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Tartan, Chloe Ceren

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A Blockchain-Based Welfare Distribution Model for Digital Inclusivity

Chloe Ceren Tartan[1]

[1] nChain Ltd, London, UK

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Abstract. An unprecedented rate of technological advancement, compounded by the COVID-19 pandemic, has expedited our transition to a fully digitalised society. Traditionally, digital inclusion focuses on an individual's ability to connect to and access information from the internet. The adoption of novel technologies such as artificial intelligence and blockchain is little distinguished in the literature from internet accessibility. While these digital solutions present novel opportunities, they may also perpetuate or exacerbate the existing hurdles faced by digitally excluded localities. However, these technologies could also be used to tackle the digital divide. Inspired by the design of Bitcoin, the current study offers a conceptual blockchain-based welfare model that adopts a two-pronged approach to enable the fair distribution of capital and resource allocation across the UK regions. The model offers transparency over institutional processes and improves their trustworthiness while preserving privacy. At the community level, the model assumes the application of economic incentives in order to promote digital inclusivity and stimulate cooperation and competition within local cultures. By mobilising both public institutions and communities, such a holistic model would assist the flow of information between the supply and demand side of the regional economy. This approach may not only help to dissolve the welfare losses arising from the digital divide, but also improve social well-being in all regions.

1 Introduction

The emergence of Industry 4.0 technologies (I4T) such as artificial intelligence (AI), blockchain and big data has marked the onset of a Fourth Industrial Revolution (Liao et al. 2017, Lu 2017, Popkova et al. 2019). The digitalisation of public services in healthcare and welfare has facilitated remote access to key support services during the COVID-19 pandemic. By utilising digital technologies for the delivery of these vital services, the impact of a lack of human capital diminishes, ultimately leading to an increase in a population's welfare (Grigorescu et al. 2021). I4T offers great promise for regional growth opportunities in terms of knowledge production and innovation (Balland, Boschma 2021). Yet there is a substantial risk that these benefits may only become a reality for digitally literate localities (Coldwell-Neilson, Cooper 2019). The literature on regional divergence and polarisation (Martin et al. 2016, Storper 2018, Venables 2020) suggests that the widespread adoption of digital technologies is likely to compound the existing digital divide that arose from the Internet. Given that the key drivers of the digital divide mirror structural social inequalities, technological innovations in the public sector threaten to reinforce social inequalities and further isolate disadvantaged groups who rely upon support services (Robinson et al. 2015). In other words, the digitalisation of the public sector poses a tangible threat to the welfare of those on the periphery of the digital revolution due to regional and socio-economic disparities.

Our research question is as follows: can a welfare data management system be created using the cutting-edge technologies of the Fourth Industrial Revolution that ensures the digital inclusion of all groups in society? Surveying the literature on I4T and management systems, there have been numerous studies investigating the use of AI (Oke 2008, Zawacki-Richter et al. 2019, Benbya et al. 2021, Collins et al. 2021). However, the debate in mainstream and regional economics has focused largely on firms, employment and consumer behaviour (Frey, Osborne 2017, Tubadji et al. 2021, Hidalgo 2021), with little attention paid to the use of AI for welfare management (Oravec 2019, Vinuesa et al. 2020). Additionally, there has been only partial recognition of the use of blockchain technology for management systems, primarily in the context of identity and digital rights management (Faber et al. 2019, Chen et al. 2019). Studies on the application of blockchain technology in social welfare have largely been limited to its use as a digital payments platform for the issuance of benefits and philanthropic donations (Li et al. 2018, Hsu et al. 2020), with the UK government also commissioning a study for a blockchain-based welfare payments system (Walport 2016, Barber 2016).

At the time of writing, we have identified a gap in this stream of literature: a welfare data management system that utilises the transparency, auditability and accountability of blockchain technology. In this paper, we describe how the integrity of data stored on a public blockchain such as Bitcoin combined with the economic incentives underlying its security model can offer significant promise when implemented in a digitalised welfare management system. Incentive mechanisms are necessary to ensure that such a system is fully inclusive for all classes of society and stimulate action by communities and institutions so that they can collectively support the social welfare of digitally excluded individuals. Our conceptual model aims to spark further research to address this gap in the literature through digital inclusion policies enacted at the micro- and macro-level, whereby the latter is realised through the integration of the Bitcoin blockchain with the management of welfare records, and the former uses the micro-incentives inherent to the Bitcoin network to demonstrate how the technology can be used to narrow the digital divide. It is important to note that the paper is written from a technical point of view, as an open letter of invitation to economists and welfare specialists to contribute and elaborate upon the open questions around designing an appropriate incentive structure to handle individual participation in the welfare model.

The structure of the paper is as follows: Section 2 will present a review of the literature on digital inclusion and the effect of I4T in regional economics on the socio-economic development of people and places. Section 3 will focus specifically on the state of the social welfare system in the UK and how it relates to the digital divide, with particular reference to regional and socio-economic disparities. Section 4 will provide an overview of Bitcoin fundamentals and Section 5 will present our conceptual model of a blockchain-based management system that promotes digital inclusion in the welfare services provided by the state. Section 6 will offer some discussion, while Section 7 will conclude the paper. An Appendix is provided for more information about the UK welfare system.

2 Literature Review

Digital inclusivity is a term that is traditionally ascribed with Internet accessibility. Since the rise of I4T, related terms such as digital divide, digital literacy and digital inclusion have adopted a myriad of definitions in political, media, and academic discourse (Jaeger et al. 2012). In the most general sense, the digital divide refers to a division pertaining to digital technologies, which arises from disparate access to hardware, software, or digital infrastructure (Bertot 2003). It is influenced by factors relating to age, region, socio-economic status, and disability (Helsper 2008). Digital literacy is a term that extends the notion of accessibility to one of utility i.e., the ability to utilise digital technologies and services effectively (Gilster 1997). It is a measure of one's digital skills and information literacy; the ability to locate, evaluate and use digital information (Thompson 2008).

The term may also encompass media literacy i.e., one's ability to create and absorb content (Hobbs 1998, 2010). Lastly, digital inclusion refers to the design of strategies and policies that narrow the digital divide and solve the problems arising from digital illiteracy (Jaeger et al. 2012). These policies often target demographics such as ageing populations (Olphert et al. 2005) or people living in rural areas (Correa, Pavez 2016).

Several research studies have highlighted a strong macro-level correlation between the digital divide and the social gap from class-divided societies (Helsper 2008, 2012, Parsons, Hick 2008, Mariën, Prodnik 2014, Mervyn et al. 2014, Robinson et al. 2015). According to Mervyn et al. (2014), the link between social exclusion and the digital divide reflects a "dichotomous disparity" between those that are digitally included and those that are not. Despite the statistically significant association with socially disadvantaged groups, policy-makers tend to adopt a user-centric, micro-level approach to digital empowerment (Helsper 2008). Micro-level policies take a bottom-up approach to address the challenges faced by individuals and are often enacted by local organizations or communities. An example of a micro-level digital inclusion policy is the provision of training and education to support digital literacy (Mariën, Prodnik 2014). Given that digital exclusion occurs for a number of reasons (Correa, Pavez 2016), user-centric policies allow inclusive strategies to be tailored to each individual according to their needs. However, micro-level policies fail to consider how social inequalities resonate to digital inclusion, nor do they take into account the causes of structural disempowerment at the macro-level (Mariën, Prodnik 2014). Public policy interventions at the macro-level adopt a top-down approach to tackling broader social issues. Such policies are intrinsically informed by economic growth. For example, public institutions may address the large-scale mechanisms of digital and social exclusion through wealth redistribution using social welfare support services (Mariën, Prodnik 2014). While it is arguably in the economic interest of the government to invest directly or indirectly in technological infrastructures that enable the digital empowerment of its citizens (Sharma et al. 2022), macro-level policies lack the individualistic approach needed to reach marginalised groups in society (Madon et al. 2009).

In their analyses of case studies from developing countries, Madon et al. (2009) outlined four key processes that can aid the institutionalisation of digital inclusion projects designed to support vulnerable individuals: the first relates to acceptance by the community that the project is targeting; the second is to stimulate valuable social activity and gain traction with relevant social groups; the third involves securing viable revenue streams that ensure the sustainability of the project; and the final process is to enrol government support. These four processes highlight the complementary roles that public institutions and local communities play in broadening the reach of digital inclusion initiatives. At the micro-level, the importance of local community action is evidenced by the success of projects led by and for its people (Phahlamohlaka et al. 2008). At the macro-level, the importance of institutional engagement is evidenced by the success of projects that align with political development (Madon 2005) alongside the inevitable failure of those that do not seek government backing (Roode et al. 2004).

Whether at the micro- or macro-level, the efficacy of a digital inclusion project is partly dictated by the cultures prevalent within a locality or region. Culture is defined by the attitudes and modes of thinking that the local population has strongest affinities for (Tubadji 2020). As a result, local cultures influence decision-making at the individual and institutional levels due to inherent biases that permeate through society. The existence of unconscious biases may thus perpetuate the prejudices that contribute to a social divide (Alesina, Giuliano 2015, Guiso et al. 2006, 2009, Tubadji 2020). Given the highly interconnected relationship between social and digital exclusion, it may be possible for welfare institutions to adopt a unified strategy in tackling digital exclusion since it is their responsibility to address socio-economic issues. A question therefore emerges around whether the culture of welfare institutions can be practically changed to become more inclusive. In a 1944 study entitled 'An American Dilemma' (Myrdal 2017), the Swedish economist and sociologist Gunnar Myrdal described discrimination arising from unconscious biases dating back to the early 1900s as the underlying reason for the dynamics of ethnic and racial conflict in America today. The American sociologist, Professor Robert Merton, expanded on this view by describing the "tragic circle of the self-fulfilling prophecy" in which society's fears and falsities are perpetually reinforced "only in the absence of deliberate institutional controls" (Merton 1948). In other words, Merton claimed that the only way to break the perpetual reinforcement of unconscious biases is by enacting appropriate institutional change.

