

Singapore Management University

Institutional Knowledge at Singapore Management University

Sim Kee Boon Institute for Financial Economics

SMU Institutes, Centres, Labs & Initiatives

8-2024

Quantinar: A blockchain peer-to-peer ecosystem for modern data analytics

Raul BAG

Bruno SPILAK

Julian WINKEL

Wolfgang Karl HARDLE

Follow this and additional works at: <https://ink.library.smu.edu.sg/skbi>



Part of the [Data Science Commons](#)

This Journal Article is brought to you for free and open access by the SMU Institutes, Centres, Labs & Initiatives at Institutional Knowledge at Singapore Management University. It has been accepted for inclusion in Sim Kee Boon Institute for Financial Economics by an authorized administrator of Institutional Knowledge at Singapore Management University. For more information, please email cherylds@smu.edu.sg.



Quantinar: a blockchain peer-to-peer ecosystem for modern data analytics

Raul Bag^{1,2} · Bruno Spilak^{1,2} · Julian Winkel¹ · Wolfgang Karl Härdle^{1,2,3,4,5,6}

Received: 8 August 2023 / Accepted: 12 June 2024
© The Author(s) 2024

Abstract

The power of data and correct statistical analysis has never been more prevalent. Academics and practitioners require nowadays an accurate application of quantitative methods. Yet many branches are subject to a crisis of integrity, which is shown in an improper use of statistical models, *p*-hacking, HARKing, or failure to replicate results. We propose the use of a Peer-to-Peer (P2P) ecosystem based on a blockchain network, [Quantinar](#), to support quantitative analytics knowledge paired with code in the form of [Quantlets](#) or software snippets. The integration of blockchain technology allows Quantinar to ensure fully transparent and reproducible scientific research.

Keywords Blockchain · Machine learning · dao · p2p · e-Learning

1 Introduction

The invention of the transistor is commonly regarded as an initial step into our modern era: The Information Age. Increased IT activity, though, naturally, brings also more data to our hands and requires proper analysis. With more computational power, this has sparked new fields like computational statistics and data science. Statisticians have quickly found that this required “proper analysis” must be based

✉ Raul Bag
bagcrist@hu-berlin.de

¹ School of Business and Economics, Humboldt-Universität zu Berlin, Dorotheenstr. 1, Berlin 10117, Berlin, Germany

² Institute for Digital Assets, Bucharest University of Economic Studies, Bucharest, Romania

³ Sim Kee Boon Institute, Singapore Management University, Singapore, Singapore

⁴ Asian Competitiveness Institute (ACI), NUS, Singapore, Singapore

⁵ Department of Information Management and Finance, National Yang-Ming Chiao Tung University, Hsinchu, Taiwan, ROC

⁶ Department of Mathematics and Physics, Charles University, Prague, Czech Republic

on the interplay between adequate scientific methods and efficient computational implementation.

Statistical inference and quantitative data technology have undoubtedly contributed to the scientific advances of clinical testing, financial risk management, economic forecasting, and policy making. This data-driven success story of quantitative technology has created a rich toolbox of possibly adequate instruments. The overwhelming abundance of knowledge and tools brought the necessity to develop proper analytics on top of the adequate “proper analysis”. This is where [Quantinar](#) (Qr) comes into play since it offers a new peer-to-peer (P2P) system to preserve and produce knowledge, evaluate ideas, and educate the growing amount of practitioners. It offers a unified platform to perform proper data analytics since knowledge elements are sliced into “Courselets” (CLs), knowledge containers, that are created, consumed, and owned by the [Quantinar](#) community.

[Quantinar](#) uses the stable and proven concept of a platform economy. Many Web 2.0 approaches provide isolated elements, like Coursera, but do not provide horizontal and vertical integration. Another example is journals which are a proven way of retaining knowledge.

