LONG FINANCE

DISTRIBUTED FUTURES

Smart Ledgers & Collective Defined Contribution Pensions

July 2018

CARDANO FOUNDATION

The Z/Yen Group

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July 2018

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Foreword

There couldn't be a more pertinent publication for Distributed Futures than one on pensions. Why? Because pensions require long-term, complex administration against a set of rules with good governance. Think immutable ledgers, smart code, and well-thought-out long-term governance, i.e. smart ledgers.

Few financial institutions should be more important over a lifetime than those providing for old age. The conventional reckoning of a 'generation' as thirty years has degenerated to twenty, while lifespans have increased to nudge and pass the century mark more often. A lifetime's planning has moved from two or three generations to five. Yet pension policies everywhere are in disarray – defined benefit schemes in Britain are almost completely closed to new members and also closing down; private sector workers are outraged by public sector pension commitments; the young are outraged by obligations to the old; and accountants and actuaries around the world should be ashamed of their historical performance – and would be, if they weren't so busy re-estimating future liabilities from minute to minute.

We are pleased to sponsor this challenging publication, uniting smart ledgers with an important social problem. Smart ledgers are not the solution. But they could be a significant part of the solution by enabling this publication's suggestions for Collective Defined Contribution (CDC) pensions to work. Surely, given the vision this publication paints for us, if governments had the will to act, their pension systems the world over could provide appropriate and just provision for old age. Little stands between us today and the pensions world this publication imagines, except complacency.

Michael Parsons FCA
Chairman, Cardano Foundation

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Executive Summary

Pension provision is among the most consequential of our lifetime's financial activities. In the UK, as the state pension offers only a very limited level of income replacement, private pensions are particularly important for quality of life in retirement. The tax concessions offered to promote pension saving are recognition of this situation and try to encourage and incentivise private savings. This report has a decidedly UK bias, but many of the issues are universal.

As in other jurisdictions reliant on private prudence, the level of saving we see in the UK is too low and many people are likely to have insufficient funds on which to retire or will experience a much lower standard of living in retired life than they envisioned. It appears that the population lacks confidence in, and does not trust, the institutions and by extension markets to save at the appropriate level. This is not helped by the complexity and lack of transparency of the pension products offered, and management discretions are particularly suspect.

The defined benefit occupational schemes which were the primary form of provision in post-war era are now overwhelmingly closed. The employer guarantees which backed these schemes are now simply too costly. The substitute offered, the defined contribution (money purchase) plan, is simply a tax-advantaged savings scheme; there is no provision of an income in retirement. All risks are borne by the individual.

Stylistically, we may think of pensions as consisting of two phases: saving or accumulation and drawing or decumulation. It is the accumulated investment returns which account for the majority of the pension available – contributions may account for less than ten percent, and the majority of the total investment return is likely to occur after retirement.

The 'at retirement' problem of DC is substantial. It has been identified as such by the FCA in their Retirement Outcomes Review. The choice between an appropriate annuity for a given individual and drawdown is not simple. For the vast majority of individuals expert advice is warranted, and that is costly. The simple fact is that none of us know when we will die, and that greatly complicates matters.

The collective defined contribution (CDC) pension scheme is an attempt to remedy these problems. It is collective in order to reduce the longevity uncertainty to a statistically manageable expectation. In addition to this risk-pooling, CDC schemes may include risk-sharing among members, while maintaining an equitable balance between them.

Of course, a common problem with any collective arrangement is the possibility of over-consumption today at the expense of future beneficiaries. However, it may be avoided by the consistent application of some simple rules, and that essentially meet the definition of a “smart contract”.

The introduction of smart contracts does more than ensure consistent, low, administration costs, it should enhance the confidence of scheme members in the integrity and trustworthiness of the scheme. This is a critical concern for CDC schemes where one of their defining properties is that the target pensions promised may be altered through time and may be cut if investment returns are insufficient. With members able to withdraw from a scheme, this is a clear concern best countered by transparency for members.

The use of smart ledger technology, which ensures both accuracy and immutability of previous records, is ideally suited for application in pensions. The multi-period accruals of assets, contributions, and the entitlements of scheme members, as well as the payment of pensions and the associated development of defining parameters are all linked in chains over time. This technology also affords transparency for members; they may view both the capital value and the pension income equivalent of this in near real-time, as well as their historic evolution. This technology minimises the cost of scheme administration, a material concern for the sufficiency and generosity of a pension income.

Introduction

Veterans of the UK pensions scene often describe a former world in which pensions were organised on a best efforts basis. They tend to lament its passing and view the current situation, in which pensions promises are either hard and immutable, as is the case with UK defined benefit (DB) schemes, or non-existent, as is the case with defined contribution (DC) schemes, unfavourably. However, in recent years, there has been an aspiration to allow greater flexibility and innovation in pension provision, than is allowed by these two extremes.

This is the background to the current drive for collective defined contribution (CDC) pensions. Royal Mail has indicated that it will offer such a scheme to their employees once the legislative and regulatory impediments have been resolved.

CDC schemes may be viewed as completing the current individual DC arrangement in the sense that they will offer post retirement income arrangements. DC is currently no more than a tax-advantaged savings scheme; CDC is an integrated savings and retirement income solution.

This new integrated system of accumulation and decumulation, however, brings with it some new technological challenges. There is a need for an integrated administration and management system. Some aspects of a CDC scheme are rooted in practices arising in the DB world and some in DC, but there are also some which are entirely new, such as risk-sharing among members.

This paper describes the requirements of such a system and proposes some solutions, using distributed ledger and smart contract technologies. We recognise that there is also another dimension to a total system, document management, but see that as an issue of interactivity with some of the excellent systems, such as Parade, which already exist.

The very nature of pensions is one of savings, aggregated and chained together over time for both the individual and the scheme, on and from which, immutable, often conditional, transactions occur. The link to modern technologies is immediate.

1. An Overview Of Different Types Of Pension Arrangements

Pensions are often described as sitting on a continuum with defined contribution (DC) schemes at one end and full defined benefit (DB) schemes at the other. This spectrum is useful for describing these types of pension arrangements (and everything in between) and essentially differentiates such arrangements based on the risk-bearer.[1] In a DC arrangement, all the risk is borne by the individual, whereas in a full DB arrangement, all the risk, with the exception of sponsor insolvency, is borne by the scheme sponsor.

Characteristics Of Defined Contribution Pension Arrangements

A defined contribution, or money purchase scheme, is now the most common pension scheme offered in the private sector. Although, given the structure of DC arrangements, this would be better described as a savings wrapper rather than a pension in its truest sense, as there is no risk pooling, risk sharing, or even mechanism for conversion of these savings into an income in retirement.

In a DC scheme, the employee and the employer make contributions, which are usually a fixed percentage of the employee's salary, in to a fund. These contributions are, then, invested in a range of assets, based upon the asset allocation choices of the employee. The final value of the pension (at retirement) is the sum of the lifetime contributions paid into the scheme, plus any returns on investment through capital appreciation and investment income earned over the accumulation period.

An individual then has several options, which can be taken from the age of 55, as a result of Freedom and Choice. For those that wish to secure an income for life, their pension savings can be used to buy an annuity. Life annuities are a good option for many people as they are a form of insurance, ensuring an income until death. Moreover, they do not have the investment risk of some of the other options that can be taken. However, securing an income for retirement in this manner is often expensive.

[1] Such a taxonomy is problematic, as there is no continuum between these two extremes, merely a sequence of discrete and discontinuous arrangements. Moreover, some of the risk-sharing within DB arrangements are rendered redundant by the presence of the sponsor guarantee.

Income drawdown is another way of using the accumulated pot to generate an income in retirement. Unlike an annuity, here the retirement pot stays invested, and money is taken from the pot to provide an income. Consequently, the value of the pot can fluctuate depending on the value of the stock market, as this is, commonly, what the pot would remain invested in. The size of the retirement pot can therefore decrease as the market goes down, but can also increase as the market goes up. The funds available may, therefore, prove insufficient to provide an income for life if the market declines significantly.

A DC pot can also be accessed as one-off lump sums through what is known as Uncrystallised Funds Pension Lump Sums (UFPLS), rather than through income drawdown. The ad-hoc withdrawal of lump sums allows for an individual to take money out as and when they need it, and this can be done as one lump sum or as smaller sums through time.

For all these arrangements, there are different tax treatments and depending on an individual's tax position, this may influence how and when they access their DC pension pot.[2]

In looking at the risk characteristics of at DC pension, it is clear that all the risk falls solely on the employee. Employees bear the investment and longevity risk, while the employer is simply committed to paying the agreed contributions through time.

Characteristics Of Defined Benefit Pension Arrangements

The final salary defined benefit (DB) pension is the most generous form of pension from the perspective of the employee. Here, the pension that is paid out on retirement is typically a function of age, years of service, contributions, and final salary. Over an individual's working life, contributions are paid by both the employer and the employee and these are invested in a portfolio of assets.

[2] It is worth noting that under all of these arrangements, an individual can take 25% of their pot tax-free, and the marginal tax consequences of any access will depend on an individual's personal taxable income.

On retirement, the pension income that is available to the retiree is a function of their pension accrual, and not the value of the assets in a notional pot. Each year of employment where contributions were made determines how much an individual receives. An individual might accrue 1/80 of their final salary for every year worked. If working life commences at age 25 and retirement at age 65, then an individual accumulates 40 years of pensionable service, and so, on retirement, will be eligible for 40/80, or half their final salary. The accrual rate is a key determinant of the inherent cost of providing a defined benefit pension. For example, if the accrual rate was 1/60, then for 40 years of service, this would equate to 2/3rds of final salary.

