumption because the dynamic-accrual scheme achieved the best performance of the scheme types considered previously, and because our consultations suggested that this scheme broadly matched industry understanding of how much risk it is appropriate for a member to take.

To find a collective drawdown design which gave outcomes comparable with a dynamic-accrual scheme, we varied the parameters of our score functions and examined the resulting optimal outcome. We continued to vary the parameters until we found a strategy whose outcomes were easily compared with the outcomes of the dynamic-accrual scheme. The results are shown in Figure 4.2 below.

Figure 4.2: Collective drawdown outperforms dynamic-accrual[32]



Deciles of the replacement ratio for a dynamic-accrual scheme (left, sold lines), vs deciles of the replacement ratio for one choice of collective-drawdown strategy (right, solid lines). The first percentiles are shown in each case with dotted lines.

In the pension outcomes illustrated in Figure 4.2, the collective-drawdown scheme always outperforms the dynamic-accrual shared-indexation scheme. This suggests that, irrespective of one's risk preferences, the strategy identified in Figure 4.2 outperforms the shared-indexation scheme.

The results of our modelling for all the different designs we have considered are shown in Table 4.1 below. The collective drawdown design outperforms all the other designs when assessed in terms of the top 99% percentiles of the lifetime-mean replacement ratio.

Table 4.1: Collective drawdown outperforms DC + Annuity, flat-accrual and dynamic-accrual designs. The scheme designs in this table have not been optimised.[33]

Percentile	1%	10%	20%	30%	40%	50%	60%	70%	80%	90%
DC + Annuity	11%	20%	26%	31%	36%	43%	50%	60%	74%	100%
Flat accrual	14%	23%	30%	36%	42%	51%	61%	77%	102%	157%
Dynamic accrual	10%	23%	31%	41%	53%	66%	83%	109%	151%	245%
Collective Drawdown	24%	48%	67%	85%	105%	128%	155%	192%	249%	353%

Percentiles of the lifetime-mean replacement ratio for all the designs considered so far.

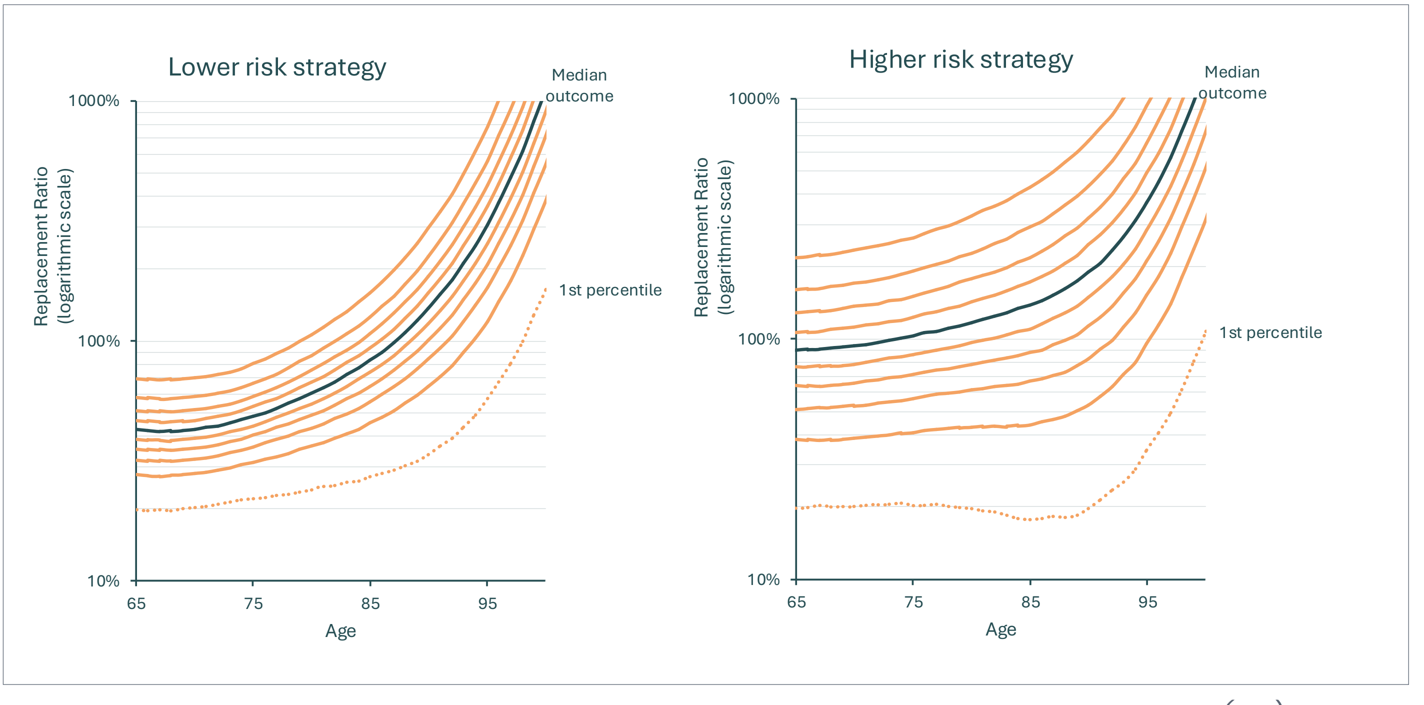
[32] Computed using the PPI economic model
[33] Computed using the PPI economic model

This does not mean that the strategy illustrated in Figure 4.2 is the optimal strategy for all members. Figure 4.3 shows two different illustrative sets of pension outcomes, one which is optimal for a more risk-averse member and another which suits a less risk-averse member. The more risk-averse member draws down more slowly on their pension to improve their chances of having a better income later in retirement.