Yet, according to [Albright \(2017\)](#), we are navigating through a post-truth or fake news era, where public opinion is easily manipulated through various information channels. Despite the peer review process, research publications are not immune to misinformation. The pressure on academics to publish, driven by career milestones and external pressures, often leads to questionable research practices aimed at producing “significant” results ([Harvey 2017](#)). This environment likely biases or falsifies today’s research findings, overly reliant on p-values ([Ioannidis 2005](#)). Practices like *p*-hacking ([Bruns and Ioannidis 2016](#)) and HARKing ([Kerr 1998](#)), employed to meet academic expectations, compromise the integrity of research. The peer review process itself, intended to assure research quality, faces numerous criticisms ([Ziman 1968](#); [Spier 2002](#); [Rowland 2002](#); [Ware 2011](#)), including unreliability and inconsistency, delays, lack of accountability, and publication bias. Top journals in Economics do not necessarily guarantee higher quality, as shown by [Heckman and Moktan \(2020\)](#), and the necessity of peer review is questioned in the Internet age by [Ellison \(2011\)](#).

With the development of the internet and in response to those critics, multiple solutions have been suggested for disseminating research in opposition to the traditional scientific publication process and as part of the Open Science movement promoting transparency, accessibility, and collaboration ([Vicente-Saez and Martinez-Fuentes 2018](#)), such as [arXiv](#), [SSRN](#), [Academia](#), [ResearchGate](#), [CRAN](#), [GitLab](#), [GitHub](#), [Hugging Face](#), [Kaggle](#), [Coursera](#), [edX](#), or [YouTube](#).

However, the previously cited platforms are either limited by centralized control, or miss the vertical integration in terms of reproducibility, data visibility, and transparency. Education platforms are typically top-down approaches that do not provide ownership for creators and fail to connect the creators of knowledge with their consumers and pave the way for today’s consumers to be tomorrow’s creators. Most importantly, those platforms cannot ensure the quality and reproducibility of research results. In this context, a methodology that enhances both research reproducibility and reliability is critically needed in today’s academic environment and

beyond. We propose **Quantinar**, a P2P platform that strengthens research collaboration and reproducibility in different areas. The architecture of Qr is extensible, and flexible and may host all kinds of scientific knowledge elements that involve quantitative analysis. Here we present the Qr system across Fintech, Blockchain, Machine Learning, Explainable AI, Data Science, Digital Economy, Cryptocurrency, and Maths & Stats. It aims to provide better integration of scholarly articles, the studied data, and the code of the implemented analysis to ensure the reproducibility of the published results, while also providing educational content.

On top, Quantinar fosters scientific research by rewarding its participants through a modern data-driven algorithm that assesses the value of their publications. This algorithm draws inspiration from PageRank and maps the Quantinar ecosystem using a graph that represents the contributors and their contributions. The method is dynamic and flexible, ensuring temporal and spatial scalability, score inertia for each contributor, and community control.

Finally, employing a game theory-based approach, Quantinar presents a novel peer-review process that aims to incentivize community members to conduct efficient and impartial publication reviews. Through simulations, we demonstrate the efficacy of this process.

Quantinar's philosophy is Open Science and provides a framework for transparency, accessibility, sharing, and collaborative development of knowledge. Our goal is to implement Qr with Blockchain technology and smart contracts via a decentralized autonomous organization (DAO) yielding a tokenized ecosystem. With the recent developments of Web3 technology, Quantinar makes it possible to spread the benefits of AI by equalizing the opportunity to access and monetize data, code, and scientific ideas.

The first part of this paper presents the technology used within the platform and the status of Qr. Then, we demonstrate how Quantinar addresses some of the aforementioned issues through the utilization of cutting-edge innovations in blockchain technology. Finally, we show how quantitative methodologies are used within Qr to promote research production, collaboration, and quality.

2 What is Quantinar?

Quantinar is a peer-to-peer (p2p) platform that strengthens research collaboration and reproducibility in different areas like Fintech, Blockchain, Machine Learning, Explainable AI, Data Science, Digital Economy, Cryptocurrency and Maths & Stats. It aims to provide better integration of scholarly articles, the studied data, and the code of the implemented analysis to ensure the reproducibility of the published results. The conceptual architecture of Quantinar is called *C5* and it stands for *Creation, Content, Consumption, Coins, and Chain*. Blockchain technology (*chain*) and smart contracts via a decentralized autonomous organization (DAO) with a tokenized ecosystem (*coins*) can be used today to promote Open Science, transparency, and accessibility of research and collaborative development of knowledge

(Tenorio-Fornés et al. 2019). In this section, we will present the features, applications, infrastructure, and technology of Quantinar.

