A Detailed Analysis of Blockchain Pilots and Applications in Highly Impacted Areas

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September 4, 2021

Abstract
The provision of trusted, transparent and accountable public services is an important element of the social contract between a State and its citizens. Blockchain technology can help to automate these attributes including trust. Therefore, blockchain technology can disrupt the service industry and provide trusted, accountable, and transparent services. Although there are some systematic literature reviews on blockchain technology and applications, most of the literature used for their reviews is highly conceptual. Furthermore, they have excluded most of the recent work, including major infrastructure projects, government test networks, current pilots, empirical studies, and currently running blockchain applications. There are leading initiatives in the public sector to experiment with blockchain technology for public sector services. These include the European Blockchain Service Infrastructure, Chinese Blockchain Service Network, National blockchain test network in Slovenia (SI-Chain), Government blockchain test network in Estonia, and Singapore government blockchain innovation programme. This work includes systematic literature of applied blockchain research to investigate how specific characteristics of this disruptive technology can revolutionize services and highly impacted areas. This study uses articles published in high ranked scientific journals and conference proceedings, project reports, company news, and articles about recent projects and pilots. This report presents a comprehensive classification of highly impacted blockchain application areas and promising pilots and applications in them. We believe the outcome of this research provides a significant value for both researchers and practitioners to reinforce their current work, align innovation directions, and develop blockchain roadmaps.

1 Introduction
Blockchain technology is becoming increasingly popular and applicable in various domains because of its inherent characteristics, including decentralised,
trusted, transparent, immutable, and accountable nature. These characteristics are very desirable elements of the social contract between a State and its citizens and accordingly blockchain technology has the potential to transform centralised services into decentralised trusted, transparent, and accountable services. Therefore, blockchain technology can make a significant impact on the service industry.

The Australian government published their national blockchain roadmaps focusing on regulatory standards, skills and innovation, investments and collaborations, and sector opportunities[27]. The British Blockchain Association has recently published the UK national blockchain roadmap, including vision 2030 and evidence-based blockchain innovation echo-systems having close collaborations with the government, academia, industry, and society[3].

Mainly there are two types of blockchain architectures and frameworks available. They are public permissionless blockchains and private permissioned blockchains. Of course, both technologies have their pros and cons. However, consortium blockchains are introduced for some applications, combining both the security and privacy of private permissioned blockchains and the openness of permissionless public blockchains. The consortium blockchains enable the common public to freely participated in the network using their valid identities, whereas transactions are verified only by the authorities. That is, authorities are maintaining the trust and privacy of the transactions.

The realisation of blockchain applications for use mostly has legal and regulatory concerns. Therefore, legal acceptance and regulatory compliance are needed. Thus, the public sector has a leading role in blockchain adaptation. Some of the leading public sector blockchain initiatives include the European Blockchain Service Infrastructure, Chinese Blockchain Service Network, National blockchain test network in Slovenia (SI-Chain), Government blockchain test network in Estonia, and Singapore government blockchain innovation programme.

Most of the literature reviews regarding blockchain technology and applications are based on scientific publications, and most of them are highly conceptual. We have analysed systematic literature reviews, including [9, 12, 9, 1, 23, 13] to identify the highly impacted blockchain application areas. However, most of these previous systematic reviews have excluded most of the recent work, including major infrastructure projects, government test networks, current pilots, empirical studies, and currently running blockchain applications.

This report mainly focuses on the above gap. We have carefully explored project reports, blockchain news reports, articles from organisations, and company news reports to identify promising blockchain pilots and blockchain applications tested within the public sector and within other organisations. We have classified promising blockchain pilots within the highly impacted application domains. We believe the outcome of this report in specifically highlighting impacted blockchain application domains, and promising pilots and applications within those domains will provide some inputs to develop blockchain strategies, roadmaps and further blockchain adaptation.
2 Research Methodology

In this section, we describe the overall methodology, search strategy, and methods of analysis. The overall methodology includes:

- Analysing systematic literature review articles on blockchain technology and applications within the major databases.
- Detailed exploration and analysis of major infrastructure projects, government test networks, pilot projects, and running projects on blockchain.