The design of our collective-drawdown scheme would allow members to choose between these alternatives.

The lower-risk, and higher-risk strategies we have shown are purely illustrative. The pension provider and employer should carefully consider the needs of the members to design appropriate strategies. Using machine-learning techniques it is possible to quickly identify how the optimal strategy will change if you vary any of the parameters in the score function. This provides a tool that could be used to help in designing an appropriate strategy.

Figure 4.3: Collective drawdown allows members to choose their preference between different strategies.[34]



The deciles of the replacement ratio for the optimal strategy for a more risk-averse investor (left) and a less risk-averse investor (right). The first percentiles are shown in each case with dotted lines. The strategy on the right is the same as shown in Figure 4.2.

[34] Computed using the PPI economic model

Risk-adjusted comparison of schemes

To generate the collective drawdown design shown in Figure 4.2 we had to choose a score function. In this section, we will assume that this is the score function of a typical investor. Using this assumption, we can calculate the certainty equivalent of any scheme design. This is defined to be the level of guaranteed income in retirement that would give the same score. This gives a risk-adjusted assessment of the merits of different scheme designs.

In Table 4.2 we have shown the certainty equivalents for different scheme designs. In this table we have optimised all the scheme designs' investment strategies to find the one which gives the best value of the typical investors score function. The optimal-level of risky investment in the shared-indexation schemes was lower than the level of risky-investment we have used earlier in this report. See Appendix C for a sensitivity analysis of these results.

Table 4.2: In our model, collective drawdown provides an approximately 75% better pension than an optimally invested DC strategy followed by full annuitisation.[35]

Design	Certainty-equivalent replacement ratio
Optimal DC + Annuity	0.35
Optimal DC + Flex-then-fix	0.51
Optimal flat-accrual CDC	0.44
Optimal dynamic-accrual CDC	0.45
Optimal statistically-calibrated CDC	0.52
Collective drawdown	0.62

Certainty equivalents of different scheme designs using the same score function as Figure 4.2

Our headline figure of an approximate 75% improvement of collective drawdown over DC + Annuity comes from this table: 0.62 is 77% larger than 0.35. We have rounded this down to avoid giving a spurious impression of accuracy.

Collective drawdown gives the best performance of all the scheme designs. In Appendix B we explain the mathematical theory that shows why collective drawdown will always give the optimal strategy. Because the optimal flat-accrual and dynamic-accrual have lower investments in risky assets than we used in our earlier modelling, we now find that they both perform approximately equally well from the perspective of our reference investor. This is because the size of the drag effect decreases rapidly as the risk of the investment strategy decreases.[36]

[35] Computed using the PPI economic model
[36] See Armstrong et al (2025b)

The central theme of this report is risk-management. The reason collective drawdown is able to outperform other designs is that it manages risks more effectively. Surprisingly, some studies of CDC design have not attempted to quantify risk and have focussed attention exclusively on expected benefits.[37] Moreover, throughout this report we have seen various unexpected phenomena which could have been detected in simulation studies. This leads to the following recommendations.