The most fundamental part of a defined benefit scheme is that the employer/sponsor underwrites an implicit return on the contributions made by both employer and employee, and it is this rate that needs to be achieved to deliver the projected benefits promised. However, the much-publicised deficits of DB schemes are not derived in this manner. Here, the liabilities are valued as the discounted present value of projected benefits, using either bond yields or the expected return on assets, as the discount rate.

Unlike in DC schemes, where the employee bears all of the risk, in DB it is the employer/sponsor who bears the risk. As such, making good on any deficit is the sole responsibility of the sponsor. The benefits of members from past service are unalterable. However, the trustees of the pension scheme can call upon the sponsor to provide additional finance to the scheme to ensure that deficits are repaired.

Within the structure of a DB scheme, there are elements of risk pooling and risk sharing. However, this collective pooling and sharing arrangement is not directly beneficial to the scheme member, as their pension benefits are fixed and guaranteed by the sponsor employer. That said, the benefits of collective pooling of risk is beneficial to the sponsor, as it lowers the overall cost of providing benefits. From the member’s perspective, this does help contain the one risk that they do face in a DB arrangement-sponsor insolvency.

Risk-Shifting From The Employer To The Employee

Final salary schemes are all but closed in the private sector having been replaced by DC arrangements. This is a process that accelerated from 2001 onwards, and there have been several drivers for this change.

First, increasing longevity means that employers/sponsors are having to underwrite DB pension benefits for a much longer period (and therefore at a greater cost) than was originally estimated. Second, increasing amounts of legislation, with regards to pension fund solvency requirements, have increased the risk and cost faced by sponsors. Third, changes to accounting standards brought pension liabilities onto the corporate balance sheet, and the process of mark-to-market valuation of assets and mark-to-assumption valuation of liabilities introduced a significant amount of balance sheet volatility for sponsors.

From the perspective of the employee, the move from DB to DC has resulted in less generous incomes in retirement, as well as having to bear all the risk. Any shortfall in the pension under a DC arrangement simply reduces the final value of the pension pot, and therefore, the value of the income that can be received in retirement. Similarly, increased life expectancy means that the value of the annuity received is lower, as the insurer must pay out for longer.

Ultimately, DB pensions no longer work, because of the hardening of the pension promise through various regulations and legislative changes, which has meant that the cost of the guarantees is, simply, too high.

Collective Defined Contribution (CDC) Arrangements

In a CDC arrangement, as with DB and DC, there are employee and employer contributions which are invested. However, unlike a traditional DC arrangement, where the amount to be received on retirement is wholly unknown, in CDC there is a target income or amount that a member should receive in retirement, which can be viewed as a 'promise'. This 'promise' is, however, made on a best efforts basis and may not prove feasible. Unlike DB there is no sponsor guarantee as to this target retirement income. In CDC, this 'promise' is collectively underwritten by the scheme members. CDC is therefore a collective member mutual structure, whereby members 'owe things to themselves', so there are no enforceable external liability claims. Crucially, these promises are ambitions not guarantees; they are best efforts endeavours.

The role of the 'promise' is to define the equitable interest of a scheme member and is endogenous, thereby defining the relative magnitudes of claims of members on the assets of the scheme. The equitable interest may be expressed as either (or both) capital value or equivalent pension income terms. The totality of all members' interests is a metric of the total ambition of the scheme, and comparison of this with the value of the investment fund provides a solvency type diagnostic, as to the sufficiency of the assets currently held.

The existing scheme types come to an equivalent of the member's equitable interest is with the unitisation of a DC investment fund; the arrangement under which the member purchases units in the fund with each contribution. With DB, the member claim is expressly in a pension income, and the only circumstance in which it becomes necessary to arrive at an asset equivalent of this, is in the calculation of transfer values. This process involves the discounting of the projected benefits awarded to the member, and may prove profoundly inequitable among members, as well as with respect to the employer sponsor. In other words, the calculation, modification, and monitoring over time of a member's equitable interest is a new requirement of a CDC administration and management system.

As we shall see later, equitable interest is central to the risk management of a CDC scheme. An important aspect of CDC schemes is that it admits explicit management of scheme liabilities, through the equitable interests of members. Moreover, expressing the promise in the manner of traditional DB, where a specific contribution confers the right to a particular defined retirement income for the member's lifetime in retirement, is useful, as it embeds risk-pooling and sharing among members. The equitable interest of a single member serves to ensure solidarity between members, and with that, fair division of the assets of the scheme and distributions from it as income. Crucially, the concept of the equitable interest of a member can be used to maintain fair balance among members, both instantaneously and through time, in accordance with the scheme rules.

CDC And The Need For Technology

Historically, a CDC arrangement as described above would have required a level of technology to track and monitor the evolution of the scheme and maintain the equitable interests of members that was simply not feasible. While latterly, although technologies have existed that allowed for this to occur, these systems would have been prohibitively expensive and clunky. As will be discussed in the following sections, this is no longer the case.

A crucial feature of the CDC pension that makes it a superior pension arrangement is the risk sharing and risk pooling that occurs between members, and the ability to maintain the equitable interests of members with precision and in a timely fashion. The risk sharing properties of the scheme feed into the objective as well as the techniques for management of the fund. With individual DC, the objective is to maximise the asset value at all times; this is intrinsically short-term in nature. It, also, sets up a tension with scheme members, whose preference would be for low asset values during their accumulation phase, and maximal values at retirement and in the decumulation phase. By contrast, the objective of a CDC fund is to achieve or surpass a specific target on average. This average is determined by the detail of the risk-sharing rules of the scheme. When combined with the far longer time horizon of CDC, this allows for a broader set of investment asset opportunities to be utilised as well as more diverse strategies to be undertaken, in order to achieve the target of the scheme.

With the development of distributed ledger technologies, the necessary record-keeping and analysis are now feasible in a way which was not possible before. The next section of this paper goes on to provide an introduction to distributed ledgers and their various properties; briefly explore some of the existing platforms from other domains; and then describe how a MDL solution with smart contracts can be implemented to support the running of the CDC arrangement described above.

2. Smart Ledgers

Mutual distributed ledger (MDL) technology provides shared and synchronised databases in which consensus must be reached before transactions can occur.[3] MDLs are often referred to as 'blockchains', though strictly that term refers to the Bitcoin MDL. The simplest definition of MDLs might be "multi-organisational databases with a super audit trail". Consensus refers to the reaching of a general agreement between multiple parties before it is recorded on the multi-organisational database. Consensus can be as simple as two parties storing a digitally-signed copy of an agreement in the ledger. It can be as complex as the 'mining' game in Bitcoin where thousands of parties can be involved in agreeing the state of affairs. Technically, MDLs by implication support peer-to-peer network communication, decentralised data storage, and consensus algorithms.

It would be impossible to list all the MDL approaches that exist and have been developed in recent years. Equally, current popularity means that the pace of evolution has sped up tremendously from the early days of MDLs in the 1980s to today's burgeoning environment of innovative claims for Initial Token Offerings and Initial Coin Offerings, as well as numerous new technical approaches not over-burdened with hype and speculation. This section, therefore, focuses on drawing out the key characteristics that might be useful in aiding CDC takeup.

The first step is to look at adding 'smarts'. **Smart Ledgers are based on a combination of MDLs with embedded programming and sensing**, thus permitting semi-intelligent, autonomous transactions.[4] Smart Ledgers are touted as a technology for fair play in a globalised world. Some implementations can work at speeds up to 1 trillion database transactions a day, at a cost of millicents per transaction, with complex instructions embedded in the database itself. This compares with the few transactions per second and enormous energy cost of 'public' blockchains such as Bitcoin or Ethereum (Bitcoin approaches the energy consumption of the Netherlands or Switzerland at the

[3] Distributed Ledger Technology: beyond block chain. UK Government, Office for Science, 2016

[4] Large sections of this chapter were provided by Professor Michael Mainelli of Z/Yen based on a variety of his publications.

moment). In fairness, the public blockchains have plans to improve, but private ledgers are well ahead.

Why use Smart Ledgers? Returning to the definition above, "multi-organisational databases with a super audit trail and some embedded code", to understand the deep interest in Smart Ledgers one needs to understand the most common approach people have used for millennia to handle multi-party transactions, 'central third parties'. Examples of central third parties in action include lawyers holding escrow accounts, banks providing letters of credit, or exchanges trading and central counterparties clearing. Often the central third party sits at the centre of a large network, e.g. SWIFT or credit card processors. Pension administrators are central third parties.

Central third parties are a well-known approach to trust problems and often work well, sometimes earning the sobriquet 'trusted third parties'. Central third parties typically do three things in financial services. (1) They preserve the definitive set of market transactions. This raises the prospect of charging market participants to 'get their own data back'. (2) They safeguard the definitive set of market transactions against alteration. This raises the threat of being bribed or rewarded for falsifying transactions. (3) They validate new transactions and authorise their addition to the definitive set of market transactions. This raises the possibility of falsifying assets or admitting maleficent participants.[5]

Further, central third parties frequently become 'natural monopolies'. A natural monopoly is a supplier whose costs are lower than the alternative of multi-firm provision. Natural monopolies are not inherently 'evil', but two aspects are clear. First, a natural monopoly creates at least the three temptations to cheat enumerated above. Before you find this extreme, remember the scale of the FX or Libor scandals just to get started. This is one reason monopolies attract social attention, and in turn regulatory attention. It is also the reason natural monopolists are often paid well by members. If they get caught cheating they put a cushy life at risk.

The second temptation is to extract excessive 'economic rents'. Economic rents are payments to an owner or factor of production in excess of the costs needed

[5] Mainelli, op cit.

to bring that factor into production. This economics jargon means central third parties can charge much more than things cost. Banks, for example, have long complained about the charges of SWIFT, credit card processors, and exchanges. Switching suppliers in financial services incurs the cost of changing processes for a new supplier, or finding a new supplier with the same level of connectivity, but one of the biggest switching costs is historic data. Often, only the central third party has the authoritative dataset. The longer-term the commitments, e.g. pensions, often the stronger the role of a central third party.