Quantinar is organized as a DAO, an online community that jointly controls the organization's funds to pursue common goals (Buterin 2013, 2014). As described in 4.1, the Quantinar DAO will represent a P2P platform for knowledge sharing that will have a reputation-based governance, meaning that only active contributors in the academic environment will be able to control the update of the platform and the management of its funds. Quantinar's main goal is to enforce scientific research reproducibility by creating a new digital publication platform that requires more input from scholars, namely giving access to the code, data, results, and extra information provided by courselets (see Sect. 2.2 for a definition of such a knowledge unit). Moreover, the peer-review process described in 4.4 ensures the quality control needed by an academic journal. On top of that, Quantinar is designed to become an integrated solution for presentation, data loading and exploration, code execution, and computing power. By creating an integrated research environment, the platform will also offer a marketplace for Datalets (DI), Models, or Quantlets (QI) (see Sects. 2.2 and 2.8) that aims to connect the academic environment to the industry. This will generate the revenue needed for the growth of the platform, and for other causes like funding research that the community decides it's needed. The governance process and tokenomics research of Quantinar will be described in a separate publication. At the time of writing, Quantinar (quantinar.com) is a website that manages the C5 paradigm.

2.1 Overview of existing solutions

Before describing in details the innovations of Quantinar, we briefly compare it with existing platforms, such as Coursera, Khan Academy, EdX, GitHub, and HuggingFace. While the first three are education-focused platforms offering courses and resources for learning, GitHub and HuggingFace are fundamentally different.

As Quantinar, Coursera and edX are online learning platforms offering courses, specializations, and degrees across a wide range of subjects, including technology, business, arts, and sciences. Their content is either free or requires payment depending on the creator's wish, as in Quantinar. However, their target audience is slightly different, focusing on adult learners, professionals, and students, while Quantinar also addresses the needs of academics, providing research materials and results. On the other hand, Khan Academy is an educational organization providing free online education. It offers practice exercises, instructional videos, and a personalized learning dashboard with a strong emphasis on traditional academic subjects such as mathematics, science, and humanities. It primarily targets students at the school level (primary or high school level). Quantinar focuses on highly educated users.

GitHub serves as a platform for code hosting version control and collaboration, allowing users to host and review code, manage projects, and build software alongside millions of other developers. It is not an educational platform in the traditional sense but is instrumental for learning coding and development practices. GitHub was primarily created for developers, programmers, and software engineers, but

also today it is used by data scientists and researchers for collaboration on projects involving code.

HuggingFace has carved out a niche for itself by focusing on natural language processing (NLP) and machine learning (ML), offering a different kind of resources compared to traditional educational platforms and GitHub's code collaboration service, such as datasets and ML models. Mainly known for its open-source library Transformers, Hugging Face is a platform that offers a vast repository of pre-trained machine learning models, particularly in NLP and computer vision. It also provides a collaborative environment for researchers and developers to share and work on technologies. Data scientists, AI researchers, and developers focused on machine learning and natural language processing are its main target audience.

Bringing education, code hosting, models, datasets, and analytics under one umbrella is the aim of Quantinar. However, Quantinar is not just an integration platform, it introduces several innovative approaches and features that distinguish it from the presented platforms. The next sections of the article will present them.

2.2 Content and creation

The main content on Quantinar is a "CourseLet", abbreviated as CL. A CL is a scientific knowledge unit, such as a research study or course unit, in the form of slides with a presentation video and the associated PDF file of the slides for reading. If applicable, it must be accompanied by a Quantlet and a Datalet, the associated implementation, and data. Any user of Quantinar can create a courselet that will have three statuses: unverified, verified, and peer-reviewed. The unverified status is the default status obtained at the time of publication on Quantinar. The verified status is given if the courselet contains the slides with the link to the verified QuantLet (QL) and DataLet (DL), ensuring that the research results can be reproduced. The peer-reviewed status can only be obtained after passing the open peer review process defined in Sect. 4.4. Finally, a simplified pre-publication review will be used to verify that the uploaded content complies with the platform's rules, using e.g. [AOBDL](#) to avoid offensive content.