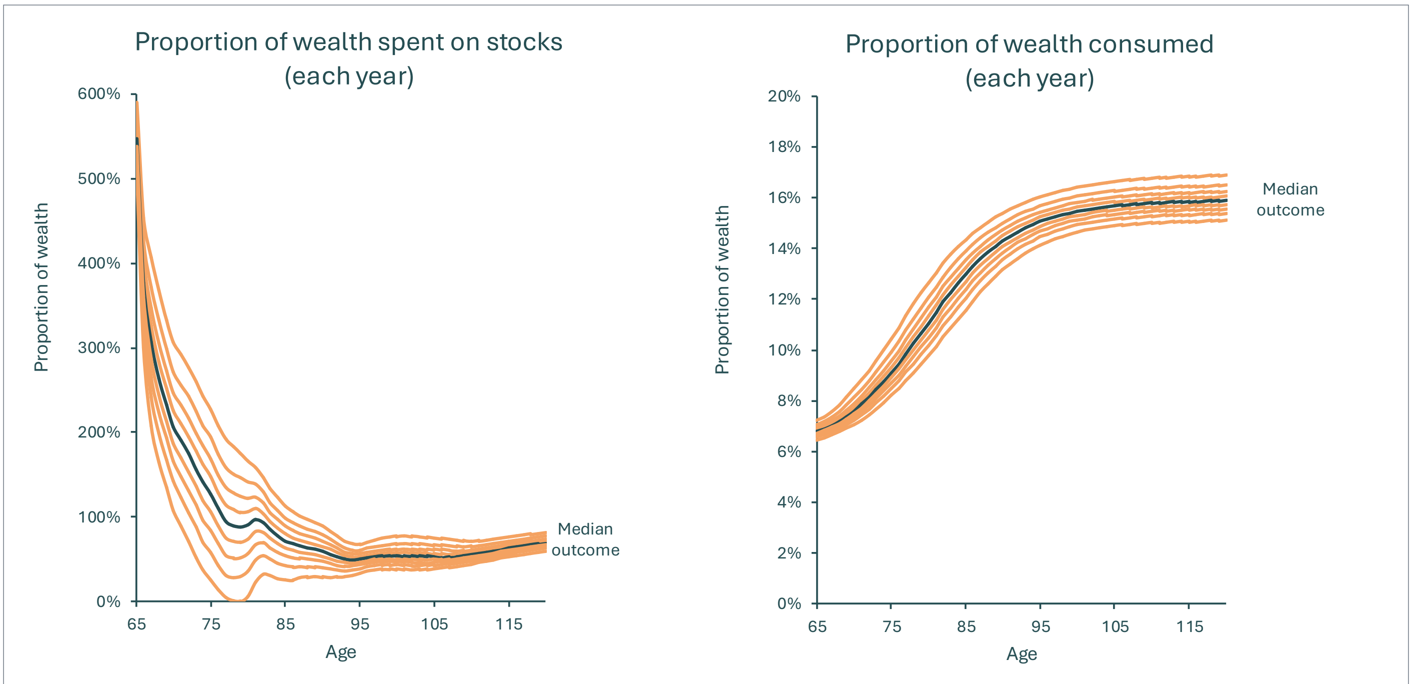
> **Recommendation 6:** Regulators should require schemes to quantify the risk of any collective design in published simulation studies. Investment strategies should be validated using simulations as part of the routine assessment of a scheme's performance.

> **Recommendation 2:** Pension providers and employers considering different collective scheme designs should consider benchmarking their designs against a collective-drawdown approach.

Leverage

The optimal proportion invested in risky assets (stocks) and the optimal rate of consumption for the medium-risk investor are illustrated in Figure 4.4.

Figure 4.4: The optimal strategy is leveraged during accumulation



Deciles of the optimal proportion invested in stocks for the less risk-averse investor (left) and deciles of the optimal proportion to draw down each year (right).

[37] For example, WTW 2020.

Where more than 100% of a member's funds are invested in risky assets, this indicates that the member is taking a leveraged position which seeks more risk and proportionately more return than investing in a stock-market index.

One way to take a leveraged position is to borrow money, and use this to purchase more stocks, but this is not practical for an individual investor. Another way to take a leveraged position is to invest in riskier assets that have the potential for high returns, such as in emerging technologies. Our model doesn't specify the strategy used to obtain higher returns and higher risk than a stock-market index.

When one considers the total amount invested in stocks by an entire scheme containing members of different ages, the scheme as a whole will not need to take as highly leveraged position (or will only need to take a modestly leveraged position). This is because the most leveraged investments occur when a member is young and they have not accrued a particularly large pot. The scheme as a whole can then allow younger members to take leveraged investments without needing to borrow money externally and without needing to identify alternative higher-risk higher-return investments.

Shared-indexation schemes also provide younger investors with leveraged investments. This is because the effect of a change in the prevailing level of indexation is felt much more strongly by younger members than older members, and this produces a leveraging effect.

These results show that the potential benefits of a collective-drawdown scheme come partly from the internal insurance market, but also from the benefits of netting members' funds when interacting with external markets.