The proliferation of I4T is likely to further exacerbate regional and socio-economic disparities. According to regional diversification literature (Hidalgo et al. 2007, Neffke et al. 2011), regions are more likely to develop technologically based on their existing technological activities due to a key driver of specialisation – the so-called principle of relatedness (Hidalgo et al. 2018). As identified by Hidalgo (2021), policies that exploit this principle are likely to benefit from the diffusion of knowledge spillovers and an increase in economic complexity within a given region i.e., the accumulation of knowledge and expertise based on the collective human, social and physical capital in the economy. In the UK, the economic complexity related to technology is comparatively higher than other countries in Europe (Balland, Boschma 2021). Yet there remain significant regional disparities across the nation due to regions of high and low economic complexity (Mealy, Coyle 2022). Given the strong positive effect of relatedness on the probability that a region specialises in a new I4T, it is recommended that public policy interventions target regions with related I4T capabilities to perpetuate knowledge spillovers to adjacent regions (Balland, Boschma 2021). The literature suggests that relatedness also helps dampen the effects of labour displacement by allowing the workforce to exploit cognitive and technological proximities, in addition to geographical and cultural forms (Hidalgo et al. 2018).

Based on the above streams of literature, there is a distinct need for a holistic digital inclusion strategy in which both public institutions and local communities are mobilised into action. This combination of community and institutional action may also enact the cultural change needed to make society more inclusive as a whole. By exploiting the principle of relatedness, policy-makers can maximise the impact of community support to promote collective learning within localities and increase knowledge diffusion across regions in an effort to minimise the regional disparities arising with the Fourth Industrial Revolution. In the next section, we will outline the framework within which our digital inclusion policy will be developed by looking into the scale of digital exclusion across the UK with respect to regional trends, how recent global events have impacted high risk communities, the allocation of capital to the welfare system and digital inclusion, and issues arising from new digital welfare systems.

3 UK Welfare System

3.1 The Landscape of Digital Exclusion

A consortium coordinated by the Lloyds Banking Group and the Tech Partnership has led to the development of an essential digital skills (EDS) framework (Department for Education 2019), which categorises the basic digital skills for life and work into communicating (e.g., sharing information online), handling information and content (e.g., using a search engine), transacting online (e.g., buying items or services), problem solving (e.g., verifying sources of information online) and being safe and legal online (e.g., identifying fraud or cybercrime). In the UK Consumer Index, Lloyds Bank (2018) used the EDS framework to map regional variations across the UK population. The study found that Wales had the lowest proportion of basic digital skills (19% of the population has zero EDS) while the South East of England had the highest (only 5% of the population has zero EDS).

The Office for National Statistics (2018) survey on the scale of digital inclusion across the UK revealed that a growing number of citizens interact with public authorities and services online e.g., by obtaining information from Government websites, or downloading and submitting official forms (Figure 1). While the survey also revealed an overall decline in the percentage of non-internet users (defined as those who have never used the internet or last used it more than 3 months ago) across all UK regions from 2012 to 2018, it also revealed the regional disparity in internet use, with Northern Ireland having the largest

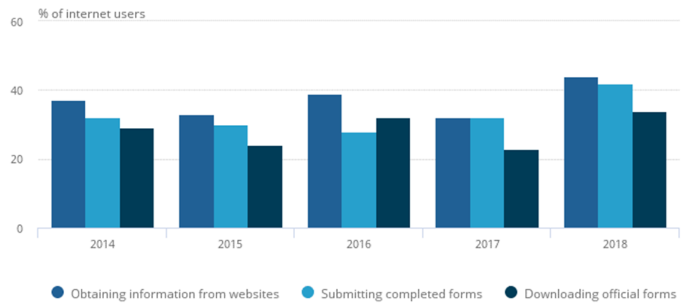

Figure 1: A survey on the percentage of internet users by type of interaction demonstrated that the internet is increasingly being used to interact with public authorities or services (Office for National Statistics 2018)

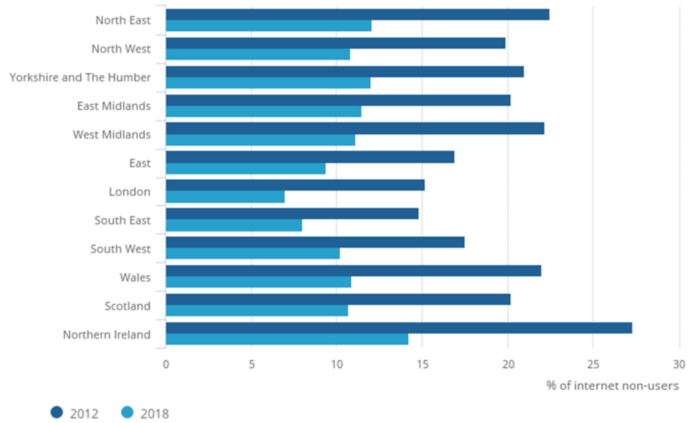

Figure 2: A survey on the percentage of internet non-users in the different UK regions revealed existing regional variations yet an overall decline from 2012 to 2018 (Office for National Statistics 2018)

percentage of non-internet users, followed by the North East of England (Figure 2).

In 2019, the start of a series of UK lock-downs to control the spread of coronavirus during the pandemic led to many individuals becoming completely isolated, further exacerbating the existing digital divide (Baker et al. 2020). The UK Consumer Digital Index 2020 found that 7% of those surveyed could not use the internet as much as they would like to during lock-down because they did not have someone to help them, while 55% of respondents claimed that technology could not replace key services they they needed in their daily lives. The report also found that 37% of the UK workforce lacked the basic skills to stay safe and legal online, while 36% of respondents did not understand the importance of staying safe online. A survey by the insurance company Aviva found that 20% of respondents suspected that they had received fraudulent correspondence relating to coronavirus (Baker et al. 2020) as a growing number of COVID-19 scams were reported in the form of phishing emails and fake Government emails containing links that steal personal or financial information.

Children from lower income households were also at a disadvantage as schools transitioned to remote learning over lock-down. An Ofcom survey conducted between January and March 2020 found that children from 9% of the surveyed households did not have access to a laptop, desktop PC or tablet (Ofcom 2020). A Sutton Trust survey in April 2020 (Cullinane, Montacute 2020) found that children from disadvantaged backgrounds were less likely to participate in online lessons, with only 23% of deprived schools having an existing online platform for remote learning compared to 60% of private schools. Nations with existing infrastructures on digital inclusion were shown to have better education policy responses across the UK. Wales acted quickly by leveraging their existing infrastructure to support policymakers and schools in repurposing existing stocks of laptops and wireless routers, which were delivered to disadvantaged pupils by the end of May 2020. England's response was comparatively slower, with digital equipment being distributed in mid to late June 2020. Device roll-out was the slowest in Scotland and Northern Ireland, where distribution was completed by or after the end of the school term (Sibieta, Cottell 2020). Home schooling over lock-down also raised awareness into data poverty as many households struggled to pay for their increased data usage with many pay-as-you-go customers being forced to chose between data and food (Lucas et al. 2020).

3.2 Capital Allocation

Benefit claimants in the UK have struggled to make ends meet during the pandemic due to historical cuts on benefits (Department for Work and Pensions 2021) and welfare funds (Keep 2022) that together restrict the amount any individual can claim. The benefit cap was introduced in 2013 to limit the amount of Government spending by limiting the total amount of benefits that can be claimed per person. The cap was intended to incentivise people to return to work by disincentivising welfare dependency. However, many individuals have avoided the cap by claiming Working Tax Credit or benefits not affected by the cap (UK Government 2022). The welfare cap was subsequently introduced in 2014 to further limit the total amount that the Government can spend on social security benefits and tax credits per year. In 2016, the benefit cap was tightened further, a measure that was found to unfairly penalise single parents that are reliant on benefits but cannot return to work (House of Commons 2017). The Department for Work and Pensions (2017) released statistics showing that for every child whose parents had returned to work, eight other children were left living in worse conditions. Thus the caps are widely viewed as an ineffective incentivisation scheme that punishes the vulnerable and encourages dishonest behaviour.

The 2021 UK Budget (Norman 2021) announced by the Chancellor of the Exchequer, was an opportunity for the Government to allocate capital to the welfare system and address the growing digital divide, which directly impacts those individuals reliant upon welfare support. The Chancellor stressed that "for businesses, certainty matters", yet the Budget received criticism for the lack of welfare certainty it offers to low-income households (Tims 2021), with no measures taken to permanently reverse restrictions on benefit claimants. With respect to digital inclusivity, the Budget outlines a three-year £295 million Help to Grow Digital scheme for 100,000 small and medium-sized businesses to grow and become more efficient.

However, this scheme is only suitable for those that already possess basic digital skills, thus further alienating the digitally illiterate. The new online job finding support service also marginalises those with limited or no internet access. Thus the Budget fails to account for communities at the extreme end of the digital inclusion spectrum i.e., the nine million people in the UK that cannot use the internet without help (Milner 2021).

3.3 Digitalising Social Welfare

In a United Nations (2019) report, poverty and human rights expert Philip Alston warned that governments around the world that are automating social welfare systems need to "alter course significantly and rapidly to avoid stumbling zombie-like into a digital welfare dystopia". Alston expressed his concern over governments automating key welfare functions with inadequate transparency, accountability and due diligence. After representing numerous individuals poorly affected by automated decision making of public benefits, Professor Michele Gilman – the Venable Professor of Law at the University of Baltimore School of Law – has also called for more transparency into how automated welfare systems function to establish accountability and to ensure that the design of such systems are based on honest incentives (Gilman 2020).