The choice of the CL video format is not insignificant. Indeed, videos allow a faster sharing of research studies compared to scholarly articles and emphasize scientific ideas and results generation, not formal writing. On top, a video does not replace scholarly articles that can always be referred to in the CL but rather motivates reaction and direct communication between Quantinar community members via our discussion channels (see Sect. 2.7).

Finally, the authors keep their copyright and full ownership of their creation as each CL in the C5 framework is mapped to a Non-Fungible Token (NFT), a coin in the blockchain (see Sect. 3.3) and they give an open access license instead.

2.3 Features

Quantinar's features are designed to benefit the scientific community as a whole. In particular, Quantinar answers the needs of three main categories of users. By

offering open access to CLs and certification, students and professionals can acquire skills necessary for their careers. By offering a classroom and the possibility to reuse other users' courselets, universities and professors can attract more students and gain online visibility. Finally, researchers increase their reputation by creating transparent and reproducible research, reviewing other users' publications, and share knowledge via a simplified publication and communication channel.

2.4 Applications

Quantinar's purpose is to become a platform that can be used by any person that works in the field of data analysis, analytics, and science, namely *students, teachers, and researchers*.

It can be seen as a *student platform* because students can easily understand individual research problems in the form of courselets that offer slides and presentation videos accompanied by code examples that are already implemented by top researchers. Moreover, students can enroll in courses that tackle a wider range of subjects and get a certification after passing a series of tests to verify their knowledge. Running algorithms in the cloud, exploring datasets and models, and sharing their work will all be integrated under the same platform that makes learning and acquiring knowledge interactive and accessible.

Quantinar is a *teacher platform* as much as it is a student one. Teachers can create CLs which link other CLs to their courses, to compose more complex and more complete teaching environments. Apart from that, teachers can also get coins, reputation, and citations when others use their courselets, a feature which is thoroughly described in 4.1

For *researchers*, Quantinar delivers the ability to publish CLs that represent their research articles and projects. By doing so, they gain coins (QNAR and QLET), reputation, and citations when other people use their research (see Sect. 4.1). Quality is ensured by a P2P review process that is later described in 4.4. By publishing their work in the form of courselets, researchers must publish a video presentation, code, and data (when possible), on top of the article itself, which strengthens the reproducibility of the results.

2.5 Prosumers and consumption

Quantinar is also a prosumer platform. This means that students can become teachers by creating CLs of their own. Researchers are also encouraged to post their preliminary results and get feedback from the community while also contributing to its growth. In Fig. 1 we can find an example of a CL, that represents work done by one of the authors of this paper.

2.6 Case study: extending a course

As we briefly mentioned in Sect. 2.4, Quantinar is also a platform for teachers. Teachers can compose courses using both their content and CLs that are already

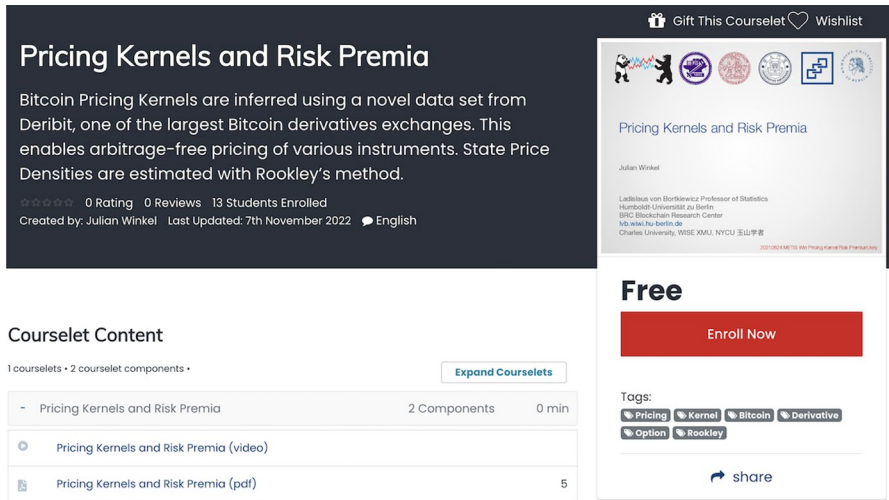


Fig. 1 Courselet: Pricing Kernels

posted on the platform by other prosumers. As we can see in Fig. 2, the CL created in Fig. 1 was made available in the [Statistics of Financial Markets \(SFM\) Course](#). Of course, the other courselets that are available in the SFM course can be further linked to develop courses that are more suitable for other teacher’s visions