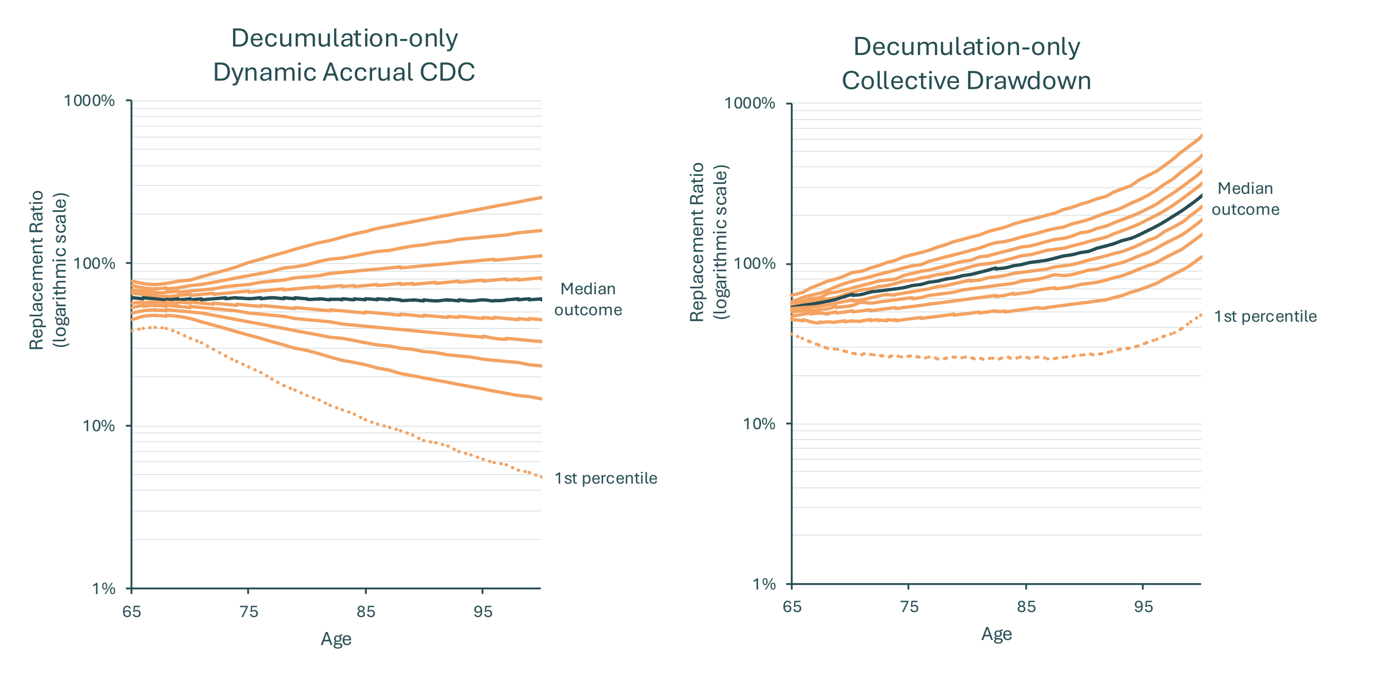
Decumulation-only schemes

A collective-drawdown design could also be used to develop a decumulation-only product. Figure 4.5 illustrates the outcome for one possible strategy for a decumulation-only collective-drawdown scheme compared to a decumulation-only dynamic-accrual scheme.

After the first 5 years of retirement, the collective drawdown scheme gives better results for the best 90% of outcomes. For the worse 1% of outcomes, the collective drawdown scheme provides lower benefits than the dynamic-accrual scheme earlier in retirement, but higher benefits later in retirement.

This means that although we expect that many investors would prefer the collective-drawdown strategy shown, there may be some individuals who would prefer the shared-indexation scheme. We expect that such individuals would prefer an annuity to either option shown. The payments from an annuity could be reproduced using an alternative collective-drawdown design that invests solely in index-linked gilts. An advantage of collective drawdown is that, because of the choice it allows for investors, both strategies can be used within the same scheme, but for different members.

Figure 4.5 Deciles of the benefits in retirement for a decumulation-only dynamic-accrual scheme (left) compared to a decumulation-only collective-drawdown scheme (right).



Deciles of the replacement ratio for a dynamic-accrual scheme (left, sold lines), vs deciles of the replacement ratio for a decumulation-only scheme (right, solid lines). The first percentiles are shown in each case with dotted lines.

The advantage of longevity pooling only really begins to take effect post-retirement, so the main advantage of collective drawdown is preserved in a decumulation-only design.

An investor who has an individual DC scheme who wishes to purchase a decumulation-only collective-drawdown scheme at retirement should, ideally, follow essentially the same investment strategy as an all-life collective-drawdown scheme before retirement. The key features of this compared to a standard DC investment strategy is the use of leveraged investment when young and some continued investment in risky assets up to retirement.

Obstacles to collective-drawdown schemes

As there are currently no collective-drawdown schemes in the UK, there are several issues that would need to be addressed to create a commercial product. These include:

- Design and testing of member communications
- Practical implementation issues such as the development of IT systems to support such a product
- Regulatory approval
- Design of a full benefit structure, potentially including spousal benefits and lump sum, together with the specific strategies that members can choose.

Member Communications

As part of this project, we have gradually refined the communication of the collective-drawdown design to ensure that the design is clear to pension experts. An example of possible member communications has been included in the project output CDC Design in the UK: Cross Subsidy, Shared Indexation and Alternatives to Longevity Pooling (PPI Briefing Note 141),[38] but we have not performed any consumer testing, as this was outside the scope of the project.

> **Recommendation 7:** Research should be conducted to understand to what extent members can understand how different scheme designs operate, how this impacts upon their benefits, and how schemes might be presented to encourage the adoption of designs that most benefit members.

Practical implementation

Any pension provider offering a collective-drawdown product would want to ensure that they have the in-house expertise to support the product. This includes the modelling skills required to design and test collective-drawdown strategies. An understanding of leveraged investment strategies would also be required. As a collective-drawdown scheme is not a derivative product, expertise in derivative pricing would not be required.

Since we have used machine learning to identify optimal strategies, one should ask whether this raises any risks. Since machine learning is not used to assess the effectiveness of the strategies, we do not think the use of machine learning is problematic. Before following the investment advice generated by the machine-learning algorithms, one can thoroughly simulate the effectiveness of its advice. This thorough testing should be an essential part of the design of any pension product no matter how the strategy is identified.

