Blockchain for Science, Technology and Innovation

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Abstract

At the recent OECD Blue Sky III 2016 Forum held in Ghent from 19th till 21st September 2016, the idea of developing Blockchain for Science Technology Innovation (STI) Indictors[2] *was proposed. As the name suggests the OECD Blue Sky Forum aims at exchanging amongst the members of the relatively closely connected OECD-linked community of STI academics, policy makers and statisticians, new ideas about future challenges in the field of STI indicators and policy making.*

In this short note, we describe a new, alternative way for funding (a part of) public research, making transparent the externalities and spill-overs which emerge from publicly funded research and which become ultimately integrated in private value creation. The current digital technique which comes closest to capture the various spill-overs from public research, we argue is blockchain. In so far as a blockchain could serve as the distributed, encrypted public trail of a part of STI investments which has led to significant innovation rents that can be easily audited, the funding of a part of public research could become integrated in the economic system directly through a reallocation of those innovation rents to public research, but also as collateral for attracting more private funding in public research.

We propose the development of a pilot project using blockchain in one or two PRO's providing insights into the problems and limits of using such new technology.

[1] This is a first brainstorming concept paper to be further developed. Comments are welcome.

[2] See the slides of my presentation "A Sky Without Horizons. Reflections: 10 years after" at the OECD Blue Sky III Forum, Towards the next generation of data and indicators, 19-21 September 2016, Ghent, Belgium.

An emerging challenge: how to guarantee long term public funding to research?

There is general consensus that publicly funded research plays an essential role both in finding solutions to the many global challenges human kind is confronted with and as public, open knowledge platform to private R&D investment and innovation leading to new value creation in a variety of different forms (new products, processes, organisation, etc.).

At the same time there is also broad consensus that the public commitment to research, as reflected in the political priority given to the public funding of research, has come under pressure in most countries. Not just in a declining priority given by politicians to R&D as reflected in governments' annual budgetary expenditures, but also indirectly through the growing emphasis put on the valorisation and impact of research within public research funding organisations and universities. While difficult, if not impossible to measure, showing ex-ante the possible future value or (social) impact of research funding is today what is expected from researchers applying for funding in many research fields.

Hence the particular emphasis put on "science communication", on the need for popular presentations of scientific output to the public at large using different social media channels, and at the science policy level on the need to provide policy makers with evidence on the rate of return to publicly funded research. Living off tax payers' money, the research community has to prove its worth to the citizen. This emerging trend reflects the dominant political view, that the public funding of research is ultimately part of democratically chosen, public choices as reflected in a country's budgetary priorities. If over time, those priorities shift to new, short term priorities, such as migration, security or, as in the case of the UK, leaving the EU, such shifts represent democratic political priorities.

Whatever the political context, ultimately the minister(s) responsible for funding research will have to report to the public what the government has spent on research, where the spending has occurred (location and industry), what the spending was for (socio-economic objectives) and what the public has gained as a result of this funding. It is this last item that motivates what follows.

In this short note, we describe a new, alternative road based on a technologically driven, secure and trusted ledger system *recording the* direct impact of publicly funded research. The way to do so, we suggest, is by making transparent the externalities and spill-overs which emerge from publicly funded research and which become integrated in private and/or public value creation. The current digital technique which comes closest to capture the various spill-overs from public research is **blockchain**.

The idea is that a blockchain in STI could serve as an encrypted public trail of the long chain from public research to innovation that could be relatively easily audited and ultimately form the basis for an objective, ex-post redistribution of innovation rents to the various contributors, including the underlying public research efforts. What could be referred to as solving the "Mazzucato problem"[3].

Blockchain and trailing public research's contribution to innovation and society

Blockchain technology has become most well-known as part of 'Fintech', the generic name for new digital financial products such as the Bitcoin. Bitcoin filled an important niche by

[3] See a.o. "Apple's changing business model: What should the world's richest company do with all those profits?"

providing a virtual currency system without any trusted parties and without pre-assumed identities among the participants.