The Welfare Reform Act 2012 introduced several notable changes to the UK welfare system (Department for Work and Pensions 2022). The most controversial of these was the introduction of Universal Credit (Human Rights Watch 2020), a *digital by default* social security that according to the government is intended to simplify the benefits system (Cabinet Office 2012). Since 2012, there has been a gradual transition to Universal Credit for claimants of six of the main means-tested benefits and tax-credits (income-based Jobseeker's Allowance, income-related Employment and Support Allowance, Income Support, Housing Benefit, Council Tax Benefit, Child Tax Credit and Working Tax Credit). Universal Credit has been heavily criticised for the minimum 5-week delay to receive a first payment, and the transition to Universal Credit has been directly linked to a notable rise in the use of food banks, primarily by individuals who depend on benefits as their main income (The Trussel Trust 2018). Vulnerable groups that are most impacted by the design and/or operation of Universal Credit include disabled people, claimants affected by chronic health conditions and families with dependent children. Reports by The Trussel Trust (2018, 2019) highlighted that an increasing percentage of food bank referrals were due to an increase in debt as people struggle to meet housing costs and energy bills. The Universal Credit application form has also been heavily criticized for its length and complexity, with many lacking the digital skills to successfully complete their identity verification online. The majority of individuals applying to Universal Credit are those that cannot afford to pay for internet access, yet ironically the form itself can only be accessed online. The Trussel Trust (2018) claimed "People are falling through the cracks in a [welfare] system not made to hold them".

There are many more factors to consider, most of which are not unique to the UK, with respect to the social and economic impact that technology is having on our welfare systems and other aspects of society (see the Appendix for more information). In the UK, the welfare system lacks support for the digitally excluded, lacks transparency in welfare distribution, and lacks incentives to support people truly in need. There appears to be a fundamental absence of information flowing between the supply and demand sides of the UK economy and the examples provided highlight the urgent need for more transparency and accountability in digital welfare distribution methods. Digital welfare systems only work under the assumption that every citizen is digitally included, and that algorithms do not fail. Since neither of these assumptions are valid, the result is that people are not able to trust the welfare system. By logging welfare data in a transparent and auditable database, such as the blockchain, modern welfare systems can more accurately identify people in need of support, in addition to calling out people that are exploiting social welfare. Improving the quality and availability of welfare records could also better inform the allocation of UK capital, and generate long-term economic benefits for communities and public institutions alike.

3.4 Our Contributions

This paper proposes a conceptual model that benefits from the native features of the Bitcoin blockchain to solve the key issues in the UK welfare system by:

1. using community-level participation to ensure that vulnerable individuals are digitally included and can access welfare support,

2. using a transparent and immutable public blockchain to monitor welfare data, and

3. taking inspiration from Bitcoin's incentive model to stimulate local community action and reward positive contributions to the welfare system.

The model uses the blockchain as an auditing tool, which offers a mechanism to establish transparency and data integrity, to ensure that there is sufficient accountability in the welfare system. For digital welfare systems, these features enable fast dispute resolution in cases where IT problems are encountered and/or algorithms fail. Designing a digital welfare system that promotes honest incentives can help establish a fully inclusive welfare state in which technology serves to support the social well-being of all its citizens.

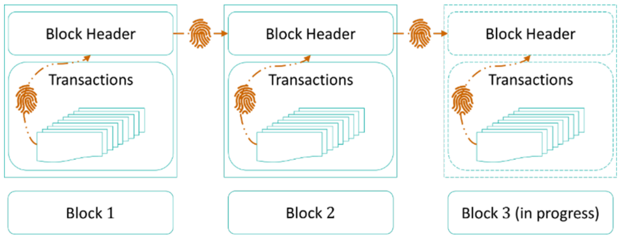

Figure 3: Bitcoin Blockchain Data Structure

4 Bitcoin Blockchain

Blockchain technology enables a public timestamped distributed ledger that benefits from transparency, immutability and auditability. Time-stamping a digital document was initially proposed by Haber, Stornetta (1991) as a method of certification. Their work demonstrated how time-stamps could be linked together in a linear fashion to generate a verifiable chain of authentication, from one document to another. Subsequent developments to this linking scheme entailed replacing the linear list with trees as originally developed by Merkle (1980), which led to more efficient and reliable digital time-stamping methods (Bayer et al. 1993). Blockchain technology has evolved significantly from a peer-to-peer electronic cash system to a global ledger as a service (Song et al. 2021). The technology is most well-known for its implementation in Bitcoin, with a growing number of applications being built upon the Bitcoin SV (2021) blockchain to benefit from its inherent features of data integrity, scalability and security (Bitcoin Association 2021, Tartan et al. 2021, Unbounded Capital 2022).

The ledger records Bitcoin transactions in order, as well as securing any data embedded within each transaction that is published on the blockchain (*on-chain*). One use case of this feature is to replay events and conduct auditing with full confidence in the integrity of the embedded data. The ledger is structured as a chain of data blocks. Each data block contains a block header and a set of ordered transactions. The first transaction in each block (*coinbase transaction*) is used by block producers (*miners*) to collect transaction fees and block subsidies once a successful block is produced and published on the blockchain. The financial gain from coinbase transactions is the incentive for miners to follow the rules (*consensus*). Blocks are chained together by inserting the fingerprint of the previous block header to the current block header. Each block header also contains a fingerprint (Merkle 1989) of all the transactions in that block, as shown in Figure 3. This fingerprint offers the means to verify that a piece of data was entered in the ledger at a certain point in time and prove the integrity of the data (*integrity proof*). Note that these fingerprints do not reveal anything about the data itself. In order to produce a valid block, miners must carry out a process that involves repetitive computations of a mathematical function on different inputs, and which cannot be replicated easily. This process generates the fingerprint of the current block, which is considered as the proof of work for the block. Once a block is produced and propagated through the network, other producers verify the block and its contents. If the block is valid, all miners start the process again by taking the valid block as the previous block, and continuing to build upon the chain of blocks. By virtue of this data structure, any changes to a transaction in a published block renders all subsequent blocks invalid. Thus there would be a necessity to redo the proof of work for all these blocks, which is considered economically unviable or computationally infeasible. Moreover, any misbehaviour can be identified and mitigated as all information about the blockchain and its transactions are publicly available.

In short, it is the combination of data immutability, transparency and the incentive mechanism that collectively secure the Bitcoin blockchain. The conceptual model proposed in this paper utilises Bitcoin as an immutable and transparent ledger, while also taking inspiration from the incentive-driven system inherent to the design of Bitcoin.

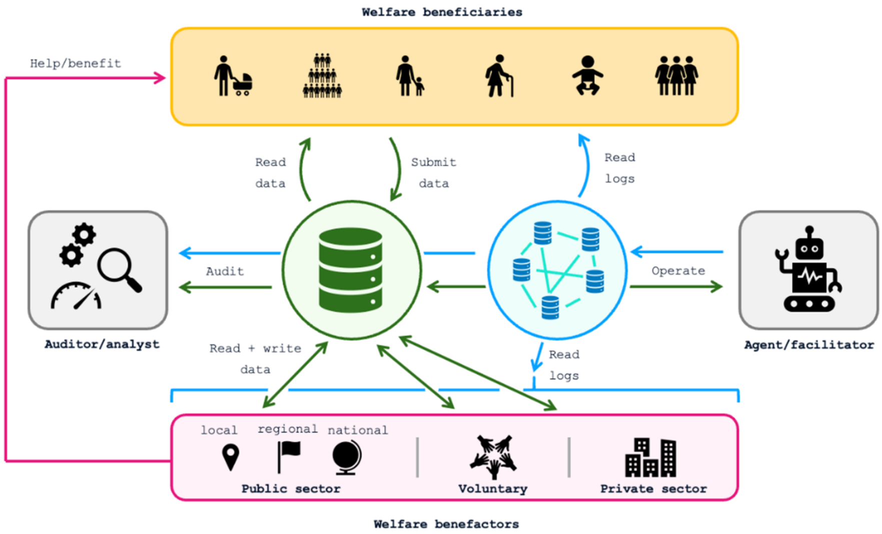

Figure 4: A Bitcoin-based Welfare Management System

5 Bitcoin-based Welfare Management System

The aim of the conceptual model is to implement a Bitcoin-based welfare management system (BWMS) that can address digital inclusion at a local, regional, and national scale. Our approach is to consolidate any existing processes of the incumbent policy-driven *macro-welfare* system by community actions within the incentive-driven *micro-welfare* system. The model is designed based on the following:

1. an incentivisation framework to encourage participation and meaningful action in the welfare system,
2. a state-based monitoring framework to track the status of citizens and regions with a focus on digital inclusion, and
3. a robust digital platform that allows users to interface with a central repository of welfare data anchored by a public blockchain to ensure accountability and trustworthiness.

Figure 4 shows an overview of the BWMS. The system is comprised of four core components and one auxiliary (external) component. The key features of each component are described below with respect to the colours used in the figure.

Core 1: Central Repository [in green]

The central repository aggregates all raw welfare data supplied/submitted by both benefactors and beneficiaries of the system. Examples of welfare data include disability status and socio-economic information derived from an individual's level of education, their employment status, whether they are in receipt of support services such as benefits and social care etc. The use of a centralised infrastructure ensures that the relevant public institutions possess access control over the platform.

Core 2: Blockchain Audit Trail [in blue]

The transparency and integrity of the data exchanged within the platform is ensured using a secure and public distributed infrastructure, the Bitcoin SV blockchain. The blockchain maintains trustworthy logs i.e., fingerprints of the raw welfare data to enable verification of the state of the central repository. The immutable property of data stored on the blockchain ensures that historical records cannot be tampered with and that an audit trail exists to help identify any attempts of fraudulent behaviour. Using the blockchain to monitor and audit events in the centralised system ensures that the welfare platform can operate securely and at scale. The blockchain audit trail imbues the central repository with integrity proof data that ensures its integrity and can be used in conjunction with the actual data stored in the central repository to audit the entire system. The blockchain audit trail enables auditors to detect malicious users that abuse their privileges thereby mitigating potential security threats to the platform.