[38] Upton, J., PPI (2025)

Regulation

Currently the only form of CDC permitted in the UK is for a single-employer scheme based upon the principles of the Royal Mail scheme. Given the advantages of the collective drawdown design, we make the following recommendation.

> **Recommendation 8.** Policy makers should encourage the development of collective drawdown schemes and should be prepared to update legislation to allow schemes operating on this design.

It is difficult to develop legislation in a vacuum, so it is likely that the DWP will only develop appropriate legislation in response to industry interest. The regulation for CDC schemes was developed in consultation with the Royal Mail to ensure it meets their needs. The DWP has shown a similar responsiveness to proposals for developing multi-employer CDC and drawdown-only CDC and has been supportive of the development of such innovations.

There are various issues which would need to be resolved during this process which would necessitate new regulation and potential legislation. The scale of this will depend upon scheme design and its place in the market.

It is not clear whether new CDC scheme benefit designs would be administered through a trust structure, regulated by The Pensions Regulator (TPR), or a contract structure, regulated by the Financial Conduct Authority (FCA). This may affect the extent of legislative changes needed as the FCA has the power to set its own regulations. In this report we have viewed collective drawdown as a form of CDC scheme, but that it is not clear whether that would be the correct way to view the scheme for the purposes of developing legislation. To resolve these issues requires understanding where a new scheme would sit within the market and so it is difficult to be more precise in the abstract.

Detailed design

In common with all collective designs, there is a question of the consumer appetite for longevity pooling. Some may be concerned that if they die shortly after joining, they will receive a poor deal from the scheme, and others may wish to leave a bequest. Just as in other designs, this may be mitigated through framing or by developing a more complex product than we have modelled, which includes features such as a lump sum or partial bequest.

In common with other collective designs, there may be a concern of selection risk as members who believe they have lower life expectancy may not wish to join. This might be mitigated by providing more accurate underwriting. Another concern investors may have is that they lose control of investment decisions. This is less of a concern in a collective drawdown design than in other collective designs because collective drawdown allows for individual choice. There is considerable scope for a scheme designer to decide how much flexibility to allow members and how frequently they can review these decisions.

In this report we have envisaged a limited portfolio of investment choices for members, perhaps choosing between a selection of different risk levels, but with the strategy then fixed. Increasing the flexibility beyond this would have some advantages but would also raise challenges. For example, to what extent should a member's rate of drawdown be limited, and when and how should underwriting be performed in response to changes in strategy?

We have assumed for simplicity in our model that members are not allowed to leave the scheme once they have reached retirement. It would be interesting to explore the possibility of allowing members to leave the scheme during drawdown, as this may result in a more attractive product. This could be particularly useful in any default option for DC funds at retirement.

This leads to our final recommendation.

> **Recommendation 9:** Research should be conducted on using collective-drawdown designs as a default approach at retirement within DC schemes.

Summary

- Collective-drawdown schemes can offer a risk-adjusted improvement in pension benefits of approximately 22%.
- However one assesses risk, collective-drawdown schemes outperform shared-indexation schemes.
- The performance benefits of collective-drawdown come from longevity insurance, access to leverage and the use of optimal investment strategies.
- Collective drawdown can be applied to design either all-life or decumulation products. Longevity insurance between schemes could also be used to improve the scalability of shared-indexation schemes.

Chapter 5

This chapter summarises the recommendations developed in response to the findings of the research.

1. Policy makers should encourage the development of collective drawdown schemes and should be prepared to update legislation to allow schemes operating on this design.

2. Pension providers and employers considering different collective scheme designs should consider benchmarking their designs against a collective-drawdown approach.

3. Flat-accrual CDC schemes may contain unacceptably high cross-subsidies by age. Policy makers should explicitly consider what level of cross subsidy is acceptable and how cross-subsidies should be measured.

4. Policy makers should consider how members are informed about employer contributions to ensure they are not misled. If members will not benefit from payments to overcome drag or that subsidise other members, employers should not suggest that these payments form part of their total remuneration package.

5. CDC pensions which attempt investment-risk pooling are derivative products and benefits should be valued accordingly. Schemes offering such pensions should be required to seek advice on derivative pricing and regulators may also need to develop appropriate expertise in this area.

6. Regulators should require schemes to quantify the risk of any collective design in published simulation studies. Investment strategies should be validated using simulations as part of the routine assessment of a scheme's performance.

7. Research should be conducted to understand to what extent members can understand how different scheme designs operate, how this impacts upon their benefits, and how schemes might be presented to encourage the adoption of designs that most benefit members.

8. Members of a collective scheme should be informed of their projected real-terms benefit in retirement together with a quantitative assessment of the uncertainty, and there should be greater clarity on how these computations may be performed.

9. Research should be conducted on using collective-drawdown designs as a default approach at retirement within DC schemes.

Appendix A - Further modelling details

The long-term values of economic risk factors used in all models are given in the table below [Table A.1]. In Appendix C we give a sensitivity analysis showing the effect of higher equity returns on our results. This is the parameter one would expect to have the greatest impact on the relative performance of different funds.