The advantage of Smart Ledgers lies not in being cheaper or faster. The advantage of Smart Ledgers is that they allow organisations to work together without giving central third parties a strong natural monopoly. Smart Ledgers do this by giving everybody an immutable copy of the data they need while also reducing 'switching costs'. To switch to a new supplier, customers need to merely appoint a new central third party, not be hostage to a monopoly on historic data.

A. Technologies

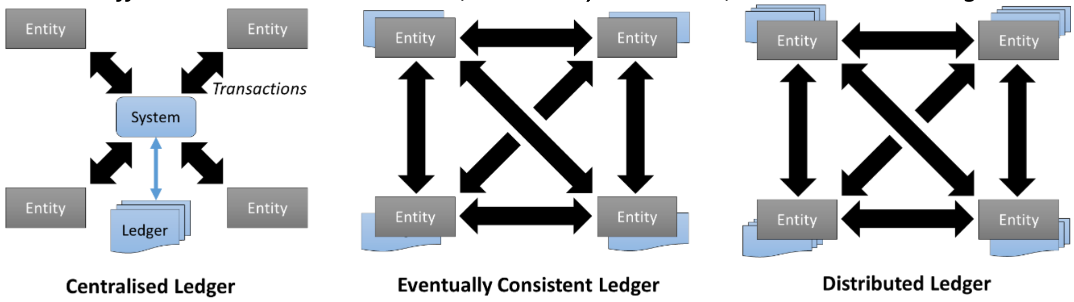
The technical environment is evolving rapidly based on the level of security and performance required, for example, traditional large-scale data storage systems are returning to favour, such as HDFS and others that are discussed later. A basic representation of MDL is shown in Figure 1 which illustrates the difference between traditional ledgers and multiple centralised systems.[6] In a traditional centralised database system, transactions are guaranteed to be atomic, consistent, isolated, and durable. When multiple systems must be synchronised, for example between organisations with their own centralised ledgers, there is the challenge of managing the consistency of the data. Large multi-ledger systems often employ the concept of eventual consistency, such that the data is in a soft state and will eventually reach consensus.[7] A distributed ledger requires consistency to be managed continuously, with each transaction

[6] Zheng, Z., Xie, S., Dai, H.N. and Wang, H., 2017. Blockchain challenges and opportunities: A survey. *International Journal Web and Grid Services*

[7] Brewer, Eric A. "Towards robust distributed systems." *PODC*. Vol. 7. 2000.

being verified using some form of consensus, such that all entities have, or could have, an identical version of the ledger.

Figure 1: The difference between centralised, eventually consistent, and distributed ledgers



MDLs and smart ledger technology have been around since the 1980s, but 'virtual money' got people's attention only after 2009. Bitcoin was described in a 2008 paper, by individuals using the pseudonym Satoshi Nakamoto.[8] The technical antecedents were work by Haber and Stornetta and others on cryptographically secured chains of blocks with timestamps used to enforce immutability.[9] Bitcoin was launched in early 2009. The intense popular interest in Bitcoin and other cryptocurrencies led to more interest in how they worked. A while later, circa 2012, the Bitcoin MDL was designated "the blockchain".

Since the days of the Lisp programming language, introduced in 1958, programmers have known that they can store computer code in a data structure for future execution. Code is data; data is code. The term 'smart contract' refers to the ability to agree (consensus) to run certain code at a future date. These pieces of code are not particularly smart (e.g. "reveal this data after a specific date") nor are they really legal contracts. Still the ability to have code execute at future agreed dates provides a powerful architecture for people to interact using automation.

Technical storage restrictions on Bitcoin meant that code could not be easily stored and executed. Ethereum popularised the concept of "building on a

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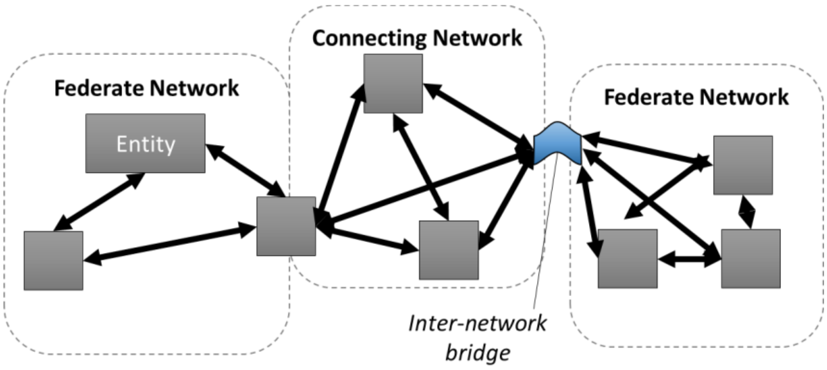
[8] Nakamoto, Satoshi. "Bitcoin: A peer-to-peer electronic cash system." (2008): 28.

[9] Haber & Stornetta, "How to time-stamp a digital document". Journal of Cryptology (1991)

blockchain" rather than merely building a blockchain.[10] Ethereum introduced the capability of incorporating state, business logic, and multi-party contracts, referring to these as 'smart contracts'. Ethereum has promoted a number of proofs-of-concept, from agriculture and farming through to the data provenance of diamonds.[11] Many other systems provide similar abilities to add 'smarts'.

However, the weaknesses of Bitcoin and Ethereum, along with significant investment monies attracted by hype and opportunity, have led to numerous new architectures. Many new systems are developing federated or joint Cloud systems. In this way, the smart ledger becomes a federation of smaller smart ledgers, each with their own network. A federated structure is shown in Figure 2, with three smaller networks that are interconnected.

Figure 2: Federated networks



There are several ways in which networks can interact, most commonly via either an inter-network bridge that manages all transactions between the corresponding networks, or through a network participating entity communicating directly with both networks, as shown on the left of the diagram. When transactions occur between federated networks, they must be verified by either independent validators or other networks, in the same fashion as

[10] V. Buterin, "Ethereum whitepaper," 2014. [Online]. Available: https://github.com/ethereum/wiki/wiki/White-Paper

[11] Diamonds Are The Latest Industry To Benefit From Blockchain Technology, September 2017, https://www.forbes.com/sites/pamelaambler/2017/09/10/how-blockchain-is-fixing-the-diamond-industrys-rampant-ethical-issues/#7a9a3ed725bc

validation within an individual network.[12] One example of this is the Nuco Aion federated blockchain.[13]

B. Smart Contracts And Consensus

For the remainder of this report let us assume that an appropriate smart ledger has been implemented based on some consensus mechanism and permits code, 'smart contracts', to be placed in the ledger for future execution.

Consensus

As previously outlined consensus is the process by which multiple parties reach agreement on the next transaction that should occur. There are several consensus algorithms that should be considered for any new system. The most prominent of these are: Proof-of-Work, Proof-of-Stake, and Practical Byzantine Fault Tolerance. Often overlooked though is a very simple consensus, let a central third party handle writing to the ledger and executing 'smart contracts. Or even just let the ledger be written to by any two parties who want to share a new agreement.

Three main factors should be considered in selecting, or developing a new consensus approach: performance and scalability, permissioning, and consensus threshold. In terms of a pension smart ledger, permissioning should reflect the differing access requirements of members (including those in-payment versus those who are active members) and the management requirements of trustees.

Smart Contracts

'Smart Contracts' can be split into code and legal elements. Code can be software written in most common computer languages, e.g. Python, Go, Java or JavaScript, or a special language, that manages how data is tracked, stored, and

[12] Mazieres, David. "The stellar consensus protocol: A federated model for internet-level consensus." *Stellar Development Foundation* (2015).

[13] Spoke, Matthew, "Aion: The third-generation blockchain network", 2017

transmitted when transactions occur.[14] Legal elements, such as legal prose and commitments, can be embedded in smart contract code. Legal enforcement is another matter, and wider arrangements such as arbitration, mediation, or expert determination, may play larger roles in future.

Given that code in a smart contract will execute no matter what, as part of a smart code contract, 'code as law' requires careful consideration.[15] Implementation must be considered in the context of consensus mechanisms which will validate the transactions. This level of automation, which is emerging across all areas of society, from pensions to personal finance through to autonomous systems in industry, will require a long period of transition. For smart ledgers this needs to go beyond consensus systems to ones that encapsulate business and regulatory logic, as well as being able to deal with disputes.

In the context of pensions smart ledgers could provide the mechanism to automate the majority, if not all, of the transactions and decisions making processes. Most importantly the reduction in central third party power could result in increased trust in pension's management, with the concomitant point that increased trust would then be more embedded in the technology. The remainder of this report outlines some of how this could be achieved along with example smart contracts.