2.1 Search Strategy

We have searched for systematic literature review articles on blockchain technology and applications within the major databases, including the Web of Science, IEEE Explorer, Springer, ACM digital library, and Elsevier. We have selected a set of the most recent literature reviews with rich information to identify highly impacted blockchain application domains. Similarly, we have extracted the recent blockchain articles from major blockchain project reports, newspaper articles, company websites, and company reports those provide rich information regarding the most promising blockchain pilots and applications.

2.2 Method of Analysis

We have analysed systematic literature reviews to identify the highly impacted blockchain application domains. Then we have made further modifications and enrich the classification based on the exploration and analysis of major infrastructure projects, government test networks, pilot projects, and running projects on the blockchain. Then we furthered the exploration to identify the most promising projects, pilots, and applications within each category. Finally, we carefully went through all the reports and considered the current state of most of the projects before selecting them for our report.

3 Detailed Classification and Analysis

Blockchain technology is widely tested in various domains. This section describes a detailed classification of highly impacted application domains and a few promising pilots and applications in each discipline. The highly impacted blockchain application areas illustrated in figure 1 include data sharing, education, decentralised digital identity, notarisation, pension services, land registry, public procurement, healthcare, food supply chain, shipping and port, finance, law enforcement, welfare, insurance, copyright protection, and renewable energy sector.
3.1 Data sharing

Trusted data sharing, including sensitive and non-sensitive data, is an important concern for most applications. This section describes four selected recent blockchain projects and pilots for trusted data sharing within public service departments.

- Trusted data sharing EBSI use case [17].
- A blockchain-based framework for information sharing between departments in China [67].
- In Estonia, Key-less Signature Infrastructure (KSI) technology to distribute information between government departments [19].
- A blockchain-based graph database to share documents internally, between branches of the department of defence and allied governments [46].

Trusted data sharing is one of the first use cases proposed in the European Blockchain Service Infrastructure (EBSI) project [17]. Authors in [67] presented a blockchain-based framework for information sharing between departments in China. The purpose of incorporating blockchain is to enhance the decentralisation of data storage, thus achieving increased credibility.

In the public sector, information sharing is vertically commanded among government departments, leading to a lack of horizontal communication. However, blockchain systems enable peer to peer communication verified by distributed consensus mechanisms.

After the 2007 cyber attacks, Estonia explored the usability of blockchain technology to ensure data integrity stored in government repositories [19].
a result, the Estonia government is rolling out the Keyless Signature Infrastructure (KSI) technology to distribute information between government departments. A new hash value is appended to the blockchain in KSI whenever a file change and data is immutable and fully transparent. The permissioned blockchain pilot presented in [46] uses FlureeDB (a blockchain-based graph database) to enable share documents between branches of the department of defence and allied governments. The FlureeDB has a peer-to-peer architecture that is highly scalable, uses data encryption, offers semantic data standard formatting, and data stored on it that is immutable.

3.2 Education

Many educational companies are working to solve the fact that their certificates are easily forged [68]. Therefore, improved transparency and validating authenticity are essential for education certificates. Here we describe three of the most recent blockchain pilots and projects within the education domain.

- Diploma use case from EBSI [17].
- Blockcerts project for academic credentials in Malta [26].
- EBSILUX project co-funded by the European Union implements the diploma use case in Luxembourg [18].

The diploma use case is one of the first use cases proposed in the EBSI project. This project gives control back to citizens when managing their education credentials. Furthermore, this project reduces verification cost and time and improves trust and authenticity [17]. As in [26], Blockcerts is an open standard project from MIT that enables creating, issuing, viewing, and verifying blockchain-based certificates. These certificates are cryptographically signed, tamper-proof, and shareable. EBSILUX project implements diploma use case in Luxembourg, which encourages the use of academic certificate records to provide transparency and trust between schools, universities, students and employers [18].

3.3 Decentralised Digital Identity

The decentralised digital identity enables trusted, secure, and easy access to various electronic services without additional logins and passwords [14]. In this section, we describe five of the most recent blockchain projects and pilots in the area of digital identity.