In practical terms, following Wright and Di Filippi (2016)[4], a blockchain is "*a chronological database of transactions recorded by a network of computers whereby each blockchain is encrypted and organized into smaller datasets referred to as "blocks." Every block contains information about a certain number of transactions, a reference to the preceding block in the blockchain, as well as an answer to a complex mathematical puzzle, which is used to validate the data associated with that block. A copy of the blockchain is stored on every computer in the network and these computers periodically synchronize to make sure that all of them have the same shared database. To ensure that only legitimate transactions are recorded into a blockchain, the network confirms that new transactions are valid and do not invalidate former transactions. A new block of data will be appended to the end of the blockchain only after the computers on the network reach consensus as to the validity of the transaction. Consensus within the network is achieved through different voting mechanisms, the most common of which is Proof of Work, 29 which depends on the amount of processing power donated to the network complex"*.

While blockchain technology was developed as part of the Bitcoin creation, it has been used in other applications and provides the means for indicator development in complex value chains, often involving smart contracts. Particularly in the creation and development of new complex products such as music or a movie, involving all sorts of different transactional arrangements, blockchain opens up new possibilities.

To quote again Wright and Di Filippi (2016): "*Blockchain technology has the potential to reduce the role of one of the most important economic and regulatory actors in our society—the middleman. By allowing people to transfer a unique piece of digital property or data to others, in a safe, secure, and immutable way, the technology can create: digital currencies that are not backed by any governmental body; self-enforcing digital contracts (called smart contracts), whose execution does not require any human intervention; decentralized marketplaces that aim to operate free from the reach of regulation; decentralized communications platforms that will be increasingly hard to wiretap; and Internet-enabled assets that can be controlled just like digital property (called smart property).*"

And as Don and Alex Tapscott put it in their HBR article: The Impact of the Blockchain Goes Beyond Financial Services[5], "*Blockchain technology provides a new platform for creators of intellectual property to get the value they create… The technology solves the intellectual property world's equivalent of the double-spend problem better than existing digital rights management systems; and artists could decide whether, when, and where they wanted to deploy it.*"

This brings us quite naturally to STI indicators and studies and their attempts at describing the creation of increasingly complex, global value chains based on a myriad of contributions coming from public knowledge, research, design, intellectual property of all sorts, only some of which will be captured using a variety of different indicators (publications, citations, downloads, patents, patent citations to scientific publications, licenses, etc.). Furthermore those "value chains" involve very different actors: large incumbent firms, newly set-up firms,

[4] Wright and Di Filippi (2016), "Decentralized blockchain technology and the rise of Lex Cryptographia", March 12th, 2015, http://ssrn.com/abstract=2580664

[5] https://hbr.org/2016/05/the-impact-of-the-blockchain-goes-beyond-financial-services

public as well as private research labs, universities, public research organisations, all involving public and private funding, sometimes purely from within the home country, but today in most countries in the world more often than not from foreign sources.

In short the development of STI is an example of a complex system, dealing with different actors (agents) in the system, involved in very different things (activities), interacting with each other in various ways (linkages) and with short term results (outcomes) and longer term effects (impacts). Many of these features are today captured in digitally collected indicators. On their own though they only describe one facet of the system and fail to describe the full functioning of the STI system, let alone provide useful insights into relevant policy making.

Hence the question raised at the OECD Blue Sky III Forum whether digital technologies such as blockchain could not be a particular useful technology for identifying at the global level, the chain of research actors in particular fields; their output and contribution to particular technologies and innovations; their location and international networking; their paid and unpaid linkages with private businesses.

Blockchain in science: capturing the cloud of open science

In science with its sophisticated bibliometric inventory of analyses on publications, affiliation of scientists, citations, the degree of international cooperation, the open cloud provides to some extent an ideal framework for the application of blockchain technology. At the same time, given the fact that there is here a well established, international system of peer evaluation recognized by both national and international public organisations, a blockchain would add primarily in areas where open science is as yet little developed such as with respect to open data, the large amount of unpublished studies, the contribution of users, including citizen science as well as inconclusive research, reducing duplicative research, etc. In short, and in line with the principles of "open science", positively influence the productivity of research at the global level.