[14] Nick Szabo, Smart Contracts: Building Blocks for Digital Markets, http://www.fon.hum.uva.nl/rob/Courses/InformationInSpeech/CDROM/Literature/LOTwinterschool2006/szabo.best.vwh.net/smart_contracts_2.html

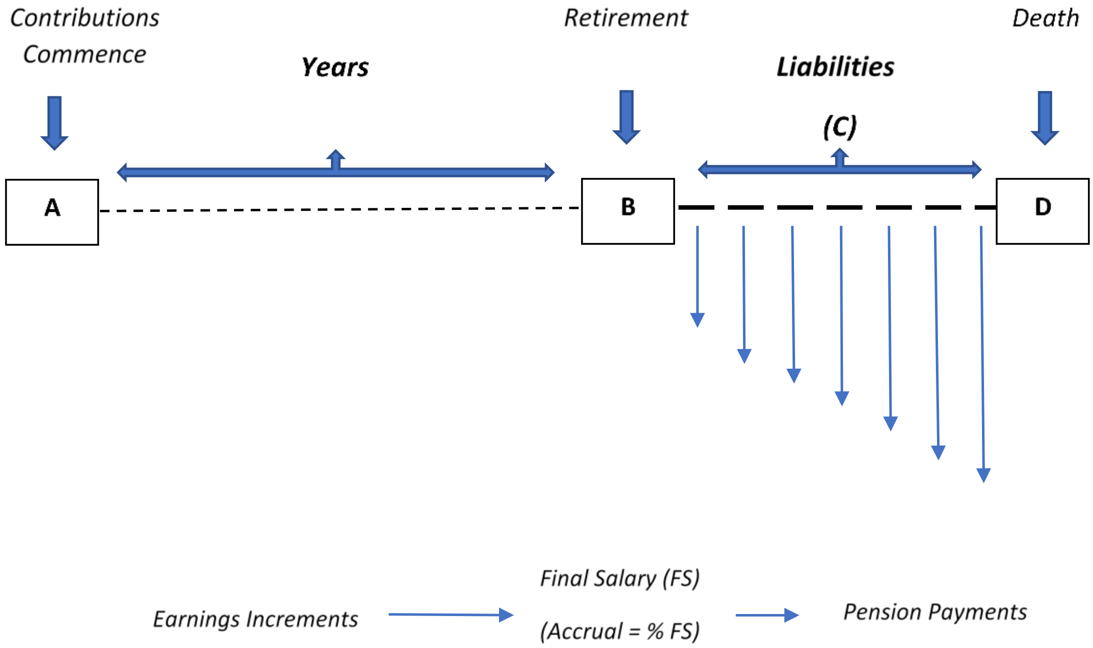
[15] Lessig, L. 2009, Code: And Other Laws of Cyberspace

3. Elements Of A CDC Specification

In the sections that follow, we outline some general requirements of a CDC management scheme, followed by some specific requirements associated with the specific form of risk management we favour. We do not focus on the administrative aspects, such as record keeping for tax purposes or banking arrangements for pension payments, as these are in common use within current systems technologies.

In figure 3, we show stylistically, the structure of the chain of contributions made and promised pensions payable. Trustees are responsible for setting the terms of new awards. This contribution pricing process involves the projection of future pension payments. This involves the trustees making, with advice from their professional advisors, a number of assumptions as to the values of these parameters. The trustees must also have regard for the value-for-money being offered to members; in essence, the estimation of a fair and achievable rate of return on the contributions made. Beyond the discretions, as much of the management of the fund as possible should be an automatic application of scheme rules. As we shall see later, this may usually be achieved through the use of smart contracts.

Figure 3: Contributions and pricing for final salary



To estimate the value of the pension liabilities, we simply sum up the contributions multiplied by 1 + the expected contractual accrual rate, which is the expected return on investments when the award for that year is made. Whereby,

$$Pension\ Liabilities$$
$$= \sum[Contributions\ \times 1 + E(Contractual\ Accrual\ Rate)$$

The combination of contribution and projected benefits payable define the award's contractual accrual rate (CAR), which may be thought of as the rate of return expected on the contribution paid. Together, these define the trajectory of the member's equitable interest over its lifetime. This is illustrated below for members aged 25, 45 and 64. In this illustration, for simplicity, lifetimes in retirement, which increase with the member's youth, are shown deterministically.

Figure 4: Evolution of the trajectories of one year's award for members aged 25, 45 and 64

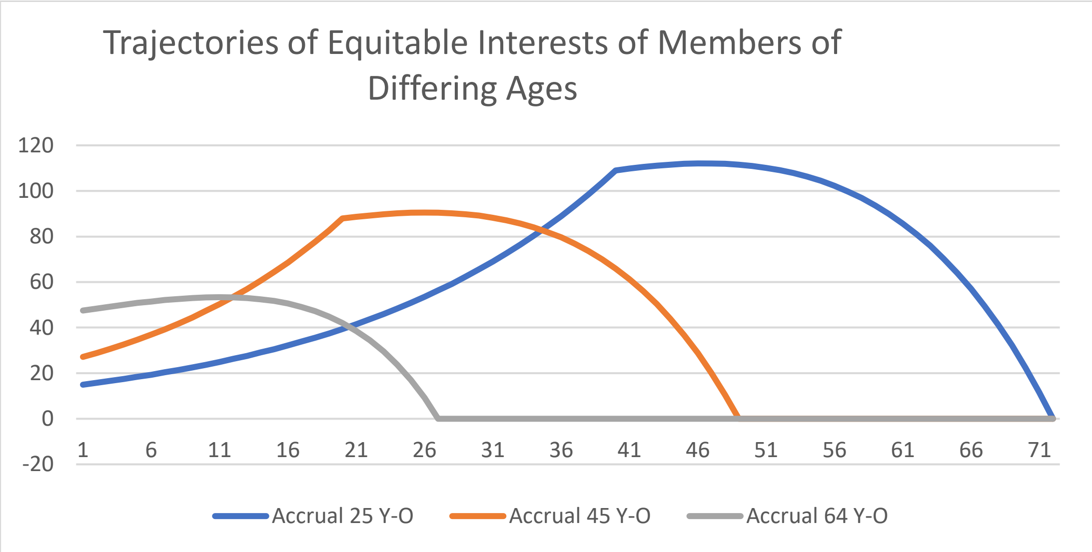
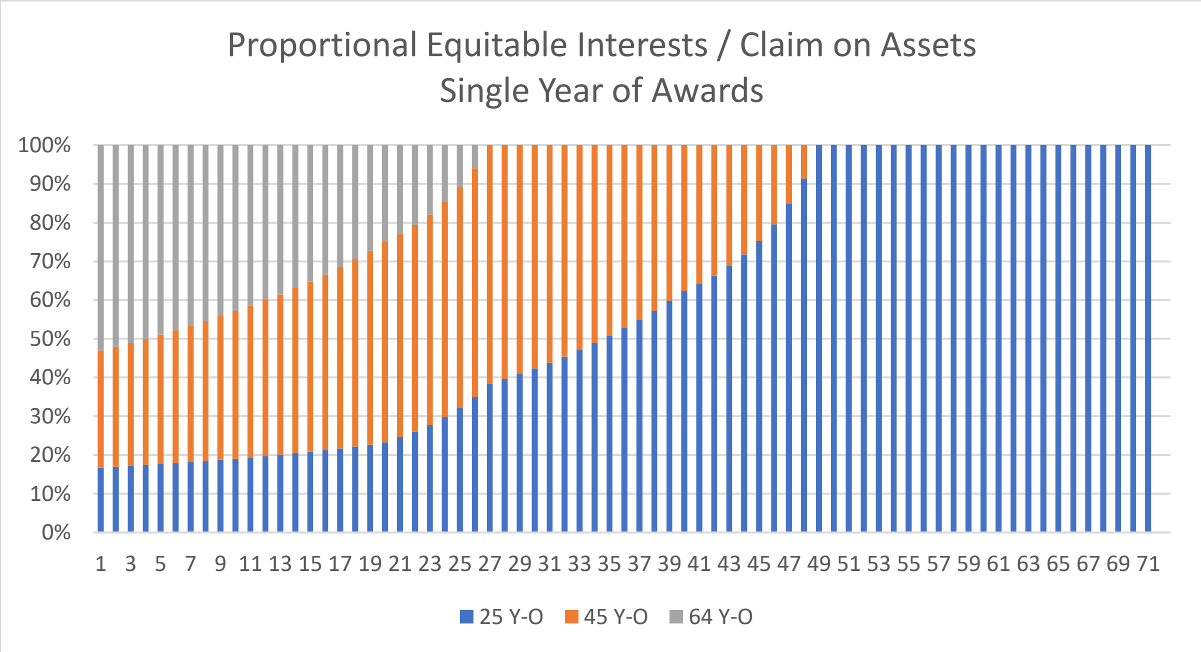


Figure 4 does illustrate one little-known feature of CDC schemes, where the accumulation and decumulation phases are integrated, in that the maximal value of the pension often occurs after retirement. This contrasts with individual DC where it is the value at retirement that is used to purchase an annuity.

The equitable interests of members, in this single award illustration, in the assets held by the scheme are simply their proportional shares of the total outstanding interests of all members at a point in time, as shown in Figure 5, for the three-member case above. These are based upon their individual equitable interest claim profiles.

Transfers out of the scheme are based upon the net asset value of their equitable interest claim; their equitable interest multiplied by the solvency ratio. There is also a one to one mapping of retirement income and capital values embedded here.

Figure 5: Proportional equitable interests/ claim on assets



A. Scaling From Individuals To A Scheme

To scale from the individual to a scheme, it is simply a case of tracking awards through time for different members, who will in all likelihood have different lengths in the scheme and differing life expectancies.

The assumptions previously made by trustees may, from time to time, be changed. For example, in the light of experience, they may wish to modify the longevity projections or inflationary expectations, and with this, the projected pension cash flows. This will, in turn, feed into a revision of the expected or required investment return (CAR). The system requirement is retention of pre and post change data.

It is possible to envisage many systems-based tools, particularly AI, which may assist with the econometric issues here, but these are merely adjuncts to the system-not core elements.