- The Self-Sovereign Identity use case from EBSI [17].
- uPort decentralised identity [59].
- Zug ID in Switzerland [14].
- ESSIF project in Luxembourg [18].
The Self-Sovereign Identity use case is one of the first use cases proposed in the EBSI project [17]. Before that, the uPort project began at ConsenSys in 2015 [60]. At present, uPort has evolved and split into two new projects, Serto and Veramo, both of which carry out the mission of decentralised identity and people-centric control of data [60]. Zug ID project leveraged the uPort project and developed a decentralised identity platform on the Ethereum blockchain. With the decentralised identity and the eZug app, Zug residents can use the city of Zug’s online services digitally, especially when they are out and about using mobile devices. For example, anyone with a blockchain-based ID has been able to borrow e-bikes since November 2019 [14]. ESSIF aims to implement a generic and interoperable Self-Sovereign Identity (SSI) framework [18]. The eSSIF-Lab is an EU-funded project and aims at advancing the broad uptake of Self-Sovereign Identities (SSI) as a next-generation, open and trusted digital identity solution [53].

3.4 Notarization

A notary is an official appointed by a state government who can certify a particular action or deed. Notarization needs to verify the authenticity of the information. This section describes four of the most recent notarization projects, pilots, and applications in the public sector.

- Notarization from the EBSI project [17, 16].
- Civil partnership notarisation in Brazil [34].
- Open Data notarisation in Vienna [62].
- Shanghai’s blockchain-powered notary platform [20].

The Notarization use case from the EBSI is for verifying authenticity, ensuring responsibility, traceability, auditability and fraud protection [17]. The pilot application is on [16] for testing. Growth Tech has used its Notary ledger platform to pilot civil partnership notarized in Brazil using blockchain technology [34]. The city of Vienna uses notarisation service on the blockchain to secures public administration data. Nearly 4,000 open data resources are already being notarized and published. The solution will be extended to all open government data on data.gv.at and used throughout Austria [62]. The Hui Cun platform managed by Shanghai Xuhui Notary Public is a blockchain-based data storage protocol that exercises notarization functions. Forty firms have used Shanghai’s blockchain-powered notary platform to handle over 3,000 cases since its launch in January 2020 [20].

3.5 Pension Services

The pension systems in the world suffer from low mobility and a lack of transparency and control. Blockchain technology provides promising directions for
developing next-generation pension systems. This section briefly describes a few recent blockchain-based pension projects and pilots in the public sector.

- UN Pension fund adopts facial recognition on Blockchain[24].
- A new pension administration application on the blockchain from APG and PGGM in the Netherlands[56, 2].
- Teachers’ pension plan on the blockchain from Canadian financial firm BMO Capital Markets[7].

The UN pension fund uses facial recognition on Blockchain for annual re-certification of pension eligibility[24]. However, there are some concerns regarding algorithmic bias on facial identification, and those should be solved for better adaptation. Two large Dutch pension administrators, APG and PGGM, have successfully completed the first phase of a pension administration blockchain prototype[56, 2]. The first phase was successful, and APG announced that it plans to further test the technology by launching a new pension fund. APG believes that the continuous development of this prototype will produce a more flexible, simple, and transparent pension administration system at lower cost[56]. The Ontario Teachers’, a pension fund investor, has partnered with the Bank of Montreal for a blockchain pilot to manage pension plans[7]. The pilot transaction – booked as a traditional Canadian Depository for Securities (CDS) issuance and successfully paralleled through the blockchain. The transaction included Bank of Montreal as the issuer and Ontario Teachers’ as the buyer[22].

3.6 Land Registry

The lack of clarity in land ownership suppresses economic activities[39]. This section describes four prototypes and pilots about land title registries on the blockchain.

- The Exonum land title registry pilot in Georgia[25].
- The Ubutaka blockchain project for the Government of Rwanda land registry[40].
- Land administration pilot on blockchain in Liberia by Medici Land Governance[39].
- Blockchain pilot for property transactions in Sweden[28].

The Exonum Land titling is a successful pilot in Georgia, first launched in 2016[25]. This pilot registered more than 1.5 million land titles on the blockchain. With this solution, the Republic of Georgia’s National Agency of Public Registry (NAPR) provided Georgian citizens digital certificates of their assets supported with cryptographic proofs. The Medici land governance has partnered with the government of Rwanda to pilot a project which records land transactions on a blockchain platform called Ubutaka[40]. The Ubutaka blockchain will be
integrated with Rwanda’s existing land registry infrastructure. Medici Land Governance (MLG) is a blockchain subsidiary of Overstock.com. MLG has another pilot for land administration in Liberia[39]. Swedish blockchain startup ChromaWay successfully piloted blockchain for property transactions in close collaboration with telecom provider Telia, consultancy group Kairos Future and two banks, SBAB and Landshypotek[28].