Note that the model ensures GDPR compliance by storing all raw database logs in the repository, and by avoiding logging any personally identifiable data on the public blockchain. In other words, private welfare records are notarised but never stored directly on-chain. These precautions are taken to preserve the privacy of UK citizens and to respect their rights to be forgotten.

Core 3: Platform Agent / Facilitator [in grey, right hand side]

The platform agent is the party responsible for running and operating the system in practice. This can include facilitating automated processes (which benefit from the *checks and balances* of a blockchain audit trail), and may also be responsible for creating and maintaining interfaces (not shown) between the other components and parties e.g., web-app, mobile interface, database integrations, APIs. The agent is also responsible for defining and implementing the access control over data.

Core 4: Benefactors [in pink] and Beneficiaries [in orange]

Benefactors are the parties who help to supply welfare data on behalf of citizens and can take meaningful action to improve some aspect of the welfare state (e.g., level of digital inclusion) for one or many citizens. Examples include public institutions such as the DWP, ONS and NHS, private firms and local organisations working in the public and voluntary sectors.

Beneficiaries are all individuals in society; a subset of which will be direct beneficiaries (i.e., that can be reclassified to an improved state of digital inclusion), and the rest are indirect beneficiaries as they are not currently at risk of digital exclusion, but the system monitors for any changes that may put them at risk. This makes the system preventative rather than reactive to people becoming excluded. Note that the welfare benefactors are the platform users, since the beneficiaries are not (necessarily) required to sign up or input their own data.

Auxiliary 1: Auditing and Analytics [in grey, left]

Raw data and events in the repository are periodically audited by a trusted third-party. The auditors are impartial entities that follow regulation, but make use of the blockchain audit trail and associated integrity proofs (i.e. certificates) during the audit. The repository is also accessed by data analysts who analyse the data and derive the current welfare state of citizens in a given region or locality. The states are derived from a set of key metrics, where each state is analogous to a risk register e.g., that assesses whether a local community is at high, medium, or low risk of becoming digitally excluded.

5.1 Monitoring Framework

The monitoring framework uses a state-based contractual approach to track processes taking place in the micro-welfare system. The platform agent facilitates the automation of these processes. These processes can be written into *automated contracts* i.e., contractual agreements between the agent and the benefactor(s) using the platform. An automated contract uses software to facilitate, verify or enforce the negotiation or performance of some or all parts of a contract, and the agent can be viewed as a computer-based algorithm that creates, executes, monitors, and terminates the contract(s). The contract is linked to a set of specific conditions, from which an *initial state* and *final state* are defined, along with a set of *inputs* (e.g., tasks or actions) that must be enacted to fulfil

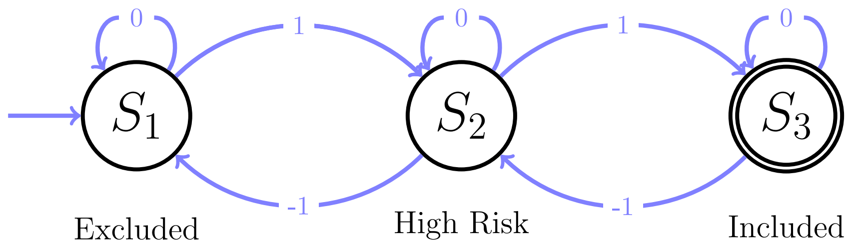

Figure 5: Example state diagram

the conditions and terms of the contract. The blockchain can be used to monitor the current state of the contract to create replayable and auditable trails of historical events in the welfare system. When given one or more inputs, the contract undergoes a *state transition* to the next or final state for any number of intermediate states as outlined by the terms of each contract. The contract is terminated once it moves into an *accepting state*. The contract is deterministic in nature, which means when given a state and an input, there is only one new state (possibly the same as the initial state) that can occur. This allows us to define a state transition table in which the future states for all possible current states and inputs can be specified.

A toy example of an automated contract involves building a garden fence from scratch within a certain time frame. The initial state of the contract indicates that no fence exists, while the accepting state tells us that the fence has been built. A state transition is initiated given a set of pre-defined inputs. The first input tells us that the necessary materials (the fence panels, posts, post supports etc.) have been acquired. The next input tells us that the appropriate tools (power drill, hammer, nails etc.) have been sourced. There may be any number of intermediate states between the initial and final state that accept one or more of these inputs. Alternatively, the contract may require the aggregate of all the inputs to trigger a single state transition to the final accepting state. It is possible that the final state is not an accepting state i.e., the garden fence was not completed or was partially built within the allocated time frame.

An example of a simple state diagram and corresponding transition table for an automated contract are shown in Figure 5 and in Table 1, respectively. In this example, the possible states are defined as $S = \{S_1, S_2, S_3\} = \{excluded, high\ risk, included\}$ where each state in the contract maps to the current welfare state (e.g., with respect to digital inclusion) of an individual, community or region. The initial state S_0, and the final state F, are both defined by the possible states in the finite set S. The contract can be designed to have any number of possible states in S, depending on the computational requirements and desired granularity of the automated contract. For example, two auxiliary states can be included to categorise individuals at low risk and medium risk, giving a total of five possible states in S.

The inputs to the contract depend on the scenario and may take a multitude of forms e.g., a set of tasks successfully completed by different platform users may collectively initiate a state transition defined by a single contract. For simplicity, consider the possible inputs $I = \{I_1, I_2, I_3\} = \{-1, 0, 1\}$, where the input $I_1 = -1$ denotes a negative state change (e.g., a high risk individual becomes digitally excluded), $I_2 = 0$ no state change (e.g., the individual remains high risk), and $I_3 = 1$ initiates a positive state change (e.g., the individual moves from high risk to digitally included). At any one time, the contract is defined by a current state from the set S and a state transition is initiated by one input from the set I. The state diagram in Figure 5 shows the accepting state as $S_3 = included$, at which point the contract is terminated. The agent monitors the work carried out by different platform users for a given contract. Each user submits evidence of their work done to prove that they have successfully completed a task that they have committed to in the platform. The agent translates the inputs from the platform users into an input within the contract to assess whether the terms of the contract have been fulfilled.

Table 1: Example state-transition table

	-1	**0**	**1**
$\boldsymbol{S_1}$	—	S_1	S_2
$\boldsymbol{S_2}$	S_1	S_2	S_3
$\boldsymbol{S_3}$	S_2	S_3	—

5.2 Incentivisation Framework

Over 200 years ago, Adam Smith described the "invisible hand" of self-interest and competition that together guide the market company (Smith, Cannan 2003). Skinner's *principle of reinforcement* led to the incentive theory of motivation, which highlighted the importance of incentives as the primary motivation for action (Skinner 1957). Since then, there have been numerous papers on economic incentives with respect to social preferences (Fehr, Fischbacher 2002, Bowles, Hwang 2008) and the field of regional economics (Bartik 2018, Mitchell et al. 2018).

The Bitcoin network is a free market within which the network operators are economically incentivised to work together on maintaining the network while competing for a financial reward. Inspired by the literature and Bitcoin's use of economic incentives, the BWMS model seeks to incentivise community participation using a combination of gamification techniques and financial / non-financial rewards staked to each task in the platform.

The workflow for the incentivisation framework starts with the agent pricing the input(s) required to trigger a state transition for each contract. This includes each task generated within a user's account that may individually or collectively map to a single input. The financial rewards are scaled to the amount of work required and resultant impact on the welfare system. Disincentives such as financial penalties may optionally be included to control for negative impacts on the welfare system. For example, the agent may introduce a penalty if a user triggers a negative state transition resulting in a diminishing welfare state. Any users identified as committing or inciting fraudulent behaviour are subject to disqualification (i.e., blacklisting) from the platform. Depending on the severity of the incident, information about blacklisted users may be published on-chain taking privacy into consideration.

It is important to note that the current model relies on the assumption that the automated contracts are allocated funds from the UK welfare budget. Each automated contract can be committed to by multiple users, who compete and/or collaborate to initiate a particular state transition in a given region. As a result, a positive state transition should improve the operational efficiency and associated costs of institutional processes, generating a high return on investment and overall cost savings for the welfare system. Such a proposition would at a minimum require some back-of-the-envelope assessments to assess whether or not this expected increase in operational efficiency is enough to finance the policy. Similarly, any non-financial incentives for the public institution, such as improvements in error and fraud detection, reputational gains as well as the trust derived from transparent systems such as the BWMS, would also require quantitative and/or qualitative assessments in order to adequately justify government sponsorship. We therefore invite economists in the field to advise on any methodologies that could appropriately qualify the efficacy of such a proposition, in addition to their views on the ethical connotations associated with the use of welfare funds to incentivise community participation and the type of rewards (monetary or otherwise) that would be socially appropriate to award to benefactors in the micro-welfare system.

5.3 Macro-Welfare System

The model adopts a hybrid approach to digital inclusivity whereby welfare institutions dictate the policies that are enacted at the micro-level by the benefactors (users) of

Table 2: The model workflow for the macro-welfare system

Macro-Level Phases	Workflow
Digital Platform Setup	Generate sector-specific user accounts Grant access control to central repository
Global State Survey	Collect and consolidate primary data Aggregate primary data in repository Analyse primary data to evaluate preliminary global state
Policy Review Period	Analyse all data in repository Audit all data in repository using the blockchain Auditing and analytics results optionally recorded on-chain Enact policy changes to improve overall strategy

the digital platform. At the macro-level, the BWMS workflow entails setting up the digital platform and conducting a preliminary survey to collect primary data in order to establish the 'global' state of the welfare system (i.e., across all UK regions). Following this, a periodic review is conducted to compare and analyse the data retrieved at the macro- and micro-levels, so that the policy can be periodically iterated to improve the overall strategy. Table 2 summarises the macro-level workflow to setup the BWMS. A description of each phase is included below.