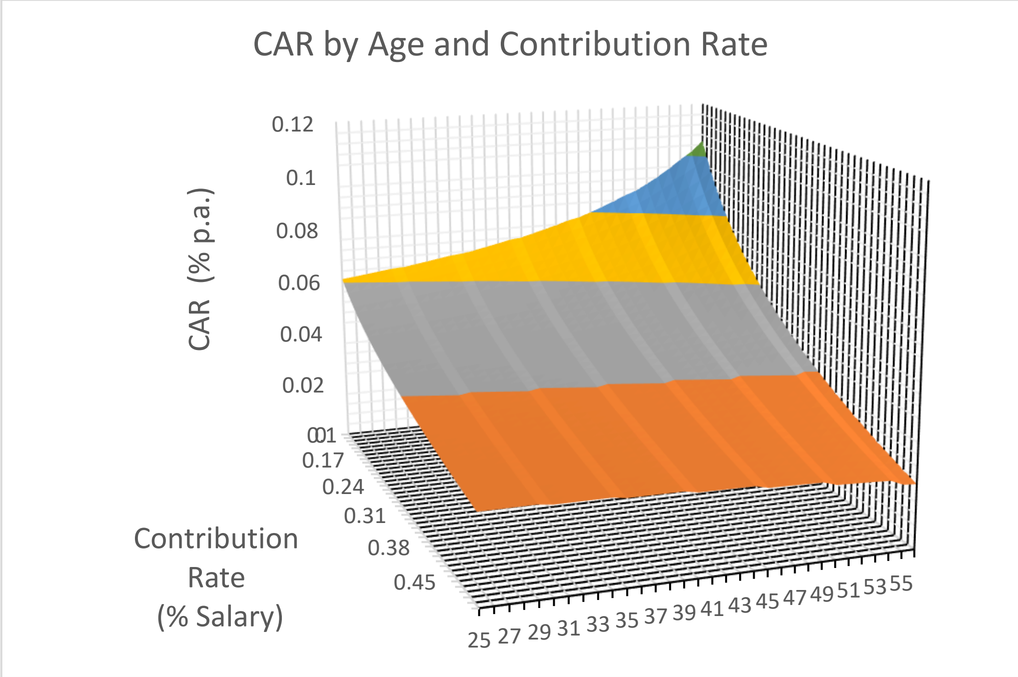
The possibilities that the collective nature of the scheme offers extend beyond the asset pooling of a common fund; these include risk-sharing, both prior to and after the investment process. These operate on and among the equitable interests of members; they may be considered as liability management mechanisms.

The uniform award structure of traditional DB arrangements is a powerful and useful risk-sharing mechanism for members, which operates ex ante. When contributions are fixed as a uniform proportion of salaries, and benefits are similarly uniform for a year of service regardless of member age, the returns on contributions effectively promised to members differ. In the earlier single contribution period illustration (Figure 4), the individual rates are: 25 YO 5.22%, 45 YO 6.39%, 64 YO 12.18%, and the weighted average of the scheme is 8.03%. The scheme CAR is the weighted average of these individual CARs.

As the insurance-like properties of this risk-sharing mechanism are frequently misunderstood due to incomplete analysis, we shall take this opportunity to explain it more fully by considering a wide range of contribution rates. This is illustrated in Figure 6. The corrugations evident in this figure are a product of the granularity of increases in life expectations in this simple model. The younger members have far longer life expectations than the older members.

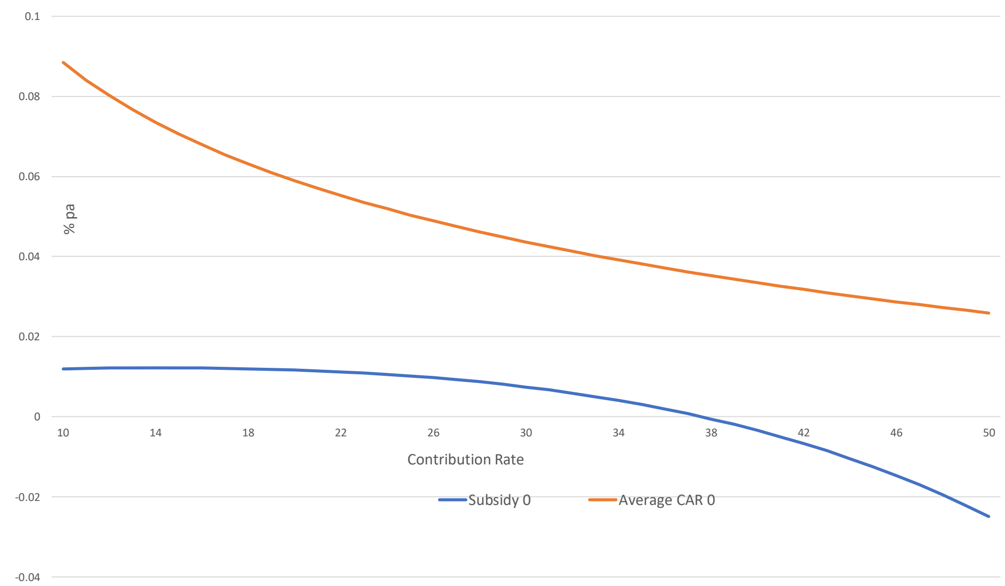
When expected returns are high, and contribution rates low, we see that younger members achieve lower than average returns, while older members achieve higher on returns. By contrast, when expected returns are low, and contributions high, younger members achieve higher than average returns, and do so over the entire life of the award, while older scheme members experience lower than average returns. This arrangement is true risk sharing, not some intrinsically inequitable subsidy. It fosters solidarity among members, as it represents a form of mutual insurance.

Figure 6: Risk sharing arising from uniformity of award



The magnitude of this effect between the oldest and youngest members of a scheme, by contribution and average contractual accrual rate is shown in Figure 7, where the average CAR and young to old support by contribution rate as a proportion of a young member's salary is presented.

Figure 7: Average CAR and young to old support



B. Scheme Risk Management

When deficits do arise between the scheme's assets and the aggregate equitable interest, the trustees should consider the nature of the causal underperformance – transient or permanent. If the deficit arises from misestimation by trustees of the achievable portfolio returns and cannot be rectified by some rebalancing of the asset portfolio, then reductions in the pensions and equitable interests of scheme members may become necessary. The tell-tale of systematic misestimation is persistent and growing solvency deficits. The most important thing is that there is time available to trustees to apply these remedial actions, and in the interim, the formulaic risk-sharing described, allows equitable risk bearing to continue.

However, in general, unless there are pensions in payment, a transient scheme deficit should not trigger interventions. When there are pensions in payment, the situation changes.

The risk management process described here differs from that commonly applied in banking and insurance. It does not rely upon probabilistic analysis and the use of capital adequacy provisions or risk buffers. It operates on the basis of events which have occurred, and not those which may arise in the future. In this regard, it is superior from a cost standpoint. Risk management is invoked only when a particular risk has eventuated. The interventions also apply only to the current situation; they do not operate over many future periods, as might be the case when, for example, cutting pension indexation.

C. Supporting Pensions And Cutting Benefits

First, if scheme assets fully cover the total equitable interest of members, then no cuts to pensions or otherwise are necessary. As noted above, if the scheme is in deficit but no pensions are payable, it is only necessary to consider cutting benefits if that deficit arises from systematic misestimation, it is persistent, and growing.

If the assets of the scheme do not fully cover the total equitable interest, then the pension payment would be at risk, but at this point, a risk sharing agreement would come into play. The pension payment is made in full, with the top-up being provided from the assets attributable to other non-pensioner members of the scheme. This top-up is not unconditional; it is subject to some scheme rules as to the duration and amount of support.

In any year, the amounts of this top-up are quite modest. To illustrate this, let us consider a scheme which is 80% funded, where the equitable interests of pensioners are 40% of the scheme total, and pensions amount to 5% of the value of assets. The top-up is just 1% of the total equitable interest, or 1.25% of scheme assets. Even if the deficit or shortfall is 50%, the transfers only amount to 2.5% and 3.13% respectively.

It is critical to maintain equitable balance among members to ensure scheme sustainability. This involves increasing the equitable interests of non-pensioner members by an amount equivalent to the support afforded as pension payments. In this case, the 40% of members who are pensioners received 1% as support, which means that the 60% who are non-pensioner members should see their total equitable interest increased by an amount of 1.5%.

Many deficits are likely to be simply the result of the transient animal spirits of markets, and likely to self-correct. This phenomenon, and the costs of intervention, either by benefits cuts or asset portfolio rebalancing, gives rise to the need for a forbearance period, during which the risk-sharing mechanism will operate. Clearly, that forbearance mechanism needs to be related to both the magnitude of the deficit and the resultant support transfer.

A simple rule suffices: a 10% deficit should have a ten-year forbearance period, a 20% deficit five years, and 50% just two years.

Some further rules are needed to cater for sequences of deficits. Increasing deficits shorten the forbearance period, so a 20% deficit has a five-year forbearance period, and if this increases in year one to 50%, the forbearance period shortens to just two years from that date.

For partial recoveries, suppose that the 50% deficit shrinks to just 20% in the first year, then the forbearance period becomes five years. However, the clock started the year previously, leaving just four years of ongoing forbearance.

This forbearance rule is further constrained by a cumulative support rule, discussed later. If a scheme is still in deficit at the end of this forbearance period, then the pension payable is cut; the payment is simply the funded level of the pensioner members' equitable interests.

To avoid an actual cut, the pensioner may choose to borrow against, or bring forward, some of his or her residual equitable interest. If and when the asset coverage of the scheme recovers, the cuts imposed will be automatically restored, but doubtless some members may have died in that interim.

If payments to pensioners are cut, so are, to a similar degree, the equitable interests of non-pensioner members.

There is, also, the issue of the amount of their equitable interest that non-pensioner members might be happy to risk in support of pensioners. This is equivalent to a capital adequacy level or risk buffer. This is constrained also by the possibility that excessive support would reduce the asset pool to a level from which recovery is not possible. A cumulative level of 10% of the total scheme equitable interest seems plausible, particularly when it is understood that this is a maximum exposure. In the case where pensioners in payment account for 40% of the scheme, this is equivalent to a risk buffer of 25% (10%/40%). Obviously, the total amount of support which may be afforded is related to the composition of the classes of member in the scheme.

It also introduces another potential scheme metric, the unutilised scheme risk-sharing support. This can also be presented as the length of time for which full pensions are in essence assured.

These risk-sharing rules will also feed into the performance objective of the asset portfolio, since they determine the length of time over which performance averaging is tolerated without cuts to benefits.