3.7 Public Procurement

A secure and transparent framework for government tenders is proposed using blockchain in [29]. This work mainly focuses on improving security, privacy, transparency, and speed of work. In this section, we describe three blockchain pilots used for public procurement processes.

- The Smart Procurement Tool project from Digipolis in Belgium[15].
- Seoul district blockchain-based system for public procurement in South Korea[36].
- A digital procurement solution for Thailand from Accenture[6].

Digipolis is responsible for providing IT systems and services for the Belgian city of Antwerp. Digipolis developed a blockchain-based application that combined the publication of requests for proposals and the submissions of tenders from vendors[15]. The Seoul district in South Korea announced that they successfully implemented a blockchain-based proposal evaluation system. The new blockchain system aims to enhance the transparency and trustworthiness of assessing responses to public tenders[36]. Accenture and Digital Ventures Co. Ltd, a fintech subsidiary of Siam Commercial Bank, have co-developed and launched a unique blockchain solution for the digital procurement process in Thailand. This solution simplifies the way companies buy and sell goods, make and receive payments, and obtain financing[6].

3.8 Healthcare

Patients are fearful that their personal medical history and financial records involved with medical care may be revealed through healthcare data hack or breach. Blockchain technology is becoming important to resolve some of these challenges. In this section, we describe three blockchain pilots and projects in the healthcare industry.

- Medicalchain in London - A Smart Medical Ecosystem[48].
- Blockchain-based system for medical image transfer in USA[45].
- Illinois Government Pilots a medical credential-sharing system running on a Blockchain[8].
Medicalchain uses blockchain technology to create user-focused electronic health records and maintain a single version of the truth on user's data[48]. US National cancer institute tested a blockchain-based information system for medical image transfer. This project aims to improve security and privacy protection, maintain flexibility, and enforce data sovereignty as described in [45]. The state of Illinois has partnered with Blockchain startup company Hashed Health to pilot a medical credential-sharing system running on a Blockchain[8].

3.9 Food Supply Chain

Blockchain for the food supply chain is a widely explored area. This section describes three of the promising recent blockchain pilots and applications in the supply chain domain.

- Blockchain tracker from Carrefour in France[58].
- FoodLogiQ’s blockchain pilot for Subway and Tyson Foods[50].
- Retail items tracking solutions from Walmart[32].

The French retailer Carrefour uses a blockchain application to track meat, milk, and fruit from farms to stores and extend it to 100 more products. They have noticed that blockchain tracking has helped them for boosting sales[58]. Subway and Tyson Foods have partnered with FoodLogiQ for a blockchain pilot that increases supply chain transparency[50]. In October 2016, Walmart and IBM announced two blockchain projects, one for tracing the origin of mangos sold in Walmart US stores and the other for tracing pork sold in its China stores. Later they have extended blockchain tracking solutions for produce, meat and poultry, dairy, and multi-ingredient products[32].

3.10 Shipping and Port

Blockchain technology has impacted the shipping and port industry significantly, making trade-related office procedures more trusted, transparent, accountable, and efficient. Given the complexity of goods movement, industry standards and meeting regulatory expectations, businesses involved in the transportation of goods need to be ready to take advantage of this game-changing technology[51]. Here we describe four of the successful pilots and applications are as follows:

- CargoX Blockchain Document Transfer in the Port of Koper, Slovenia [10],
- TradeLens from Maersk and IBM[64].
- Silsal from Maqta Gateway and Abu Dhabi Ports subsidiary[30].
- Blockchain trade initiative DELIVER from Dutch bank ABN AMRO, Port of Rotterdam, and Samsung SDS[66].
The CargoX platform enables original and confidential trade document transfer in a trusted digital environment. Recipients can always validate the original source and prove ownership of their documents[10]. Maersk and IBM have tested the blockchain technology solution TradeLens for the shipping industry. TradeLens provides paperless trade and end-to-end supply chain visibility that enables all actors involved in a global shipping transaction to securely and seamlessly exchange shipment events in real time[64]. Silsal from Maqta Gateway and Abu Dhabi Ports subsidiary combines blockchain technology and unique digital user identities to provide a seamless and secure link between stakeholders across the trade community[30]. Dutch bank ABN AMRO has collaborated with the Port of Rotterdam and Samsung SDS on a blockchain trade initiative, DELIVER, to track and instantly finance shipping containers. After successful pilot testing, these three firms confirm that DELIVER can manage the entire shipping process securely without the need for physical documents or lengthy verification checks[66].