Phase 1: Digital Platform Setup

The digital platform (Gansen et al. 2018) is set up by relevant public institutions (e.g., UK Government Digital Service). The platform agent delegates access control over the central repository to the sector-specific user accounts i.e., benefactors of the model. A rulebook for platform users is published on-chain. User accounts are generated in the platform when benefactors successfully enrol to the micro-welfare system. Appropriate identity checks are carried out during enrolment to ensure that users are certified for their selected account e.g., a social worker must prove that they are legally certified to interact with vulnerable members of the community.

Phase 2: Global State Survey

During this policy-driven phase of the model, primary welfare data is collected by relevant public institutions and stored in the central repository. Primary data refers to data acquired by processes in the incumbent macro-welfare system (e.g., via national surveys such as Census, written correspondence, phone calls or home visits) while secondary data refers to data collected by micro-processes in the novel micro-welfare system. Government departments can consolidate siloed datasets by integrating their existing welfare records into the repository. Figure 6 shows examples of the types of datasets added to the repository. Each log includes the source of the information, along with the time, location and mechanism used to acquire the data.

The data is analysed against a set of metrics to assess the current global state of welfare of an individual, community, locality, or region within the UK. The data analytics results are included in a state register and signed off by the auditors for publication in a Bitcoin data transaction. For example, the lower state boundary of the register may correspond to *digitally excluded* while the upper state boundary may correspond to *digitally included*. The on-chain state register acts as a source of data integrity and promotes transparency between all stakeholders (beneficiaries and benefactors) of the welfare system. Key metrics are also indicated in the state register to show how the states were derived. Recall that no personally identifiable information is stored on-chain to preserve privacy.

The repository is managed collectively by the system's benefactors, with oversight from incumbent government agents, and is notarised on the Bitcoin blockchain to prove data integrity. All events in the repository are also logged on-chain to maintain trans-

Figure 6: Aggregate welfare (in blue) and citizenship (in pink) datasets stored in the repository

1. Auditor obtains a data set from the repository (e.g. Internet Connectivity data).
2. Auditor requests logs corresponding to the current version of the data set from the system/agent.
3. Auditor verifies the integrity of the logs:
   (a) Auditor obtains integrity proofs for the on-chain attestations of log entries.
   (b) Auditor verifies integrity proofs of log attestations.
4. Auditor verifies that logs corroborate the current version of the dataset.

Figure 7: Example verification algorithm

parency over access control and to monitor any modifications to the off-chain welfare records. Examples of events in the repository include data entries or modifications such as *insert*, *read*, *write*, *update*, *delete* e.g., 'Table 5: row 16: entry deleted'. Such events may trigger alerts to the data auditors to request verification of some modification. An example of a verification algorithm is shown in Figure 7.

Phase 3: Policy Review Period

Routine data audits are carried out during the policy review period, whereby auditors use the blockchain to verify the logs in the repository and investigate any suspicious events or log entries with the perpetrator(s). Any misbehaviour may be penalised by blacklisting user accounts and disqualification from the platform. Auditing reports consisting of event records and documentation verifying the authenticity of the raw welfare data (though not the private data itself) may be published on-chain. The efficacy of the policy itself is also assessed so that the overall strategy can be adapted and optimised based on empirical evidence. The review entails comparing data collected at the macro- and micro-levels and reviewing the results with key stakeholders.

5.4 Micro-Welfare System

The micro-level phases of the model are defined by the contractual agreement workflow. The role of the micro-welfare system is to provide welfare support at the community level and to consolidate gaps in the primary data to ensure that all individuals are accounted for by the welfare system. Table 3 shows the workflow for the contractual agreement, for which the phases are described below.

Table 3: The contractual agreement workflow for the micro-welfare system

Micro-Level Phases	Workflow
Initial State Survey	Agent initiates state S_0 using primary data. Agent prices positive state transitions (optional rules may be included for punishment i.e., decreasing state).
Intervention Period	Users commit to contract(s) and work on associated tasks. Users collect secondary data in repository.
State Transition Survey	Agent verifies user inputs against secondary data. Agent evaluates current state against expected state (S_0 + inputs = actual output). Agent finalises contract and records outcome on-chain. Agent issues financial rewards or penalties.

Phase 1: Initial State Survey

The platform agent defines the terms of each automated contract using the primary data obtained during the preliminary global state survey by specifying a set of conditions that must be met to initiate a state transition. When a user commits to a contract, tasks are automatically generated in their account based on the resources available to them, with a financial reward indicated alongside each task. A state transition rulebook may be published in a data transaction on-chain that defines the rules of the game for all platform users. The terms of each contract may also be recorded on-chain to insure against any potential instances of dispute resolution, while omitting personally identifiable data to preserve privacy.

Phase 2: Intervention Period

The benefactors may commit to one or more automated contract, after which they commence working on a set of allocated tasks generated in the platform. The work carried out by the benefactor results in the collection of secondary data, which is recorded in the repository and logged as part of the evidence (inputs to the contract) in a bid to win the staked reward. Note that secondary data is also subject to routine audits during the periodic reviews.

Phase 3: State Transition Survey

During the final phase of the automated contract (triggered by a pre-determined date/time), the platform agent starts verifying the inputs against the secondary data populated in the repository by the contract's signatories (the benefactors). The agent evaluates the current state of the contract against the expected (i.e., next or final) state, which is a combination of the initial state and the inputs to the contract. A state transition is triggered if the actual output is equivalent to the expected state. In the case that the expected state is the final state, the agent finalises the contract by terminating it in the platform, recording the outcome of the contract in a transaction on-chain and issuing any rewards (and/or penalties).

In the next section, we walk through a real-world example of a contractual workflow that aims to tackle digital inclusivity in a high risk UK region.

5.5 *Example Workflow*

The DWP conducts a national survey to analyse the current landscape of digital inclusivity across the UK regions. The output of the survey identifies a rural Welsh village as having a large percentage of individuals at high risk of digital exclusion, and a small proportion of elderly citizens as digitally excluded. The results of the survey are uploaded to a central repository accessible via a digital welfare platform. The platform agent prepares an automated contract "Digital Inclusion of Rural Welsh Village" based on the survey results, including a set of priced tasks that each require signatories from one or more sector-specific benefactors for the contract to be initiated. The platform sends notifications to notify its users about the new tasks in their user accounts. A number of organisations working in Wales respond to the survey by committing to the tasks under the contract. The tasks are distributed according to two state transitions: from *excluded* to *high risk* ($S_1 \rightarrow S_2$), and from *high risk* to *included* ($S_2 \rightarrow S_3$).

Through this contract, a broadband provider pledges to build new infrastructure in regions where individuals have little or no physical connectivity. The company also lowers their subscription fee for 6 months to support those that face digital exclusion due to data poverty. Individuals residing on the outskirts of the village are less interactive within the local community and as a result, some are not motivated to be digitally included. A local charity therefore commits to a contractual agreement to onboard these isolated individuals, such as via home visits by their local volunteers that have passed the necessary security checks and are qualified in social welfare. The volunteers are able to adopt a more personable approach to motivate individuals that exist on the cusp of society to become digitally included. Collectively, the work carried out by these benefactors triggers a state transition from *excluded* to *high risk* ($S_1 \rightarrow S_2$).

The state transition triggers the start of a new set of tasks for the relevant signatories who committed to the next (and final) state transition in the contract. Namely, a local community centre pledges to organise a series of digital inclusion workshops to support its members in acquiring the foundation-level digital skills outlined by the Essential Digital Skills (EDS) Framework (Lloyds Bank 2020). The workshop needs to be tailored to the local demographic to gain traction with the elderly community identified in the online survey. The community centre reaches out to the local Bingo hall to organise a series of collaborative Bingo nights and educational workshops, since the Bingo hall is known to have a good reputation with the older demographic. The workshops prove to be a success with the 60+ age group, with a high proportion of the community obtaining certification in the basic digital skills that transition them from digitally excluded to the high risk category. Further initiatives to up-skill the community are carried out by the community centre as well as the local library. A successful attendance to a series of workshops hosted by these organisations results in a large proportion of the community obtaining more advanced digital skills that allow them to access online public services that help them transition to a digitally included way of life.

Table 4 summarises the inputs (i.e., actionable tasks) under the themes of *connectivity*, *on-boarding* and *up-skilling* that collectively finalised the terms of the contract outlined by the platform agent in response to the initial survey. The contract is finalised and the relevant benefactors are financially rewarded for successfully completing their respective tasks. The output of the contract is captured on the blockchain and any relevant data collected during the different contract phases is stored in the central repository and reflected in the global state of the welfare system.