The presentation to scheme members is simple. If you place, at risk of partial loss, 10% of your equitable interest in the scheme in support of pensioners, you may expect to enhance your own pension outcomes by a similar or larger amount.

There is one prospective new risk management indicator – the unutilised risk-sharing capacity. This may be expressed as a "first time to cut" metric. It is the time during which cuts to pensions are not expected. It also informs the term over which fund management target return averaging is desired.

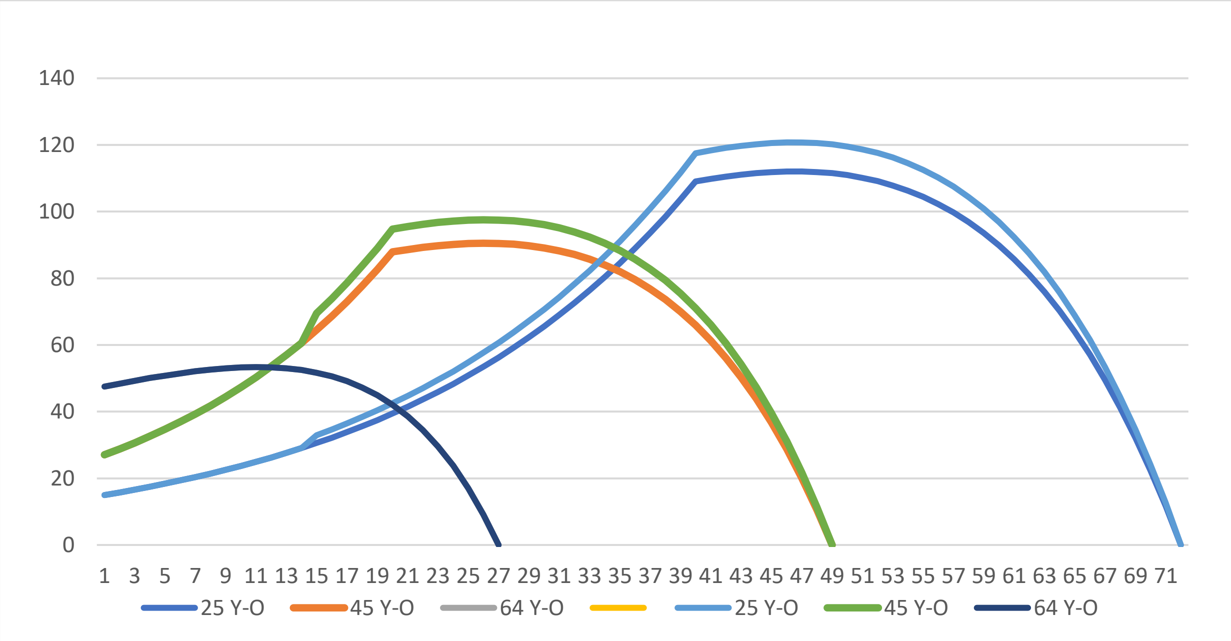
D. Risk-Sharing In Action

We now present a simple worked example in Figure 8, to clarify the operations of risk management. We use the simplified three-member scheme for which the individual equitable interests were shown earlier (Figure 3).

To this scheme we apply a shock in year 15. In that year the fund suffers a loss of 50% of the fund's value. This is extreme. It means that the fund has a negative return on the original contributions at the end of 15 years. The likelihood of such an event is vanishingly small (5 in 100,000). However, it means that half of the pension payment of £7.40 to the retired 64-year-old is at risk.

However, this pension is paid, implying that the retiree has received £3.70 more than was justified by scheme funding. To maintain equitable balance, as this section of the scheme accounts for 33.4% of the overall scheme, it is necessary to add a total of £7.37 to the equitable interests of the 25-year-old and the 45-year-old, distributed as £2.37 to the 25-year-old and £5.00 to the 45-year-old, while the equitable interest of the 64-year-old is unchanged. The effect of these transfers is illustrated below.

Figure 8: Evolution of equitable interest with and without risk-sharing



There are numerous ways in which the effects of risk-sharing may be communicated. For example, the participating scheme members will see a 7.76% increase in their target pension, or equivalently, that their relative equitable interest in the scheme assets has increased.

It should be recognised that even though this event is dramatic, the effect on the lifetime cost of the scheme is modest – the contractual accrual rate of the scheme rises from 8.03% to 8.15%.

Let us, further, speculate that a year passes and cuts become necessary. Then, for the non-pensioner members, these are cuts to the higher, post risk-sharing target benefits.

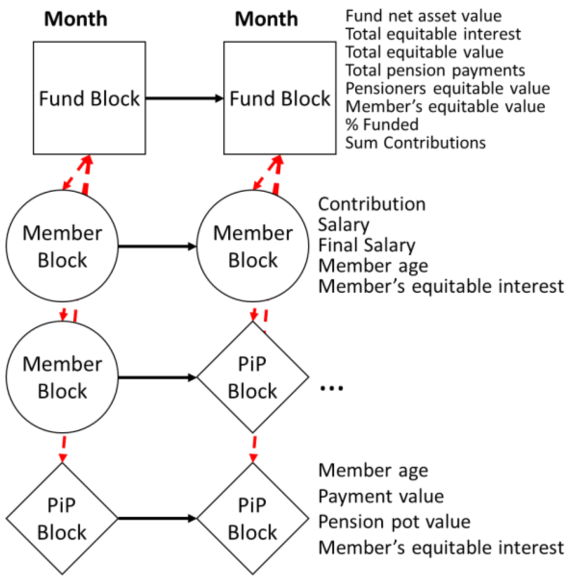
4. The Technical Structure Of Smart Ledgers For Pensions

Having earlier considered the different ways in which smart ledger technologies can be built, we now explore the application of a smart ledger solution in the context of the running and management of a CDC pension. With respect to the CDC structure described above, the setting of new awards, target outcomes, realised performance, and changes in equitable interest, a smart ledger lends itself to tracking and record keeping of the financial transactions of the fund and of individual members. Our proposed system therefore involves multiple ledgers representing:

- the fund and its transactions;
- individual members making contributions and receiving new awards through time;
- pensioners in receipt of payments.

Figure 9 below shows from a member's perspective, chains that capture the transactions of contributions (by members, and their employers) and payments to pensioners. From the fund's perspective, the master chain monitors the expected and actual return on investments, in capital and income terms, as well as managing any surplus or deficit in the fund, through the support rules defined in the scheme rules.

Figure 9: Simple pension chain and block structure

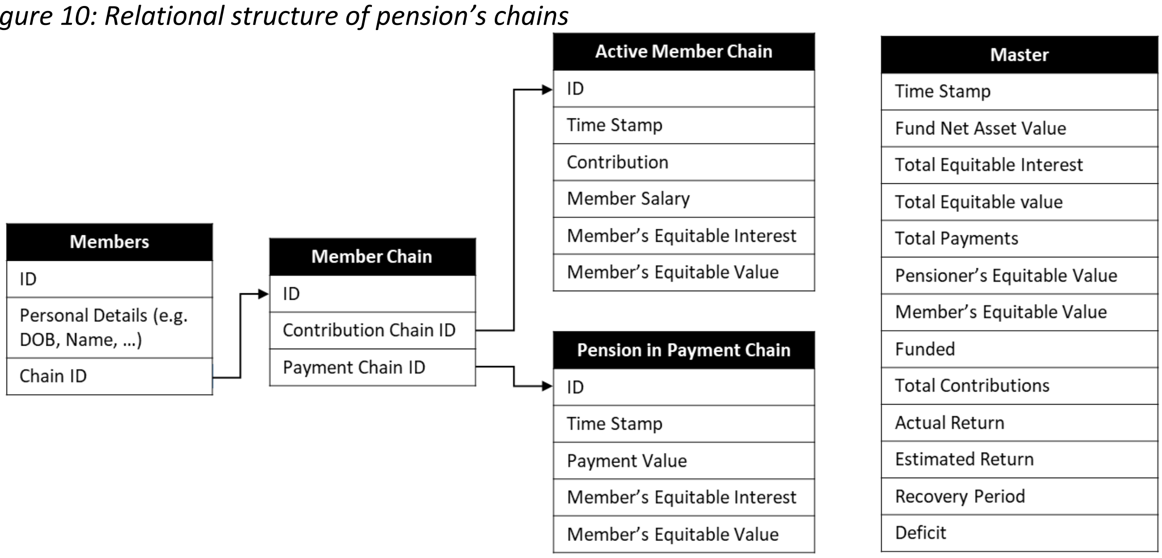


Each set of records in the ledger, which represents a single period in the life of the fund, for example a month, is comprised of master blocks, representing the state of the whole fund, and individual member's blocks, which includes both active and in-payment members. The master fund block keeps a track of member's blocks and corresponding chains. Figure 10 shows an abstraction of the block structure and a set of chains corresponding of 2 blocks each. Each block contains the relevant information for the transaction, as its impact on the fund or the member's equitable interest in the fund. For example, a member contribution block will contain information relating to the absolute contribution value, the salary of the individual at the current point in time, the predicted final salary, and their calculated equitable interest in the scheme.

From a technical software development standpoint, the core challenge is the development of a federated chain structure to allow multiple chains to co-exist and reference each other. This is unlike the single blockchain structures seen in current state-of-the-art MDL solutions. Several projects, such as R3 (Corda), Cardano, IOTA, Ocean, or Hyperledger, are exploring federations to manage performance issues on speed and storage loads.

Numerous smart ledger platforms might work well for pensions. In order to do so, the ledger platform must be able to represent relational data and, specifically, relationships between chains and individual blocks. If this was designed in a traditional relational database, the scheme could be represented using the following structure:

Figure 10: Relational structure of pension's chains



In such a structure, a chain exists in the 'Active Member Chain', a 'Pension in Payment Chain', and in 'Master' tables. The ability to build this structure using smart ledgers provides increased security through consensus mechanisms, as well as integrity and transparency, which ensures that data is immutable, and individual members can see every conducted transaction that affects their pension. From this, the actions of trustees are also recorded, and their assumptions and decisions are a matter of record. Such a level of detail would therefore present a significant increase in the effectiveness of governance and accountability of trustees.