Table A.1 Long term economic determinants

Economic variable	Long-term median
Stock growth	7.73% p.a.
Wage growth	3.83% p.a.
CPI growth	2.00% p.a.
Index-linked bond growth	4.36% p.a

All simulations assume members join a scheme at 25 and retire at age 65. Mortality is assumed to be deterministic and follows the S1PMA tables produced by the Institute and Faculty of Actuaries' Continuous Mortality Investigation, except that we assume no members die before retirement. We assume that the fund is sufficiently large so that the maximum possible benefit is achieved from longevity pooling. Numerical simulations show that this is a reasonable approximation.

Our simulations assume members' individual pay growth matches wage-growth and at any time all employees receive the same pay irrespective of their age. Members join at a steady rate up to scheme closure. The simulation results shown are for typical generations when the fund is in a steady state.

Combined member and employer pension payments are assumed to be 8%, matching the minimum contribution levels for automatic enrolement. We consider single-life pensions with no lump-sum taken at retirement. In our flat-accrual CDC model, the target level of indexation is set to match Consumer Prices Index (CPI) growth. The floor for indexation is set at 0% nominal growth and the ceiling on indexation is set at CPI+5%.

While the flat-accrual scheme we model has some conceptual similarities with the Royal Mail Collective Pension Plan, the details are very different. Contribution rates are higher in that scheme and it targets a higher level of indexation. It also provides joint-life benefits and a lump-sum at retirement.

The default DC + Annuity scheme uses a lifestyling strategy which invests 100% in equities until age 55, then tapers linearly to 100% index-linked gilts at 65. The shared-indexation schemes are designed to take investment risks broadly equivalent to a lifestyling strategy which invests 100% in equities until 65, then tapers linearly to 100% index-linked gilts at 85. Annuities are priced using index-linked gilt rates and the mortality tables mentioned above with a 5% overhead added to cover the additional costs of handling systematic risk in annuities rather than collectively.

When modelling decumulation-only schemes, we assume a member has accumulated a pot equal to 7.17 times their earnings in their final year of employment. This matches the value of the pension pot that would arise from our assumptions on accumulation using a constant economic model.

The exact numerical results in this report are sensitive to the values of these parameters. However, the key qualitative findings remain unchanged. The qualitative findings remain robust to changes in the nature of the model used and we have identified the mathematical principles underpinning these findings.

Appendix B - The theoretical limits of collective investment

The mathematical research in this project

One strand of the research in this project has been to examine collective pensions from the perspective of financial mathematics. This chapter gives an overview of this research aimed at a non-specialist. There won't be any equations.

In this report so far, we have examined pension designs which we believe could be put into practice today, subject to regulatory approval. We have shown how these designs perform when simulated using a sophisticated market model which incorporates various market risks and wage risk.

Our mathematical research is more abstract. In this research we have simplified the models we use so that they are easier to understand, and this allows us to prove mathematical theorems. This gives us theoretical insights into how collective pension schemes can work and we can use these insights to design better practical schemes.

The collective drawdown design we have proposed emerged from the mathematical research. In simplified models, we can prove that the collective-drawdown design is optimal. This means that in simplified models, it is inevitable that collective-drawdown designs will outperform shared-indexation designs. Given this mathematical theory, it is not so surprising that when comparing scheme designs in more realistic models, the collective-drawdown scheme performed the best.

When collective-drawdown is optimal

The motivation for collective drawdown is that we can prove mathematically that it is the optimal investment strategy on the assumption that the market is "complete".

A financial market is said to be complete if it is possible to place any bet you can think on future market outcomes. A simple example of a complete market occurs in the game of roulette. Suppose that the ball can land on any number between 1 and 32. If you wanted to bet that it lands on an even number you can place a chip on "evens", but if you want, you can also bet that it is divisible by three by placing a chip on every number that is divisible by 3. In financial mathematics, this technique is called replication. If you were to place a chip on every even number, you would be replicating a bet on evens.

There are only 32 numbers to bet on in our game of roulette, but this makes it possible to construct approximately half a billion different bets on each spin by choosing where to place your chips.

The same happens in financial markets. It is possible to place a simple bet by just purchasing a stock, but more complex bets are possible. An example of a more complex bet is a digital option on a stock. This pays out one if the stock price on a given date is over a certain level and pays zero otherwise. Any bet such as this is called a financial derivative.

In a financial market consisting of just a single stock there are many different simple bets you can make, because you can choose when to buy and sell your stocks. This means that there may be many financial derivatives that you can replicate by choosing an appropriate strategy on when to buy and sell.

The breakthrough mathematical result that created the modern market in financial derivatives was proved by Black and Scholes in 1968. They showed that in one reasonably realistic model of a stock market it is possible to replicate a particular class of derivatives called options, and subsequently other financial mathematicians showed that any derivative can be replicated in this model. In other words, they proved that this market is complete.

If any derivative can be replicated, this means that they can, in effect, be purchased for the cost of replication. This is why Black and Scholes' theory makes it possible to calculate the price of financial derivatives.