6 Discussion

The conceptual model adopts a hybrid approach to policies and the infrastructure within which its policies are executed. In terms of its infrastructure, the BWMS benefits from both the efficiency of a centralised system (the central repository) and the security of a decentralised system (the blockchain). With respect to policy-making, the model unifies macro- and micro-level welfare processes via a digital platform that consolidates the actions taken by local communities and public institutions. At the macro-level, the blockchain ensures the transparency and integrity of private welfare records to foster the development of strategies in which social and digital exclusion are considered in unison. The use of the blockchain technology also ensures greater accountability and auditability in aid of dispute resolution, which is increasingly paramount as the implementation of new digital solutions are further exacerbating the digital divide. At the micro-level, the model aims to incentivise the up-skilling of communities by exploiting the principle of relatedness and rewarding knowledge spill-overs across regions. This in turn bolsters regional economies by tailoring up-skilling initiatives to individual interests and the lo-

Table 4: State transition survey for rural Welsh village

Current State	REGIONAL: STATE TRANSITION SURVEY Digital Inclusion of Rural Welsh Village List of Positive Inputs ($I = +1$)	Next State
S_1	*Connectivity* 1. New infrastructure to create access to broadband in rural regions. 2. Lower broadband subscription fee in areas of data poverty. *On-boarding* 1. Identify isolated individuals. 2. Outreach programme for 60+ aged community members. 3. Foundation-level EDS certification for excluded individuals.	S_2
S_2	*Up-skilling* 1. Outreach programme on access to online public services. 2. Advanced EDS certification for high risk individuals.	S_3

cal cultures within which the contractual agreements are actioned. An appropriately designed incentive structure informed by economists in the welfare sector could result in a variety of automated contracts from which diverse incentives may be realised that also take into consideration the complementary social preferences of different benefactors (Fehr, Fischbacher 2002). An impact evaluation framework, such as that proposed by Todd, Wolpin (2020) for new policy programmes, may be adopted to quantify the impact that the proposed intervention has on digital inclusion, alongside back-of-the envelope assessments to qualify the appropriate means to finance the policy through government sponsorship or otherwise. Todd, Wolpin (2020) uses a discrete choice dynamic programming structural model and compares the results to data from a randomized control trial to ensure the credibility of structural estimations. While state transitions are initially priced by the platform agent, these prices may be dynamically adjusted based on the results from any periodic impact assessments.

The model seeks to be inclusive at all levels and this paper invites contributions from economists to inform the design of an appropriate incentive mechanism to ensure that any individual, group, or organisation is incentivised to enrol as a benefactor. While the issue of how to handle the incentive structure for active participation is a general one that is typical of all welfare schemes, the model uses blockchain technology as a trustworthy, auditable log of welfare records in the macro-welfare system to avoid introducing further challenges around accessibility for the digitally excluded beneficiaries of the micro-welfare system. The incentive mechanism is also critical to ensure diversity amongst the benefactors, which is a fundamental component of policies that aim to support the inclusion of individuals (beneficiaries) from all socio-economic classes. The benefactors may range from community groups, charities and social welfare organisations from the voluntary sector; to healthcare and welfare firms, broadband providers or SMEs from the private sector; and local councils, leisure or community centres, and social workers from the public sector. Community participation is necessary to improve the output from the model. The more community members contributing to the micro-welfare system, the greater the total output and the greater the positive impact on the welfare system. The result is a cohesive and cooperative welfare system in which institutional efforts are simultaneously reinforced by positive community actions.

Despite our aim to develop a model that supports digital inclusion, the generality of our model serves to aid the collection and dissemination of any type of welfare data. Collecting high-quality data for the welfare sector would help to assess the risk of an individual or community becoming socially and/or digitally excluded, with the latter becoming increasingly pivotal in the existing welfare system as more public services become digitalised. The model therefore proposes that information relating to internet connectivity, data poverty, access to online services and digital skills be integrated with a citizen's welfare records. The model also unveils the need for welfare issues stemming from digital exclusion to be reflected in society's dissatisfaction with public institutions. This is an aspect that is yet to be captured by the current survey from which the European Quality of Government Index (Charron et al. 2019) was derived. However, recent events such as the COVID-19 pandemic have highlighted that digital inclusion will impact society's trust in public institutions. Our conceptual model offers a solution to the issues that prevailed during the pandemic as a means to continuously monitor and improve the digital inclusion of individuals across different regions to ensure the prosperity of the national welfare sector.

The BWMS may also be combined with big data to help make better sense and use of it for policy purposes. The model provides up-to-date, reliable and granular data on the interventions, such as, how effective they are, how long they take, which are popular, what sort of parties (users) are taking them on, and what value provides a compelling incentive. The data is available at community and regional levels, both on a national scale, and could expand to cover a vast range of target issues and interventions. The potential impact of this data, both in terms of research and policy-making is extensive. Moreover, blockchain is one of the few technologies that is appropriate to manage this amount of huge volume, high precision data. The model may help to eliminate the discrimination that societies have historically faced on a self-fulfilling prophecy basis in cases that relied upon self-selection and skill sets. For example, the BWMS could be used to ensure the public provision of education to ensure work for all socio-economic classes, along with the public provision of digital skills that ensure access to any future welfare service that will rely upon big data, while avoiding the biggest danger of perpetuated digital discrimination i.e., the developmental trap.

7 Conclusions

In this paper, we set out to investigate how the new technological revolution can help society and the welfare provision by the state. Our research question was whether the cutting-edge technologies of the Fourth Industrial Revolution could facilitate the creation of a welfare data management system that ensured the digital inclusion of all groups in society. Examining the literature on I4T, we found that little attention was paid to the welfare sector, and there was an over-focus on AI over other technologies. Therein we identified a gap in the literature – a welfare data management system that exploits the transparency, auditability and accountability of the blockchain technology. Our solution to providing a more inclusive welfare state uses a conceptual model that benefits from the data integrity offered by the Bitcoin blockchain, in addition to the transparency, auditability and accountability of the technology. The holistic nature of our model means that incumbent macro-level policies enacted by public institutions are positively reinforced by novel incentive-driven policies enacted by local communities. As a result, the macro- and micro-level processes occur in unison and positively reinforce collective efforts to address the digital divide. The model also ensures the collection of high-quality welfare data at all levels of the welfare system. The data is privately stored in a central repository and secured via a blockchain-based management system. A digital welfare platform unifies this data, allowing benefactors of the system to interface with the system, and incentivises positive community actions using contracts between the platform (institution) and its users.

While our proposed model is not a fully evolved solution, it aims to stimulate research into the benefits of blockchain technology for future public policies for the welfare sector. As the Fourth Industrial Revolution continues to take effect on the world, regional economists may use the model to learn about the importance of data integrity in the development of regions, cities and places. Our proposed use of an incentivisation framework aims to mobilise stakeholders from different socio-economic classes. The source of inspiration for the incentivisation framework was found in the Bitcoin network, which continues to prosper as a free market due to the economic incentives baked into the protocol. We invite specialists in the field to contribute to the design of the incentivisation framework to ensure that it is appropriate for welfare programmes. We recommend that policy-makers adopt a similar collaborative approach to leverage the combined insights of technical experts, economists and welfare specialists and to ensure that the individuals and groups that its policies target are included within the design process.

Future developments may also involve consideration of other blockchain features that were not deployed in the first instance of the model. The blockchain technology is most well-known for its payments feature. Financial rewards may be issued via Bitcoin transactions, either using a new token system (e.g. a nation's central bank digital currency) or via the blockchain's native token (bitcoin) with due consideration given to the accessibility of the technology to platform users along with the legal implications around government sponsorship of bitcoins. The incentives may decrease in size if the model's welfare system becomes very popular. In this case, a micro-payment system would be needed, which can be achieved via Bitcoin payments due to the low transaction fees in the Bitcoin SV network. Micro-payments are a particularly interesting feature as they could provide a tool to incentivise individuals into interacting with the digital platform, for example by completing micro-tasks on a daily basis. More complex payment conditions could also be created in a Bitcoin transaction, such as using multi-signature transactions where large rewards are involved and shared among multiple platform users. Transacting on the blockchain would also provide more transparency into the issuance of the financial rewards and being able to track and audit the trail of welfare funds. Once the model establishes direct access to beneficiaries that may have initially been socially and/or digitally marginalised, we could introduce interventions that target the beneficiaries directly. In other words, the beneficiaries of the schemes could be inducted to act as benefactors of themselves and their very input to the platform could act as a marker of digital inclusion. This would also improve data verification, since it would be possible to check directly with the beneficiaries whether they feel more digitally capable or whether they use digital technologies more often. Moreover, financial rewards could be issued directly to high risk beneficiaries for taking on and successfully completing tasks that promote their digital inclusion. For example, a micro-payment may be issued if the individual checks a portal on a daily basis, or by keeping their welfare information up-to-date, or signing up to paperless billing, and so on.

In conclusion, this paper provides novel insights into how to disrupt the current paradigm of welfare provision using cutting-edge blockchain technology and invites comments from specialists in the field to develop this research further.

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References

Alesina A, Giuliano P (2015) Culture and institutions. *Journal of Economic Literature* 53: 898–944. CrossRef

Baker C, Hutton G, Christie L, Wright S (2020) COVID-19 and the digital divide. UK Parliament. Available at: https://post.parliament.uk/covid-19-and-the-digital-divide/

Balland PA, Boschma R (2021) Mapping the potentials of regions in Europe to contribute to new knowledge production in industry 4.0 technologies. *Regional Studies* 55: 1652–1666. CrossRef

Barber L (2016) The government has quietly been testing blockchain technology for benefits payments. City A.M. Limited. Available at: https://www.cityam.com/government-has-quietly-been-testing-blockchain-technology/

Bartik T (2018) Who benefits from economic development incentives? How incentive effects on local incomes and the income distribution vary with different assumptions about incentive policy and the local economy. Upjohn Institute, Technical Report No. 18-034. CrossRef

Bayer D, Haber S, Stornetta WS (1993) Improving the efficiency and reliability of digital time-stamping. *Sequences II: Methods in Communication, Security and Computer Science*: 329–334. CrossRef

Benbya H, Pachidi S, Jarvenpaa S (2021) Artificial intelligence in organizations: Implications for information systems research. *Journal of the Association for Information Systems* 22. CrossRef

Bertot JC (2003) The multiple dimensions of the digital divide: More than technology 'haves' and 'have-nots'. *Government Information Quarterly* 20: 185–91. CrossRef

Bitcoin Association (2021) Bitcoin SV. Available at: https://bitcoinsv.com/

Bitcoin SV (2021) Bitcoin SV node software. Available at: https://github.com/bitcoin-sv/bitcoin-sv