The main question will be here how to develop the appropriate incentives for blockchain to work. In bitcoin magazine, Zach Ramsay[6] gives an interesting personal perspective on how blockchain technology might contribute: *"The thing that had me most excited about Bitcoin back in 2013 was its potential to re-align the incentives in academia and re-define how science and research is conducted. Taught in every Research Methods 101 course, the file-drawer problem – more generally referred to as publication bias – does perhaps the most disservice to the scientific community at large. Publishing a "non-result" in a "third-tier" journal won't advance a researcher's career the way a "significant" result in, say, Nature will… everything that doesn't work is locked up in that researchers' file drawer... as far as I could tell from 5 years in academia, the scale of duplicate work across labs around the world is both unknowable and likely enormous. It isn't time consuming for these data to be published, but I suspect many academics don't feel it is worth their time, or that the contribution isn't meaningful enough if it isn't in a prestigious journal, or that it won't be archived and indexed properly. Who knows? What is known is that it's definitely a problem.*

The concepts of pre-registering experiments and widening the scope of acceptable citations begin to address this issue… the challenge – assuming we want this knowledge free, distributed, and easily accessible (forever) to anyone with an Internet connection – is archiving and indexing all the content such that our assumption is satisfied. The emergence

[6] https://bitcoinmagazine.com/articles/how-blockchains-can-further-public-science-1457972964

of the Sci-Hub is promising in that it provides free access to vast stores of human knowledge… But this solution is not distributed and, as far as I can tell, offers no permanent archival solution.

Enter the InterPlanetary File System: IPFS has emerged as the most likely candidate for long-term knowledge preservation. Using (among other future-proofing features) content-based addressing (a hash) rather than location-based addressing (a URL), reliance on central servers is all but eliminated. IPFS definitely plays nice with blockchains. Enter indexing. We need a registry to both track the hashes of all relevant content and update them. Ideally, such a registry would be shared across many educational institutions, which would be validators on a permissioned consortium blockchain. This strikes me as a likely direction for such institutions that are having to re-invent themselves in the digital age."[7]

There are some examples where blockchain is being used as proof of scientific discovery. Astroblocks[8] in the field of astronomy offers e.g. possibilities as the discovery of new asteroids or comets is now and then the result of amateur astronomers, a typical case of citizen science. In those cases that a specific well defined object has been "discovered" at a certain moment in time, blockchain technology seems useful as proof-of-existence platform.

Using blockchain to redistribute innovation rents and fund research

The more difficult part in the STI system is of course tracing the spill-overs from public research to private or public value extraction through the introduction of new innovations on the market (or in the public sector). There are a number of indicators one can start to think of.

Patents provide information on citations towards scientific publications. In many technological areas (one may think of pharmaceuticals), patents are an important indicator of innovation and a lot of economic analyses exist on the value of patents (remember the early study of Pakes and Schankerman back in 1984). Similarly in software, there is a substantial literature on both proprietary and open source software, providing information on the main actors, their location, their output contribution, etc. However, none of the activities related to intellectual property instruments or to software have been recorded in a blockchain ledger which shows what has gone before and what comes after they have been introduced.

Licensing, the trade sale of young innovative companies, IPO's, mergers and acquisitions are all phenomena on which data have been collected. However, the ultimate difficulty will be to attribute a particular value to the "spill-over" or externality in the linkages between the publicly funded research part, and the privately funded further value development.

This is why we would propose to start a blockchain try-out as a pilot case study with respect to the research carried out within public research organisations (PROs). The focus will be on PROs involved in more applied-based research building on the research carried out in collaboration with or within universities and finding its application in the public sector itself. As an example, take the Dutch PRO Deltaris[9]: an independent institute for applied research in the field of water and subsurface. Deltaris is both publicly and privately funded and operates globally on deltas, coastal regions and river basins dealing with amongst others flood risk, adaptive delta planning, infrastructure, water and subsoil resources and the environment.

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[7] https://bitcoinmagazine.com/articles/how-blockchains-can-further-public-science-1457972964

[8] http://insidebitcoins.com/news/astroblocks-puts-proofs-of-scientific-discoveries-on-the-bitcoin-blockchain/31153

[9] See https://www.deltares.nl/en/about-us/

As a Dutch PRO, Deltaris, set up in 2008 has a turnover of roughly €100 million of which the publicly funded, knowledge research base is today about €10 million down from €17 million in 2008. Yet the impact of the research in addressing the big societal challenges, Dutch (as well world) society is rather significant.