3.11 Finance

Digital assets applications in the financial sector are booming. The real state for digital assets is one of the most prominent application domains. This section details three of the recent pilots in the financial sector.

- Blockchain pilot for the issuance of asset-backed securities (ABS) from Vanguard[61].
- The Finacle Trade Connect on blockchain from Infosys[57].
- The Marco Polo trade finance platform on Blockchain from R3[54].

In a partnership with technology provider Symbiont, Vanguard investment management company has completed a blockchain pilot designed to digitize the issuance of asset-backed securities (ABS). It has successfully modelled the entire life-cycle of an ABS settlement on blockchain by replicating end-to-end transaction flows in close collaboration with a large US ABS issuer, BNY Mellon, Citi and State Street[61]. Infosys Finacle has tested a blockchain pilot, Finacle Trade Connect, for trade finance business processes to cover areas such as ownership validation, certification of documents and payments in partnership with seven Indian private banks, including ICICI, Axis Bank, South Indian Bank, and Yes Bank[57]. The Finacle Trade Connect is now available for a range of functions, including Letter of Credit, Open Account for Trade, Bill Collection, Bill Exchange, C2C Transactions for Trade, B2C Transactions for Trade, PO Financing, Invoice Financing, Bank Guarantee, and Factoring. Blockchain software company R3, trade finance tech provider TradeIX, and a group of major banks successfully tested the Marco Polo trade finance platform on the blockchain. This solution currently addresses three areas of trade finance: risk mitigation, payables finance, and receivables finance[54].
3.12 Law Enforcement

Blockchain ensures data remains trusted, tamper-proof and maintain chain-of-evidence, characteristics that are extremely important for law enforcement authorities. This section describes three of the promising blockchain pilots and applications used in the law enforcement domain.

- Blockchain Evidence in Internet Courts in China[11].
- Company registration on blockchain in China[65], Switzerland[49] and France[35].
- WeCanComply blockchain platform for compliance checking[41].

Blockchain technology has been applied in Chinese Internet Courts for tamper-free evidence generation and storage. This process is faster and more cost-effective than traditional methods. The Chinese court first accepted blockchain evidence in June 2018 in the case of Hangzhou Huatai Media Culture Media Co., Ltd. v. Shenzhen Daotong Technology Development Co., Ltd [11]. In Huangpu, Guangzhou, the Chinese local government has completed a successful pilot on a company registration project on blockchain. Now applicants can use a single platform to register a company using the “one form, one collection, one-click operation” system[65]. IBM has successfully completed a similar kind in Switzerland[49] and France[35]. Several Switzerland banks have joined the WeCanComply blockchain platform that enables private custodian banks and external asset managers to exchange compliance documents[41].

3.13 Welfare

Transparency, security, accountability, and reducing intermediaries are vital attributes when we consider welfare programmes. Blockchain promises these features and has become an ideal technology for welfare systems. This section describes three recent blockchain pilots and projects in the welfare domain.

- Blockchain for Zero Hunger - Graduated Project from World Food Programme [63].
- Decapolis for smallholder farmers from WFP Jordan Innovation Hub[31].
- Blockchain to improve labor welfare[44].

The World Food Programme(WFP) has harnessed blockchain technology to empower people to meet their essential needs. WFP aims to make cash transfers more efficient, secure and transparent. Most notably, WFP has used a blockchain application to deliver food assistance more effectively to 106,000 Syrian refugees in Jordan[63]. Decapolis is a blockchain solution for food safety and quality traceability that helps smallholder farmers to validate their product compliance with quality control standards, empowering them to access export markets and generate better income[31]. The U.S. Department of State has
granted $800,000 for a pilot project that will develop a blockchain-based system to track the working conditions of factory workers. The first phase anonymously and securely track three factories in Mexico and monitor the workforce across the factories, tracking conditions and individuals’ health and well-being[44].

3.14 Insurance

Blockchain can revolutionise the trust and transparency that powers insurance. In this section, we describe three recent blockchain pilots and projects in the insurance industry as follows:

- Blockchain claims solution from Allianz[38].
- Etherisc blockchain-based insurance platform for fair insurance products[21].
- Blockchain-Powered Insurance Placement from Marsh[55].