A. Scaling Up The System

If there were to be widespread adoption of the proposed CDC scheme, the underlying platform must be scalable to millions of members and ensure dependable and secure data storage. As such, it is worth considering a hybrid architecture with commonly used platforms from Big Data systems and Cloud computing, which are designed to reliably, rapidly, and securely handle vast quantities of data.

The basic concept that underpins most of today's large-scale systems is known as a distributed file system. One of the most important technologies in this field is the Hadoop Distributed File System (HDFS). Apache Hadoop[16], now in its third major release, is comprised of three main elements: HDFS, YARN, and MapReduce, which together, are used extensively by the likes of Facebook, IBM, Yahoo, Google, and many others.[17]

In such systems, YARN and MapReduce are responsible for managing computer resources (e.g. processing time, networks, memory etc.), as well as the running of processes across these resources. HDFS provides a managed file system across a distributed computer architecture and facilities data duplication for increased reliability. When combined with the likes of Apache HBase[18], which is

[16] http://hadoop.apache.org/

[17] https://wiki.apache.org/hadoop/PoweredBy

[18] http://hbase.apache.org/

an open-source version of Google BigTable,[19] additional necessary features for managing pensions, such as immutability and traceability, can be added. This, implicitly, forms a distributed ledger.

This raises the question of whether a new paradigm that merges these various technologies is the optimal solution, given the unique nature of pension fund management for CDC, which requires a very specific subset of features from smart ledger technologies.

B. Permissioning And Smart Contracts

A key challenge in smart ledgers is permissioning. However, due to the nature of a pensions distributed ledger, this can be easily managed. There are two classes of user: trustees and members. Members have permission to view their own personal chains and the master fund chain. Active members are therefore able to make contributions, and pensioners are able to take payments, either as drawdowns or annuities. The trustees have access to all the chains and are responsible for enacting smart contracts. In that way trustees are unable to perform actions that affect either the fund or individual members, except through smart contracts. It is at this stage that appropriate consensus mechanisms are needed among the trustees, to authorise transactions.

To build the smart contracts for the scheme is a relatively trivial exercise. As illustrated below, these are simply the codified versions of the scheme rules. We therefore present two contracts, one for the deficit recovery and a one for the recovery period.

If we take the rule for deficit recovery as set out below, the first smart contract illustration sets out the coding. As set out above, our rules for deficit recovery are simple, whereby a 10% deficit should have a ten-year forbearance period, a 20% deficit five years, and 50% just two years.

In looking at the sequences of deficits, increasing deficits shorten the forbearance period, so a 20% deficit has a five-year forbearance period, and if this increases in year one to 50%, the forbearance period shortens to just two

[19] https://cloud.google.com/bigtable/

years from that date. While for partial recoveries, if the 50% deficit shrinks to just 20% in the first year, then the forbearance period becomes five years, but the clock started the year previously, leaving just four years of ongoing forbearance.

The second smart contract looks at the changes in the funding of the scheme and whether there is a deficit or a surplus. From the worked example below, we illustrate what happens when there is a deficit in the scheme, and the second smart contract represents the codification of these rules for both surpluses and deficits.

Table 1 below shows accounting values for a scheme which is 80% funded, and where pension members account for 40% of liabilities and non-pensioners 60%. Pensions payable in the current year are £5, and the scheme 80% funded means only £4 should be paid. The risk sharing support ensures that the additional £1 is paid to pensioners, and with that payment, the equitable interest of non-pensioners increases by £1.5.

			Pension	
	Fund NAV	**200**	Total Payments	5
			Funding	80%
	Equitable interest	Equitable Value		
Pensioner	40%	100	Funded	4
Non-Pensioner	60%	150	Support	1
Total Equitable Value		**250**		
			Pensioner	1
Funding		80%	Non-Pensioner	1.5
Pensioner NAV		80		
Non-Pensioner NAV		120		
		200		

Fund NAV: £200
Funding: Fund Net Asset Value/Total Equitable Value = £200/£250 = 80%
Total Equitable Value (TEV): £250
Pensioner Equitable Value (PEV): £100
Member Equitable Value (MEV): £150
Pensioner Equitable Interest (PEI): PEV/TEV = £100/£250 = 40%
Member Equitable Interest (MEI): MEV/TEV £150/£250 = 60%

Total Payments: £5
Funded: £4
Support: £1
Relative Equitable Interest (REI): REI = (MEI/PEI) x Support = 1.5

New Total Equitable Value = £251.5
New Pensioner Equitable Interest = £100/£251.5 = 39.76%
New Member Equitable Interest = £151.5/£251.5 = 60.24%

Recovery Period Smart Contract

The "Recovery Period" Smart Contract monitors the duration that the fund has been in deficit and calculates rules for recovery. If the fund does not recover within the specified time frame, payments may be cut.

Values are stored for the fund's deficit, the recovery period, and the current time in recovery (CTIR). These are all initiated to '0'. There are therefore two stages to this smart contract:

1. The fund is in deficit (lines 3 to 8). In this case, the deficit ratio is calculated and as long as the updated ratio is less than the old deficit ratio, the recovery period is decremented on an annual basis, based on the recalculated recovery period and the time spent in recovery. If the deficit ratio has increased, the recovery period is recalculated and the stored deficit ratio is updated.
2. If the recovery period is exceeded then the equitable interest of the members (both active and in payment) must be updated (lines 10 to 12). This results in a reduction of payments and fund value. Once these are updated, the deficit clock and recovery periods are reset.

Inputs & Values

```
Old Deficit (Initial value = 0)
Recovery Period (Initial value = 0)
CTIR (Initial value = 0)
```

Algorithm

```
1  Funded = Fund NAV / TEV

2  IF ( Funded < 1 ) THEN Deficit
3     New Deficit = 1 - Funded

4     IF ( New Deficit <= Old Deficit ) THEN Continue
5         Recovery Period = 1 / New Deficit - CTIR
6     ELSE
7         Recovery Period = 1 / New Deficit
8         Old Deficit = New Deficit
9         CTIR = 0

10 IF ( Recovery Period < 0 ) THEN Adjust Equitable Interest
11    PEV = Funded x PEV
12    MEV = Funded x MEV
13    TEV = PEV + MEV
                              Reset deficit clock
14    Old Deficit = 0
15    Recovery Period = 0
```

Deficit and Surplus Smart Contract

The "Deficit and Surplus" Smart Contract automatically manages the adjustment of equitable interest and the corresponding payments to pensioners during periods of either deficit or surplus of the fund.

Values are stored for the total payments made to pensions in a year (Total Payments); the fund's net asset value (Fund NAV); the total equitable value of the fund (TEV), and the corresponding equitable values of the pensioners (PEV) and members (MEV). At runtime, values are also calculated for the funding and deficit ratios (% Funded) and the relative equitable interest (REI).

Three scenarios can occur:

- First, the fund is perfectly funded.
- The fund is in deficit and the contract therefore follows algorithm lines 3 – 9. In this case, the shortfall is calculated based on the deficit (1 – Funded). The Shortfall is then used to calculate the relative equitable interest, which in turn is used to update the member's equitable value on line 6. In practice, this means that the members will be compensated for the support given to the pensioners. The new member's equitable value is used to update the total value of the fund and new ratios between pensioners and members (lines 7 to 9).
- Or the fund is in surplus, resulting in the actions from line 11 to 18. In this case, rather than a shortfall being calculated and surplus is found. Pensioners then receive a proportional increase in their payments. Using the same method as before, the active members have their equitable value increased appropriately.

Inputs & Values

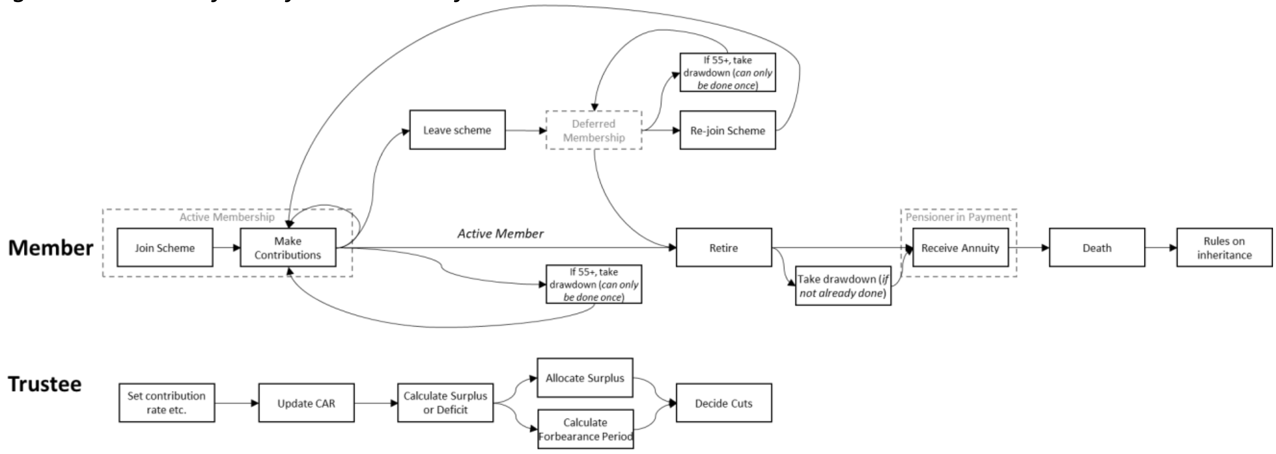
Total Payments, Fund NAV, TEV, PEV, MEV, PEI, MEI, REI, Funded

Algorithm

```
1  Funded = Fund NAV / TEV

2  IF ( Funded < 1 ) THEN Deficit
3     Shortfall = Total Payments x (1 - Funded)
4     PAY SHORTFALL
5     REI = (MEI / PEI) x Shortfall
6     MEV = MEV + REI
7     TEV = PEV + MEV
8     PEI = PEV / TEV
9     MEI = MEV / TEV

10 ELSE IF ( Funded > 1 ) THEN Surplus
11    Surplus = Total Payments x (Funded - 1)
12    Payments = Total Payments x Funded
13    PAY PENSIONS
14    REI = (MEI / PEI) x Surplus
15    MEV = MEV + REI
16    TEV = PEV + MEV
17    PEI = PEV / TEV
18    MEI = MEV / TEV

19 ELSE ( Funded = 100% ) THEN Fully Funded
20    PAY PENSIONS
```

Lastly, Figure 11 shows the process flow of transactions from both the perspective of members and trustees. All transactions, including those by members, require authorisation by the trustees.