2.7 Quantinar in numbers

The Quantinar ecosystem already gathered an international community of researchers that produces quality research on diverse scientific topics. At the time of writing, Quantinar already has an important community and can offer high-quality content with 215 CLs.

Quantinar’s community consists of 1470 users with 64 instructors. Without a marketing campaign, Quantinar has experienced important growth in the last months of 2023 as it is shown in Fig. 3.

At the time of writing, the distribution of CL instructors contributing to the CL creation is skewed (Fig. 4).

This is an effect of where the original ideas come from: [Humboldt-Universität zu Berlin](#) and [ASE Bucuresti](#). The Quantinar ecosystem has already attracted users from multiple countries and continents (Germany, Romania, United States, China, Singapore, Taiwan, etc.), as it is shown in Fig. 5.

Thanks to its Discord channel (<https://discord.gg/ebS3Bf6gfS>), Quantinar’s community is thriving: members can follow the latest updates from the platform and interact with it.

At the time of writing, Quantinar gathers 343 courselets and 80 courses in 8 categories (see Fig. 6).

We can observe in Fig. 7a an uptrend in the consumption of courselets on Qr as, in the second half of 2022, there are around 21 unique CL views

Statistics of Financial Markets

Statistics of Finance data; Quantitative finance; Forecasting

★★★★★ 4.9 Rating 9 Reviews 23 Students Enrolled

Created by: Wolfgang Härdle Last Updated: 7th November 2022 English

Statistics of Financial Markets

Jürgen Frahm
Wolfgang Härdle
Christian Hahler

C.A.S.E.

Ludwigs-Universität zu Berlin
C.A.S.E. - Center for Applied Statistics
and Economics
Humboldt-Universität zu Berlin
E-Mail: haehrdle@hu-berlin.de

© 2022 | 197 slides | Chapter 10 | External Release: Völlig frei

Course Content

49 courselets • 86 courselet components • 11h 35m total length Expand Courselets

+ Courselet: Pricing Kernels	2 Components	0 min
+ Chapter 1 - Financial Derivatives	2 Components	25 min
+ Chapter 2 - Section 2.1	2 Components	24 min
+ Chapter 2 - Section 2.2	2 Components	34 min
+ Chapter 2 - Section 2.3	2 Components	26 min
+ Chapter 3 - Probability Theory	2 Components	27 min
+ Chapter 4 - Stochastic Processes in Discrete Time	2 Components	23 min
+ Chapter 5 - Stochastic Integrals and Differential Equations	2 Components	29 min
+ Chapter 6 - Section 6.1	2 Components	31 min
+ Chapter 6 - Section 6.2	2 Components	28 min
+ Chapter 6 - Section 6.3	2 Components	30 min
+ Chapter 7 - The Binomial Model for European Options	2 Components	23 min
+ Chapter 8 - American Option	2 Components	25 min
+ Chapter 9 - Exotic Options	2 Components	27 min

Free

[Enroll Now](#)

Tags:

[share](#)