Bowles S, Hwang SH (2008) Social preferences and public economics: Mechanism design when social preferences depend on incentives. *Journal of Public Economics* 92: 1811–1820. CrossRef

Cabinet Office (2012) Government digital strategy. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/-296336/Government_Digital_Stratetegy_-_November_2012.pdf

Charron N, Lapuente V, Annoni P (2019) Measuring quality of government in EU regions across space and time. *Papers in Regional Science* 98: 1925–1953. CrossRef

Chen J, Lv Z, Song H (2019) Design of personnel big data management system based on blockchain. *Future Generation Computer Systems* 101: 1122–1129. CrossRef

Coldwell-Neilson J, Cooper T (2019) Digital literacy meets industry 4.0. In: Higgs J, Letts W, Crisp G (eds), *Education for Employability*, Volume 2. Brill, Leiden, NL. CrossRef

Collins C, Dennehy D, Conboy K, Mikalef P (2021) Artificial intelligence in information systems research: A systematic literature review and research agenda. *International Journal of Information Management 60: 102383*. CrossRef

Correa T, Pavez I (2016) Digital inclusion in rural areas: A qualitative exploration of challenges faced by people from isolated communities. *Journal of Computer-Mediated Communication* 21: 247–263. CrossRef

Cullinane C, Montacute R (2020) COVID-19 and social mobility impact brief #1: School closures. Available at: https://www.suttontrust.com/wp-content/uploads/2021/01/-School-Shutdown-Covid-19.pdf

Department for Education (2019) Essential digital skills framework. Available at: https:-//www.gov.uk/government/publications/essential-digital-skills-framework

Department for Work and Pensions (2017) Improving lives helping workless families. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/-uploads/attachment_data/file/621365/improving-lives-helping-workless-families-print-version.pdf

Department for Work and Pensions (2021) Benefit cap: Number of households capped to February 2021. Available at: https://www.gov.uk/government/statistics/benefit-cap-number-of-households-capped-to-february-2021/benefit-cap-number-of-households-capped-to-february-2021#: :text=When the benefit cap was,£26,000 per year

Department for Work and Pensions (2022) Welfare Reform Act 2012 regulations. Available at: https://www.gov.uk/government/publications/welfare-reform-act-2012-regulations/welfare-reform-act-2012-regulations

Faber B, Michelet GC, Weidmann N, Mukkamala RR, Vatrapu R (2019) BPDIMS: A blockchain-based personal data and identity management system. Proceedings of the 52nd Hawaii International Conference on System Sciences: 6855-6864. CrossRef

Fehr E, Fischbacher U (2002) Why social preferences matter – the impact of non-selfish motives on competition, cooperation and incentives. *The Economic Journal* 112: C1–C3. CrossRef

Frey CB, Osborne MA (2017) The future of employment: How susceptible are jobs to computerisation? *Technological Forecasting and Social Change* 114: 254–280. CrossRef

Gansen KV, Valayer C, Allessie D (2018) Digital platform for public services. ISA programme, European Union. Available at: https://joinup.ec.europa.eu/sites/default/files/document/2018-10/330043300REPJRCDigitalPlatformsBM-D2.5FinalReportv051018.pdf

Gilman M (2020) AI algorithms intended to root out welfare fraud often end up punishing the poor instead. The conversation. available at: https://theconversation.com/ai-algorithms-intended-to-root-out-welfare-fraud-often-end-up-punishing-the-poor-instead-131625

Gilster P (1997) *Digital literacy*. Wiley, New York

Grigorescu A, Pelinescu E, Ion AE, Dutcas M (2021) Human capital in digital economy: An empirical analysis of Central and Eastern European countries from the European Union. *Sustainability* 13. CrossRef

Guiso L, Sapienza P, Zingales L (2006) Does culture affect economic outcomes? *Journal of Economic Perspectives* 20: 23–48. CrossRef

Guiso L, Sapienza P, Zingales L (2009) Cultural biases in economic exchange? *Quarterly Journal of Economics* 124: 1095–1131. CrossRef

Haber S, Stornetta WS (1991) How to time-stamp a digital document. *Journal of Cryptology* 3: 99–111. CrossRef

Helsper EJ (2008) *Digital inclusion: An analysis of social disadvantage and the information society*. Department for Communities and Local Government, London, UK

Helsper EJ (2012) A corresponding fields model for the links between social and digital exclusion. *Communication Theory* 22: 403–426. CrossRef

Hidalgo CA (2021) *How Humans Judge Machines*. MIT Press, Cambridge, MA

Hidalgo CA, Balland PA, Boschma R, Delgado M, Feldman M, Frenken K, Glaeser E, He C, Kogler DF, Morrison A, Neffke F (2018) The principle of relatedness. *International conference on complex systems*: 451–457. CrossRef

Hidalgo CA, Klinger B, Barabási AL, Hausmann R (2007) The product space and its consequences for economic growth. *Science* 317: 482–487

Hobbs R (1998) The seven great debates in the media literacy movement. *Journal of Communication* 38: 16–32. CrossRef

Hobbs R (2010) *Democracy and media literacy: A plan of action.* Aspen Institute, Boulder, CO

House of Commons (2017) High court judgment: Benefit cap. Volume 626: debated on Tuesday 4 July 2017. UK Parliament. Available at: https://hansard.parliament.uk/commons/2017-07-04/debates/129E2864-85F3-41F2-91DB-207A9FFF73D4/HighCourtJudgmentBenefitCap

Hsu CS, Tu SF, Huang ZJ (2020) Design of an e-voucher system for supporting social welfare using blockchain technology. *Sustainability* 12: 3362. CrossRef

Human Rights Watch (2020) UK: Automated benefits system failing people in need. Available at: https://www.hrw.org/news/2020/09/29/uk-automated-benefits-system-failing-people-need

Jaeger PT, Bertot JC, Thompson KM, Katz SM, Decoster EJ (2012) The intersection of public policy and public access: Digital divides, digital literacy, digital inclusion, and public libraries. *Public Library Quarterly* 31: 1–20

Keep M (2022) The welfare cap. House of Commons Library, UK Parliament. Available at: https://commonslibrary.parliament.uk/research-briefings/sn06852/

Li J, Qu F, Tu X, Fu T, Guo J, Zhu J (2018) Public philanthropy logistics platform based on blockchain technology for social welfare maximization. *2018 8th International Conference on Logistics, Informatics and Service Sciences (LISS)*: 1–9. CrossRef

Liao Y, Deschamps F, de Freitas Rocha Loures E, Felipe Pierin Ramos L (2017) Past, present and future of industry 4.0 – A systematic literature review and research agenda proposal. *International Journal of Production Research* 55: 3609–3629

Lloyds Bank (2018) UK consumer digital index 2018. Available at: https://www.lloydsbank.com/assets/media/pdfs/banking_with_us/whats-happening/LB-Consumer-Digital-Index-2018-Report.pdf

Lloyds Bank (2020) UK consumer digital index 2020. Available at: https://www.lloydsbank.com/assets/media/pdfs/banking˙with˙us/whats-happening/211109-lloyds-consumer-digital-index-2020-eds.pdf

Lu Y (2017) Industry 4.0: A survey on technologies, applications and open research issues. *Journal of Industrial Information Integration* 6: 1–10

Lucas PJ, Robinson R, Treacy L (2020) What is data poverty? Nesta and YLab. Available at: https://media.nesta.org.uk/documents/What_is_Data_Poverty.pdf

Madon S (2005) Governance lessons from the experience of telecentres in Kerala. *European Journal of Information Systems* 14: 401–416. CrossRef

Madon S, Reinhard N, Roode D, Walsham G (2009) Digital inclusion projects in developing countries: Processes of institutionalization. *Information Technology for Development* 15: 95–107. CrossRef

Mariën I, Prodnik JA (2014) Digital inclusion and user (dis)empowerment: A critical perspective. *The Journal of Policy, Regulation and Strategy for Telecommunications, Information and Media* 16: 35–47. CrossRef

Martin R, Sunley P, Tyler P, Gardiner B (2016) Divergent cities in post-industrial Britain. *Cambridge Journal of Regions, Economy and Society* 9: 269–299. CrossRef

Mealy P, Coyle D (2022) To them that hath: Economic complexity and local industrial strategy in the UK. *International Tax and Public Finance* 29: 358–377. CrossRef

Merkle RC (1980) Protocols for public key cryptosystems. 1980 IEEE Symposium on Security and Privacy: 122. CrossRef

Merkle RC (1989) One way hash functions and DES. *Conference on the Theory and Application of Cryptology*: 428–446. CrossRef

Merton RK (1948) The self-fulfilling prophecy. *The Antioch Review* 8: 193–210. CrossRef

Mervyn K, Simon A, Allen D (2014) Digital inclusion and social inclusion: A tale of two cities. *Information, Communication & Society* 17: 1086–1104. CrossRef

Milner H (2021) Budget 2021: A missed opportunity. Good things foundation. Available at: https://www.goodthingsfoundation.org/insights/budget-2021-a-missed-opportunity/

Mitchell M, Sutter D, Eastman S (2018) The political economy of targeted economic incentives. *Review of Regional Studies* 48: 1–9. CrossRef

Myrdal G (2017) *An American Dilemma* (1st ed.). Taylor and Francis. Available at: https://www.perlego.com/book/1577775/an-american-dilemma-pdf

Neffke F, Henning M, Boschma R (2011) How do regions diversify over time? Industry relatedness and the development of new growth paths in regions. *Economic Geography* 87: 237–265. CrossRef

Norman J (2021) Budget 2021. HM Treasury. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/966868/BUDGET_2021_-_web.pdf

Ofcom (2020) Technology tracker 2020 UK data tables. Available at: https://www.ofcom.org.uk/__data/assets/pdf_file/0037/194878/technology-tracker-2020-uk-data-tables.pdf