In any pension design, the operating rules of the scheme will define the benefits members receive in exchange for their contributions. This means that when a member purchases additional benefits, they are in effect entering into a form of derivative contract.

Suppose that the pension scheme is running inside a complete market. Under those circumstances, a member could purchase this derivative directly from the market without needing to use the pension scheme at all.

If members are trading in a Black-Scholes market and the only additional risk they face is their longevity risk, once they have insured against longevity risk they are trading in a complete market. This means that there is no further benefit available by coming up with a more elaborate collective pension scheme than collective drawdown. Because the market can supply any derivative you can think of, any insurance contract you can think of for investment risk is already available. It is not possible for a collective to provide insurance against investment-risk at a better price than the market without some members of the collective losing out.

This explains the central idea of our mathematical result. It still requires a rigorous mathematical proof, as verbal arguments which sound convincing can prove to be incorrect when you scrutinise them more closely. In fact, there are a number of details missing from our informal argument which emerge clearly from the mathematics. To make our argument watertight one needs to make the following key assumptions:

- Everybody has a clear set of preferences over possible distributions of their pension benefits.
- The scheme operates for a finite time. This assumption is necessary because if a scheme operates for an infinite time, it is possible to create Ponzi schemes where each generation passes on money to the next.
- Everyone can choose whether or not to contribute to a scheme. This prevents a scheme investing in stocks on behalf of a member before they join. It also means that a scheme must be in everyone's interest, so the design cannot redistribute wealth from rich to poor.
- Members' pension preferences depend only on their own pension. Otherwise, members might choose to give their money to other members, or if you believe they are envious they might prefer other members to earn less.
- All members become happier if they have more money. Otherwise, members who are already content might be willing to give some of their money away.

These assumptions are intended to reflect the UK pension market, where members can opt out of their pension. Under these assumptions, it is not possible to outperform a collective-drawdown pension if the market is complete.[39]

As a result, in the market model used by Black and Scholes, shared-indexation schemes must lead to worse pension outcomes than collective-drawdown, since there is nothing in the design of shared-indexation schemes that tries to exploit differences between the market and the model of Black and Scholes.

[39] See Armstrong et al. (2025c) for a detailed proof.

Collective investment in incomplete markets

Real stock markets are incomplete, but they are nearly complete, and this makes it possible for derivatives traders to use the theory of complete markets to come up with effective trading strategies. In other words, one can model financial markets as being complete and this is an approach which has proved to be highly successful.

However, there are some pension risks which are much harder to insure against, namely wage-risk and systematic mortality risk. There are multiple forms of wage-risk: a member may be concerned about losing their own job or failing to get promoted, this is their individual wage-risk; they may also be worried about wages across the economy, this is systematic wage risk. Longevity risk can also be divided into individual risk and systematic risk. The longevity polling used in a collective-drawdown scheme insures against individual risk, but it does not address systematic risk.

This means that there is scope for collective-drawdown schemes to go beyond insuring against individual longevity risk and so provide even better benefits to members. Members of a collective could trade insurance among themselves to create a complete (or nearly complete) market in all risk factors.

In this approach, the pension provider would set a price for all the basic insurance contracts that are not available in external markets. The pension provider then computes the optimal investment strategy for all members given these prices. Since the market is now complete, this is the optimal collective investment strategy given the prices.

The remaining question is how the pension provider should choose the price for these basic contracts. We have proposed that they should choose a price so that the market clears – that is the quantity of insurance members wish to buy matches the quantity of insurance other members want to sell. If the price is set this way, the internal market will exactly break even.

This gives a theoretical definition of what it means to run a collective pension scheme optimally even in incomplete markets. We will describe all schemes that operate in this way as collective-drawdown schemes, with the approach of Chapter 4 being a special case. Because members will only trade in mutual insurance if it improves their outcomes, it is guaranteed that this design can only improve member benefits. The economic theory of comparative advantage implies that members will choose to trade so long as they have different views on the relative importance of risks and this will be to their mutual benefit.

Because the collective-drawdown design is optimal in this sense, from the point of view of pension outcomes it will be in members' interests to use a collective drawdown design. Other considerations than pension outcomes do exist, such as ease of member communications and administration costs. Providers and employers should consider these factors and should only use alternative designs if their benefits outweigh the costs.

Mutual insurance against systematic longevity risk

It is challenging to compute optimal investment strategies in practice, and it is even more challenging to compute the appropriate price which will make the market clear. This opens up a new and challenging type of problem in financial mathematics. We cannot yet solve the optimal mutual insurance problem in realistic market models, but have made good progress in studying simplified models.

The results we have already described on collective drawdown show what happens if you simplify the problem to assume that the only risk-factor that is not insurable by the market is individual longevity risk. This gives extremely practical results.

In this section, we will describe the work we have done to study systematic longevity risk.

Our goal in studying this is not necessarily to identify better collective pension designs. As one increases the complexity of the modelling, a design becomes harder to understand. We have already seen that this brings risks. Shared-indexation designs are derivative products, and this can make them much more difficult to understand than collective-drawdown designs. The problems we have identified with shared-indexation designs show that even pension professionals may find this approach hard to understand. As a result, individual members are very unlikely to fully appreciate the subtleties of shared-indexation designs.