Fig. 2 Course: Digital Economy and Decision Analytics

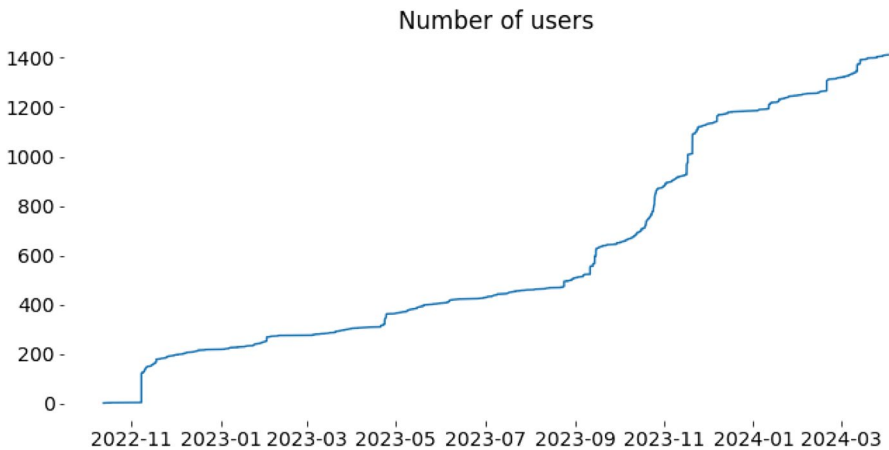


Fig. 3 Number of users

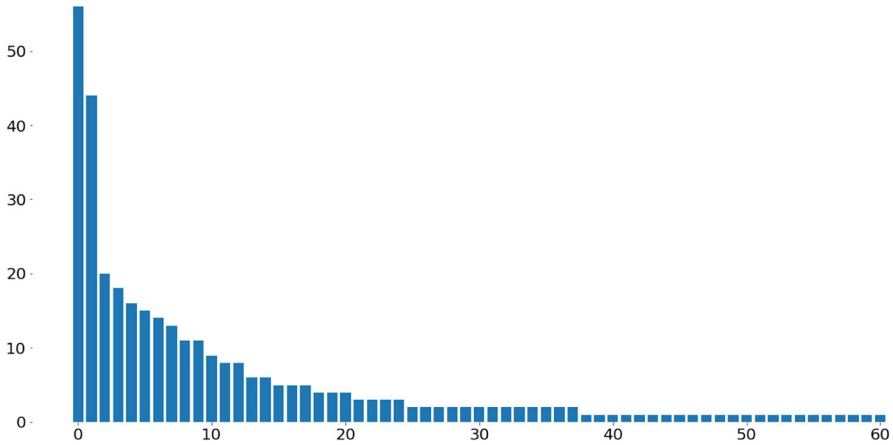


Fig. 4 Number of courselets per instructor

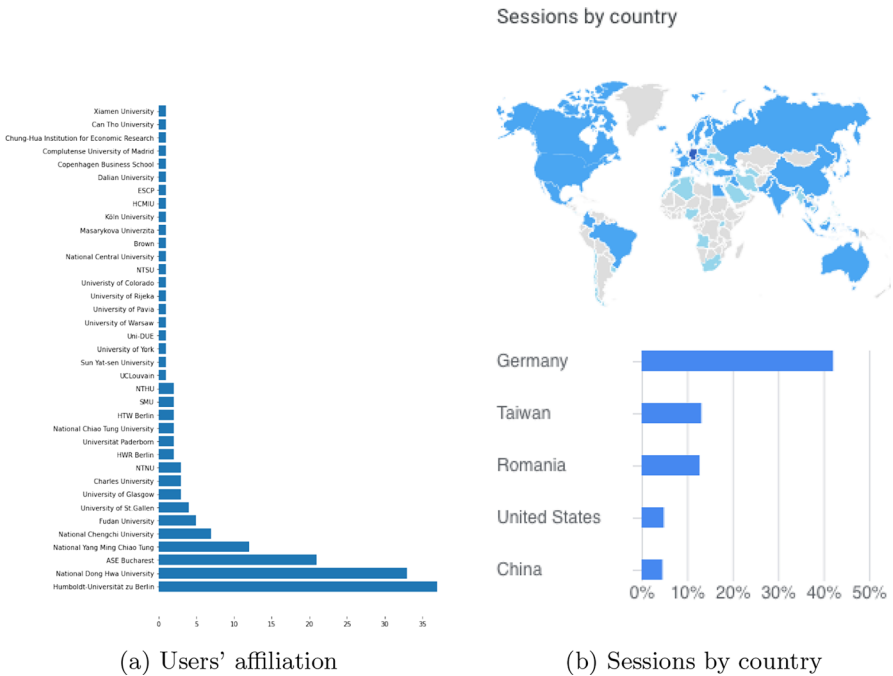
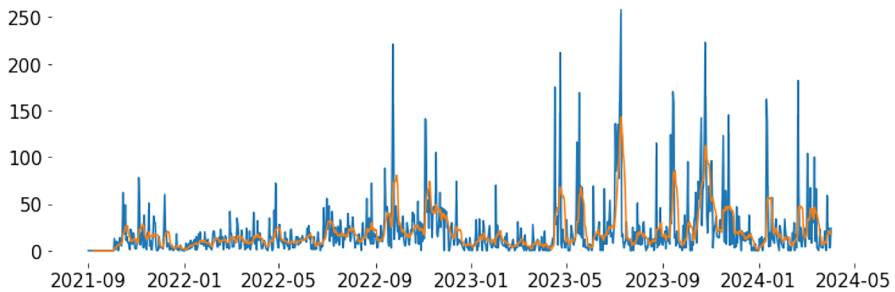
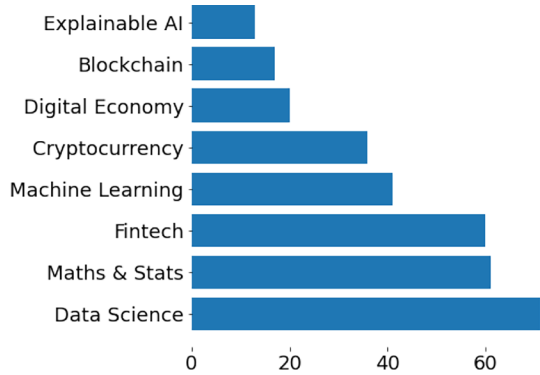
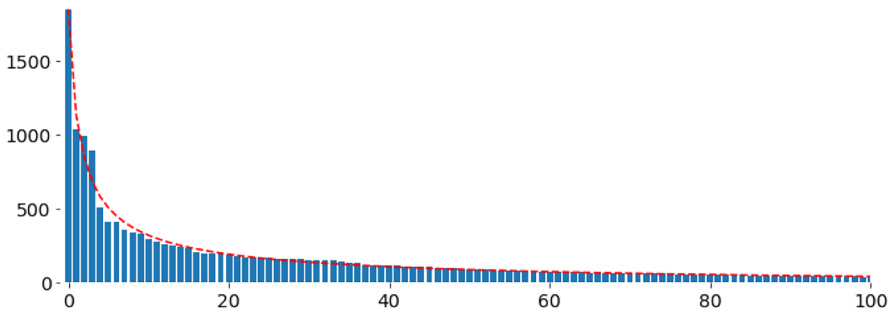


Fig. 5 Users location

per day, while there were only 9 before. The total views per courselet, y , follows a classic power law given by $y = ax^k + b$ for $x > 0$ with parameters $(a, k, b) = (1.89e + 03, -6.97e - 01, -3.69e + 01)$. The top 3 CLs are [DEDA Digital Economy & Decision Analytics](#), [Statistics of Financial Markets](#) and [Advanced](#)

Fig. 6 Courselet category distribution

(a) Total daily unique views on Qr's courselets and week rolling average



(b) Total unique views per CLs

Fig. 7 Qr's courselets views

Mathematics gathering more than 25% of all courselets views (see Fig. 7b) and the top 7% of CLs corresponds to 50% of all views.

The most recurrent topics are related to cryptos, pricing, clustering, prediction, data, or risk, as the word cloud in Fig. 8 suggests it.

Finally, Quantinar's CLs come with their respective implementation code in **Quantlet** using mostly R or Python programming languages (see Fig. 9).