Office for National Statistics (2018) Exploring the UK's digital divide. Available at: https://www.ons.gov.uk/peoplepopulationandcommunity/householdcharacteristics/homeinternetandsocialmediausage/articles/exploringtheuksdigitaldivide/2019-03-04#what-are-the-barriers-to-digital-inclusion

Oke S (2008) A literature review on artificial intelligence. *International Journal of Information and Management Sciences* 19: 535–570

Olphert CW, Damodaran L, May AJ (2005) Towards digital inclusion – engaging older people in the 'digital world'. Accessible Design in the Digital World Conference 2005. CrossRef

Oravec JA (2019) Artificial intelligence, automation, and social welfare: Some ethical and historical perspectives on technological overstatement and hyperbole. *Ethics and Social Welfare* 13: 18–32. CrossRef

Parsons C, Hick S (2008) Moving from the digital divide to digital inclusion. *Currents: Scholarship in the Human Services* 7. Special Issue on Navigating the Digital Divide, https://journalhosting.ucalgary.ca/index.php/currents/article/view/15892

Phahlamohlaka J, Braun M, Romijn H, Roode D (2008) *Community-driven projects: Reflections on a success story. A case study of science eucation and information technology in South Africa*. Van Schaik, Hatfield, South Africa

Popkova EG, Ragulina YV, Bogoviz AV (2019) *Industry 4.0: Industrial revolution of the 21st century*. Springer, Cham. CrossRef

Robinson L, Cotte SR, Ono H, Quan-haase A, Mesch G, Chen W, Schulz J, Hale T, Stern M (2015) Digital inequalities and why they matter. *Information, Communication & Society* 18: 569–582. CrossRef

Roode D, Speight H, Pollock M, Webber R (2004) It's not the digital divide, it's the sociotechno divide! Proceedings of the 12th European Conference on Information Systems, Turku, Finland

Sharma S, Kar AK, Gupta MP, Dwivedi YK, Janssen M (2022) Digital citizen empowerment: A systematic literature review of theories and development models. *Information Technology for Development* 28: 660–687. CrossRef

Sibieta L, Cottell J (2020) Education policy responses across the UK to the pandemic. Education Policy Institute. Available at: https://epi.org.uk/wp-content/uploads/2020/10/UK-Education-Policy-Response_Pandemic_EPI.pdf

Skinner BF (1957) *Schedules of Reinforcement*. Appleton-Century-Crofts, New York, NY

Smith A, Cannan E (2003) *The wealth of nations: Adam Smith; introduction by Alan B. Krueger*. Bantam Classic, New York NY

Song J, Zhang P, Alkubati M, Bao Y, Yu G (2021) Research advances on blockchain-as-a-service: Architectures, applications and challenges. *Digital Communications and Networks* 8: 466–475. CrossRef

Storper M (2018) Separate worlds? Explaining the current wave of regional economic polarization. *Journal of Economic Geography* 18: 247–270

Tartan C, Wright C, Pettit M, Zhang W (2021) A scalable bitcoin-based public key certificate management system. *Proceedings of the 18th International Conference on Security and Cryptography – SECRYPT*: 548–559. CrossRef

The Trussel Trust (2018) Left behind. is universal credit truly universal? Available at: https://s3-eu-west-1.amazonaws.com/trusselltrust-documents/Trussell-Trust-Left-Behind-2018.pdf?_ga=2.1271352.84656841.1667991093-1497778752.1667991093

The Trussel Trust (2019) Universal credit and food banks. Available at: https://www.trusselltrust.org/what-we-do/research-advocacy/universal-credit-and-foodbank-use/

Thompson KM (2008) The U.S. information infrastructure and libraries: A case study in democracy. *Library Review* 57: 96–106

Tims S (2021) Budget 2021: A missed opportunity for welfare certainty. Policy in Practice. Available at: https://policyinpractice.co.uk/budget-2021-a-missed-opportunity-for-welfare-certainty/

Todd PE, Wolpin KI (2020) The best of both worlds: Combining RCTs with structural modeling. *Journal of Economic Literature*. https://www.aeaweb.org/articles?.id=10.1257/jel.20211652&from=f

Tubadji A (2020) Value-free analysis of values: A culture-based development approach. *Sustainability* 12: 9492

Tubadji A, Huang H, Webber DJ (2021) Cultural proximity bias in AI-acceptability: The importance of being human. *Technological Forecasting and Social Change* 173: 121100. CrossRef

UK Government (2022) Benefit cap. Available at: https://www.gov.uk/benefit-cap/-when-youre-not-affected

Unbounded Capital (2022) BSV ecosystem database. Available at: https://unbounded-capital.com/bsv-ecosystem

United Nations (2019) Digital welfare states and human rights – Report of the Special Rapporteur on extreme poverty and human rights. Available at: https://www.ohchr.org/en/press-releases/2019/10/world-stumbling-zombie-digital-welfare-dystopia-warns-un-human-rights-expert?.LangID=E&NewsID=25156

Venables AJ (2020) 4 winners and losers in the urban system. In: Glaeser E, Kourtit K, Nijkamp P (eds), *Urban Empires: Cities as Global rulers in the New Urban World* (1st ed.). Routledge, New York. CrossRef

Vinuesa R, Azizpour H, Leite I, Balaam M, Dignum V, Domisch S, Felländer A, Langhans SD, Tegmark M, Fuso Nerini F (2020) The role of artificial intelligence in achieving the sustainable development goals. *Nature Communications* 11: 233. CrossRef

Walport M (2016) Distributed ledger technology: Beyond block chain. Government Office for Science. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/492972/gs-16-1-distributed-ledger-technology.pdf

Zawacki-Richter O, Marín VI, Bond M, Gouverneur F (2019) Systematic review of research on artificial intelligence applications in higher education – where are the educators? *International Journal of Educational Technology in Higher Education 16 (39)*. CrossRef

A Appendix:

A.1 Algorithmic inequality trap

As more businesses start to automate their operations, employment opportunities are growing for the digitally included and diminishing for the digitally excluded. In 2021, the HM Treasury (https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/968403/PfG_Final_Web_Accessible_Version.pdf) reported that 5 million UK workers are at risk of becoming "acutely under-skilled in basic digital skills" by 2030. A Harvard Business Review article coins the algorithmic inequality trap as the algorithmic discrimination and bias that is widening the digital gap and exacerbating inequality in the workforce. More specifically, the article refers to a "code ceiling" in which career advancement is stifled for those that rarely interact with human co-workers and are instead managed by algorithms. COVID-19 has acted as a catalyst to this transformation of the labour market, which is increasingly dominated by AI, algorithms, and automation.

A.2 The automation of welfare

Automated decision-making systems based on machine learning, a form of AI, are being widely implemented in welfare systems, with reports (https://theconversation.com/ai-algorithms-intended-to-root-out-welfare-fraud-often-end-up-punishing-the-poor-instead-131625) of a digital welfare state spanning the US, the UK, India, Australia and parts of Europe. In the US, large penalties were administered from an automated fraud detection system without human intervention. This resulted in severe consequences for low-income families ranging from evictions, to bankruptcy, homelessness and in some cases, suicide. Moreover, a subsequent state review revealed an algorithmic error from which 93% of the fraud determinations were wrong. In India, a glitch in the world's largest biometric ID database resulted in death-by-starvation for a resident whose subsistence rations were erroneously halted (https://www.reuters.com/article/india-election-starvation-idINKCN1LS0HO).

A.3 Economic effects of digital and social welfare

A study (https://cebr.com/reports/tinder-foundation-and-go-on-uk-call-for-urgent-digital-skills-funding-to-support-government-2020-fast-broadband-for-all-pledge/) by the Centre for Economic and Business Research (CEBR) found that providing basic digital skills to the entire UK population could contribute over £14 billion annually to the UK economy by 2025 due to the potential for increased earnings, better employability and communication, transaction benefits, and time savings. The study also found that training individuals to access online health resources could translate to a potential NHS cost saving of £121 million per year. Research commissioned by the Joseph Rowntree Foundation in 2016 into the economic effects of deprivation found that providing a high level of welfare to keep people out of poverty actually saves money in the long-term (https://www.cashfloat.co.uk/blog/money-borrowing/social-welfare/). They estimated a total cost of £78 billion to the economy collectively arising from the treatment of health conditions (e.g., due to inadequate housing), benefits (i.e., lost tax revenue), education (e.g., free school meals), spending on children services and policing areas affected by deprivation. This is an equivalent expenditure of £1,200 per person in Britain caused by poverty alone.

A.4 Digital inclusion charity in the UK

The Good Things Foundation is a UK-based charity that emphasises the importance of community support for the provision of personalised support for digitally excluded individuals. Research commissioned by the charity found that 75% of adults agreed that every community in the UK needs a place that can offer support with internet skills such as online banking or accessing public services online (http://www.goodthingsfoundation.org/wp-content/uploads/2021/01/blueprint-for-a-100-digitally-included-uk-0.pdf). A 2020 public poll also found that 61% of people agreed that data access should be recognised as an essential utility, like electricity (http://www.goodthingsfoundation.org/wp-content/uploads/2021/01/blueprint-for-a-100-digitally-included-uk-0.pdf). The charity has worked in collaboration with Nominent, the official registry for UK domain names, to establish a new Data Poverty Lab to ensure that every community in the UK can interact with the digital economy (https://www.goodthingsfoundation.org/what-we-do/news/good-things-foundation-and-nominet-seek-end-to-data-poverty/). Responding to the UK 2021 Budget, the Good Things Foundation has also called for the Government to publicly commit to digital inclusion policies that tackle the digital skills gap and data poverty (https://www.goodthingsfoundation.org/insights/budget-2021-a-missed-opportunity/).