Figure 11: Process flow of transactions for members and trustees



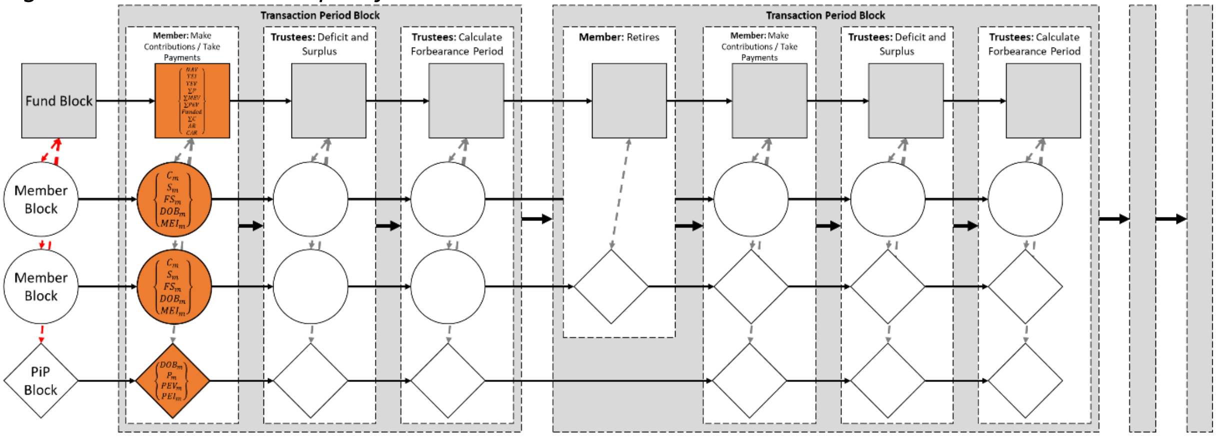
Each of these transactions would be automated using a smart contract which enforces all participants to follow the rules of the pension scheme. For example, from the trustees' perspective, the calculation of the fund surplus or deficit exactly follows the algorithm set out in the 'Deficit and Surplus Smart Contract' shown above. This contract, also, authorises the payment of pensions to pensioners. Similarly, the 'Recovery Period Smart Contract' provides the mechanism by which trustees calculate the forbearance period and decide cuts.

Pulling this together, the overall chain structure is shown in Figure 12. As discussed previously there is a block for every transaction period for every member of the scheme. Each transaction is the invocation of one of the smart contracts, with one or more transactions for every active or in-payment member of the scheme and at the fund level during each period.

Figure 12 depicts a fund which consists of three members, two of which are active, and one is a pension in payment. During the first transaction period, three transactions occur: first, contributions are made by the active members and payment are taken by pensioners; second, the Deficit and Surplus smart contract is used; third, Recovery Period Smart Contract is used to recalculate the forbearance period if the scheme were to be in deficit.

The second transaction period block continues each of the individual chains from the previous block. In this case, the first transaction shown is the retirement of a member, so that they become a pensioner-in-payment. Subsequently, the remaining transactions of this period are the same as those shown previously.

Figure 12: Combined example of a three-member chains



Conclusion

With the complete decline of traditional DB pensions and the inadequacy of DC savings wrappers for retirement, CDC as proposed in this paper is a way to ensure better outcomes for members, as it is akin to traditional DB without the employer guarantees. It is therefore a superior form of pensions savings and will go a considerable way to rectify many of the issues in retirement savings today, namely, low savings rates and poor outcomes.

In a CDC arrangement, as with other pensions there are employee and employer contributions which are invested. However, unlike DB where there is a hard, and costly guarantee or in DC, where the amount to be received on retirement is wholly unknown, in CDC there is a target income. This amount is what a member should receive in retirement and can be viewed as a ‘promise’ but one which is made on a best efforts basis and may not ultimately be what a member receives. In CDC, this ‘promise’ is collectively underwritten by the scheme members. CDC is therefore a collective member mutual structure, whereby members ‘owe things to themselves’. Consequently, there are no enforceable external liability claims as these promises are ambitions not guarantees.

In CDC, the ‘promise’ defines the equitable interest of a scheme member and is endogenous, and as such sets the relative magnitudes of claims of members on the assets of the scheme. Here, equitable interest may be expressed as either (or both) a capital value or an equivalent pension income. In sum, members’ interests is a metric of the total ambition of the scheme, and comparison of this with the value of the investment fund provides a measure of solvency of the scheme as to the sufficiency of the assets currently held.

In any collective arrangement, a common problem is the possibility of over consumption today at the expense of future beneficiaries. However, the ability of those undertaking excessive consumption today, is a function of the rules of the scheme and it may be avoided by the consistent application of some simple rules but effective rules. Such rules essentially meet the definition of a “smart contract”.

If CDC pension were to implement smart contracts, this prevents the over consumption problem and ensures inter and intra generational fairness; a key concern in pensions. Moreover, the use of smart contracts ensures consistent low-cost administration.

The use of smart ledger technology is therefore a natural solution to many of the challenges a CDC structure poses for pensions governance and administration. First, smart ledgers, ensure the accuracy and immutability of previous records including the assumptions and decisions of trustees. Consequently, there is transparency as to the decision process, which is not something that currently exists in pensions. Second, the multi-period accruals of assets, contributions, and the entitlements of scheme members, as well as the payment of pensions are all linked in chains over time. This technology therefore affords transparency for members; they may view both the capital value and the pension income equivalent of this in near real-time, as well as its historic evolution.

Smart ledgers support transparency around decisions, costs and entitlements, and allow for better implementation of collective savings schemes, which will result in superior member outcomes.

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David McKee is a Research Fellow at the University of Leeds, in the School of Computing. He has a background in large-scale autonomous systems and cyber-physical systems. He works across industries from manufacturing and supply chain management, through to financial platforms. David is particularly interested in the development of distributed fault tolerant real-time systems and their effects on Industry 4.0. He is pioneering the development of the Internet of Simulation (IoS) paradigm in collaboration with the Royal Academy of Engineering Enterprise Hub. David holds a PhD in Computing from the University of Leeds and a Masters in Computer Systems and Software Engineering from the University of York.

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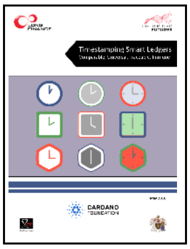
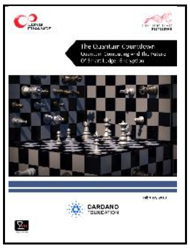
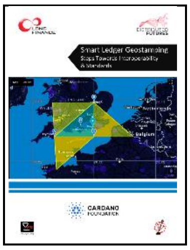
Other Distributed Futures Publications

	Title	Authors	Year	Publisher
	Timestamping Smart Ledgers - Comparable, Universal, Traceable, Immune	Sam Carter	2018	Long Finance (June 2018), 55 pages.
	The Economic Impact Of Smart Ledgers On World Trade	Centre for Economics and Business Research	2018	The Worshipful Company of World Traders and Long Finance (April 2018) 78 pages.
	Liquidity Or Leakage - Plumbing Problems In Cryptocurrencies	Rodney Greene and Bob McDowall	2018	Long Finance (March 2018), 61 pages.
	Get Smart About Scandals: Past Lessons For Future Finance	Professor Tim Connell and Bob McDowall	2018	Long Finance (March 2018), 102 pages.
	The Quantum Countdown: Quantum Computing And The Future Of Smart Ledger Encryption	Maury Shenk	2018	Long Finance (February 2018), 61 pages.
	Smart Ledger Geostamping - Steps Towards Interoperability & Standards	Michael Mainelli and James Pitcher	2017	Long Finance (December 2017), 20 pages.

Distributed Futures is a significant part of the Long Finance research programme managed by Z/Yen Group. The programme includes a wide variety of activities ranging from developing new technologies, proofs-of-concept demonstrators and pilots, through research papers and commissioned reports, events, seminars, lectures and online fora.

Distributed Futures topics include the social, technical, economic, and political implications of smart ledgers, such as identity, trade, artificial intelligence, cryptography, digital money, provenance, FinTech, RegTech, and the internet-of-things.
www.distributedfutures.net

Cardano Foundation is a smart ledger and cryptocurrency organisation based in Zug, Switzerland. The Foundation is dedicated to act as an objective, supervisory and educational body for the Cardano Protocol and its associated ecosystem and serve the Cardano community by creating an environment where advocates can aggregate and collaborate.

The Foundation aims to influence and progress the emerging commercial and legislative landscape for blockchain technology and cryptocurrencies. Its strategy is to pro-actively approach government and regulatory bodies and to form strategic partnerships with businesses, enterprises and other open-source projects. The Foundation's mission is the promotion of developments of new technologies and applications, especially in the field of new open and decentralised software architectures.
www.cardanofoundation.org

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