Thus, our goal in studying systematic longevity risk, is not necessarily to find optimal strategies, but to assess the potential benefit of insuring against this risk. If the benefits are significant, one can then identify practical strategies for achieving this benefit.

As a first step in studying systematic longevity risk, we considered the optimal investment strategy of an individual who can insure their individual longevity risk but has no means of insuring against systematic longevity risk.

Our results were surprising. Depending upon an investor's preferences, some members may do better in models with systematic longevity risk than in models without systematic longevity risk (assuming that the resulting mortality distribution is fixed). This happens because systematic longevity risk reduces over time as one receives more information on matters such as medical advances. For some members, the benefits from taking advantage of this new information may outweigh the downside of not knowing one's life-expectancy earlier.

Because members can take advantage of new information about mortality risk, the impact of systematic longevity risk is relatively small. A member can simply reduce their rate of drawdown in retirement if longevity increases, and if it decreases, they can drawdown faster. We estimate the impact of systematic longevity risk may be equivalent to a 5% change in pension savings, but this may be either an increase or decrease.[40]

[40] see Armstrong et al. (2025a)

Maurer et al (2013) estimate that an insurer would need to apply an 8% margin to have a 99% chance of solvency when providing an annuity for a 65-year-old. So, it seems unlikely that third-party insurance for systematic longevity risk will be cost effective.[41] This provides a justification for the additional 5% margin added to the best-estimate price of an annuity when comparing the DC + Annuity strategies with other schemes.

Finding: The impact of systematic longevity risk is equivalent to an approximately 5% increase or decrease in pension contributions. There would be no benefit in purchasing third-party insurance for this risk if the margin charged by the insurer to cover systematic longevity risk is similarly high.

As some members have different attitudes to systematic longevity risk (some seeing the benefit of information outweighing the uncertainty, others not) there may still be benefit in sharing mutual insurance. We can solve this problem in the case of mutual insurance among one cohort of members, where a small minority of members who are unusually risk-seeking or risk-averse obtain insurance from the majority. This gives a bound on the benefit that one would expect to be achieved by risk-sharing within one cohort.[42]

Finding: Mutual insurance of systematic longevity risk within one cohort may improve outcomes by an amount we estimate as equivalent to at most a 3% increase in pension savings.

It seems likely that greater benefits will be possible using mutual insurance between different generations, but this adds significant mathematical complexity, and we are not yet able to solve this problem.

In summary, our research on systematic longevity risk currently suggests that there is little benefit in complicating the collective-drawdown design by including it. If correct, this should be viewed as a very positive result. At present there is no evidence that collective-drawdown schemes should include any complex mutual insurance features. The simple collective-drawdown design with only individual longevity insurance already provides a better way of handling systematic longevity risk than purchasing third-party insurance. On the basis of current evidence, this simple design achieves near-optimal results.

[41] A similar conclusion is drawn by Boon et al. (2018)
[42] See Armstrong et al. (2024)

Summary

- In complete markets, collective drawdown is the optimal investment strategy.
- Collective drawdown can be a more effective strategy than third-party insurance when there is systematic mortality risk.
- Collective drawdown can be extended to incomplete markets by creating an internal insurance market.
- At present, the evidence suggests that the benefits of a more complex internal insurance market may be outweighed by the technical complexities this creates. Further research will allow us to quantify the potential benefits more accurately.

Appendix C - Sensitivity Analysis

Our numerical findings are dependent upon the parameter values we choose and so must be viewed as illustrative. A particularly important factor determining the relative performance of the funds is the market price of risk. This can be increased either by: increasing equity returns; decreasing bond returns; or by decreasing equity volatility. The higher the market price of risk, the greater the reward available for taking risks.

In Table C.1 we have performed a sensitivity analysis where we adjusted our model so that GDP increased on average by 1% more each year as did equity returns. This will increase the market price of risk. Our findings are qualitatively unchanged. Unfortunately, due to a lack of available computing time we were not able to complete this analysis for the flex-then-fix strategy.

Table C.1: The results are qualitatively unchanged when equity returns are increased

Design	Certainty-equivalent replacement ratio	
	Baseline	GDP +1%
Optimal DC + Annuity	35%	40%
Optimal DC + Flex-then-fix	51%	-
Optimal flat-accrual CDC	48%	50%
Optimal dynamic-accrual CDC	47%	55%
Optimal statistically-calibrated CDC	52%	62%
Collective drawdown	62%	67%

The key qualitative results of this report are independent of the precise market parameters. The collective drawdown design will inevitably outperform the other designs, and this can be proved rigorously in any complete market model.

During the course of this research, we have also examined variations on our models with different mortality distributions, contribution rates and assumptions about the working life. This explains the numerical differences between this report and our earlier Briefing Note (Upton 2024), but the results are again qualitatively unchanged. The key finding on these factors is that a longer working-life will increase cross-subsidies between ages, and so increases drag for the flat-accrual scheme.

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