In The Netherlands e.g. future flood protection taking into account sea-level rise and the changing patterns of precipitation and river discharge costs roughly €1 billion every year on protection by dikes and dunes. The country's so-called "flood risk committee" recommended increasing all protection standards by at least a factor of ten, a rather costly step. Deltaris, using operations research techniques, determined that it would be efficient to limit increased standards to only three critical regions. The total costs of the study were less than €1 million. It resulted in €7.8 billion less investment costs in the coming 50 years for The Netherlands while strengthening the country's defense against flooding. In most of these cases the savings realized thanks to publicly funded research, are translated into "government funding rents" freeing public resources to be spend on other priorities or reductions in taxation.

Of course, one of the central reasons for government departments to maintain mission research units such as PRO's is to identify, alongside the provision of evidence in support of regulation, new saving opportunities through innovation and technological research. Just as in the case of a private company, the size of the procurement costs will induce research and innovation efforts to reduce such costs. However, in the case of governments, such surpluses are likely to be captured by the center with only deficits being recorded and used against different departments. In such cases[10] it would actually be in the interest of the public sector, and the PRO as the "innovator", to redistribute some of those rents back into its own publicly funded research.

Conclusions: a concrete proposal to go forward

Given the complexities involved in tracking the value of STI, the idea at this stage is not to try to capture through blockchain the specific spill-overs from individual research to particular well-known innovations but rather to try to develop ideas on how one could further address the "Mazzucato problem" through the application of blockchain technology. In short, to get some sort of technologically validated estimate of the value of public research to private (or public) innovation.

The analysis could start with investigating from a blockchain perspective the two databases which are publicly audited: scientific publications and patents and which, imperfectly, are linked to each other through the citations in patents to scientific publications. This could form the backbone for a first exploratory blockchain development attempt in the area of STI.

The concrete proposal is to start with an experiment using all the evidence available in PROs which can be considered as being positioned between the science cloud and innovation rents. Focusing on PROs has the additional advantage that the innovation rents might well be publicly owned, hence avoiding the complex question on how to bring part of those monopoly "rents" in a voluntary fashion under blockchain technology to publicly funded research.

[10] A similar case can be made with respect to military research and dual use private and public outcomes. However, it is unlikely that data access to both funding and upstream linkages would be made readily available allowing blockchain application.

Once such first experiments have been carried out, the analysis can be broadened to privately owned innovations. The idea would be that "STI miners" (STI researchers) could now focus on some of the most important innovations brought onto the market thanks to PROs, involving also the private "innovators" providing their own estimates as to what the upstream contribution of the PRO and other publicly funded research has been to their innovation. For sure this will be hard to quantify. Ideally a block consists of actions – transfer of IP, sale of license, publication of a paper, hiring of a post doc… or the downstream purchase of IP, people, material, energy and ultimately the release of a good or service.

Ultimately though, it will also be in the interest of private firms, particularly those benefiting from free access to PRO research and research facilities to assist in the design of economic systems which refund out of a technologically neutral, undisputed blockchain, research in the public field. In some PRO's, "club good" systems[11] exist involving an annual ex-ante payment so as to get free access to PRO research and research facilities. Such payments remain, however, small compared to the potential benefits and force the knowledge, developed within the PRO to remain relatively close, only available to club members. Blockchain technology by contrast, focusing on the ex-post situation, providing any firm, not just those part of the club, access to knowledge from the PRO with a "smart contract" involving payment to the PRO at the release of a product which has used input from the PRO, would provide a more objective funding scheme for a PRO.

In short: in so far as a blockchain could serve as the distributed, encrypted public trail of that part of STI investments which has led to significant innovation rents that can be easily audited, the funding of a part of public research could become integrated in the economic system directly through a reallocation of those innovation rents to public research, but also as collateral for attracting more private funding in public research. Developing a pilot project in the development of using blockchain in PROs appears the next, most logical step, where there can be substantial learning by doing.

[11] A good example is the Dutch MARIN PRO in which some 13 private companies pay an annual contribution of 60K for access to MARIN research and MARIN's research facilities.