Allianz has launched a blockchain claims solution in 23 European countries in mid-May. In the first six weeks following the launch, Allianz staff has processed around 145,000 transactions supporting over 10,000 international accident claims[38]. Etherisc is an open-source, decentralised blockchain-based platform for building fair and accessible insurance products, including flight delay insurance, hurricane protection, crypto wallet insurance, crop insurance, and social insurance[21]. Marsh, a leading insurance broker in the US, has announced its piloting of Risk Exchange, a new digital placement platform powered by blockchain technology. This platform enables real-time status updates and notifications throughout the process with greater transparency, security, and collaboration among all parties involved[55].

3.15 Copyright Protection

In present systems, documents are duplicated many times across the network, having multiple versions. Blockchain can provide the most recent document version, enriching trust, provenance, transparency, and accountability. Moreover, copyright and ownership protection in the photo space is a major industry. In this section, we describe three blockchain pilots and applications related to copyright concerns and ownership protection as follows:

- Binded for image registration[52].
- Copytrack uses Qtum Blockchain[42].
- Baidu Totem for copyright protection[33].

Binded is a blockchain-based copyright platform available to protect copyrights in the photo space. PIXSY acquired Bibded and implemented an international copyright registration service. In addition, PIXSY has partnered with Flickr to monitor and safeguard their images[52]. Copytrack uses Qtum blockchain to protect copyright and track and trace unlicensed photos. They expect to expand
Copytrack having 1000–5000 nodes, with a Proof-of-Stake model[42]. Baidu, China’s leading search engine, introduced the Totem blockchain platform for image copyright protection. The blockchain doesn’t store the images themselves. Instead, it keeps just the copyright information and a link to the image. Thus, they further enable traceability and infringement monitoring[33].

### 3.16 Renewable Energy

Renewable energy sources are highly unreliable and create unreliable energy surplus and energy demands. Therefore, blockchain technology is becoming popular for implementing renewable energy integration, trading platforms, and properly managing energy surpluses and demands[4, 5]. In this section, we describe three promising pilots tested in this domain as follows:

- Decentralised energy grid project in Dutch Port of Rotterdam[37].
- Peer-to-peer rooftop solar trading pilot launched in India[43].
- Brooklyn Microgrid project uses blockchain to track and trace solar output[47].

Distro; Microgrid electricity trading platform at Dutch Port of Rotterdam, leverages AI and blockchain technology to coordinate renewable energy supply and demand[37]. The India Smart Grid Forum (ISGF) has launched a blockchain peer-to-peer trading pilot in Uttar Pradesh with an Australian tech pioneer, Power Ledger. This pilot project will demonstrate the feasibility of rooftop solar energy trading through smart contracts on the blockchain platform between prosumers with their neighbouring households[43]. The Brooklyn Microgrid project aggregates rooftop solar panels so neighbours can trade and track their solar output[47].

### 4 Discussion and Conclusion

Blockchain technology is increasingly popular in various application domains, and where applicable there are major public service initiatives on blockchain platforms with a growing number of deployed applications. In tandem with this, more countries have started developing their blockchain strategies, vision, and roadmaps focusing vision 2030.

In Ireland, Our Public Service explicitly mentioned exploring blockchain in the delivery of public services. In the summer of 2021, an aspect of the ”Future Tech Challenge”, offered a substantial prize to cloud based projects suggestions that included blockchain.

Moreover, the Blockchain Ireland Week helped enrich blockchain awareness, collaborations, government initiatives and encouraged the development of special interest groups, connecting various application domains. However, we still do not have a blockchain strategy and roadmap for Ireland.
Blockchain adaptation needs legal and regulatory acceptance and public sector leadership. This report discusses essential attributes of blockchain technology, highly impacted blockchain application areas, and selected promising pilots and applications on them. We hope this report will provide some inputs for developing a blockchain strategy and roadmap for Ireland.

5 Acknowledgement

This report has emanated from research supported in part by a grant from Science Foundation Ireland (SFI) under the Proposal ID 19/PSF/7603 (Public Service Fellowship), and also by a grant from SFI under Grant Number SFI 12/RC/2289_P2 (Insight).

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