Fig. 8 Word occurrence in courselet description

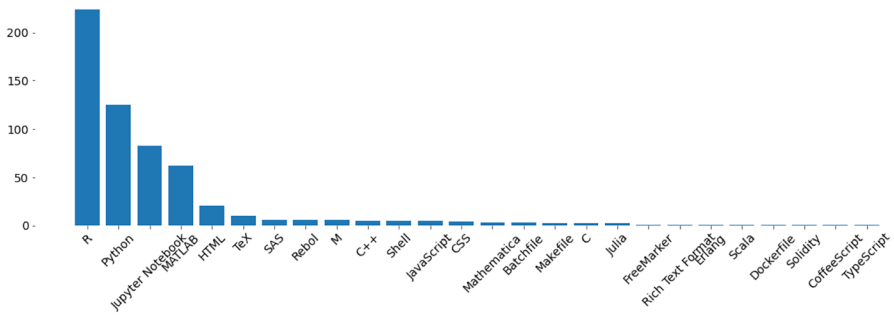


Fig. 9 Quantlets programming language

2.8 The Quantinar ecosystem

The concept of the Quantinar ecosystem refers to achieving smooth and rich integration between the DL components [Blockchain Research Center \(BRC\)](#), the [Quantlet](#) code base and the [Quantinar](#) platform. A possible goal of this integration is to establish interactive code environments generated from the (QLs) that are present in the CLs in Quantinar. This architecture ensures that the CL results and claims are easily reproducible (Borke 2017) as e.g. this current paper at [Quantinar-rep](#) with respective [courselet](#), (Spilak and Härdle 2021) at [QMLvsG ARCH](#) or (Spilak and Härdle 2022) with associated [courselet](#) and QL [QEmbed](#)

dingPortfolio. Moreover, the runtime execution environments will be able to access the data that is present in the DL components, e.g. the BRC.

This is achieved by moving the DLs from the BRC to a Ceph (ceph.io) storage backend, which is integrable into a Kubernetes (kubernetes.io) cluster, that runs OpenDataHub (opendatahub.io). The high-level architecture overview can be seen in Fig. 10.

3 Blockchain, a technology for open science

3.1 Technology

The Quantinar P2P platform—abbreviated Qr—will have most of its operations on-chain since having decentralization in its core is a strong suit compared to most educational platforms. However, as for academic journals, Quantinar must ensure that each user is indeed a real person and cannot transfer or sell its wallet addresses, and with them, its acquired reputation. To do so, a centralized software component with specific capabilities is required, as illustrated in Fig. 11.

Indeed, as accountability in the OPR process cannot be achieved without an immutable online identity, the centralized component should be able to provide identity management features such as a Single Sign On or BrowserID solution (Fett et al. 2014).

That way, Quantinar can integrate all the different components of the platform under the same umbrella. To do so, the Keycloak project (RedHat 2014) is used, with a simple MySQL Database. An extra layer of information will be sought from the users thanks to a KYC solution, for example, MouseKYC (MouseBelt 2019).

Except for identity management, a minimal gateway is needed to provide flawless document uploading to an IPFS chain and validate the uploaded content to filter out

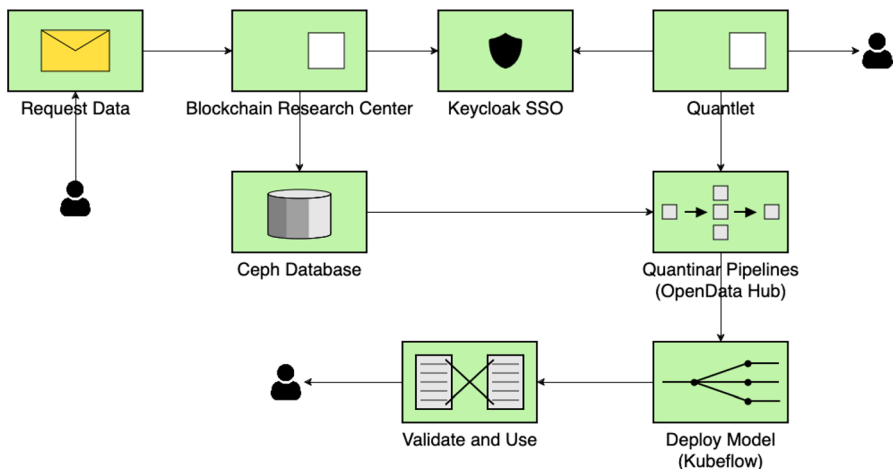


Fig. 10 Quantinar Ecosystem Integration Diagram

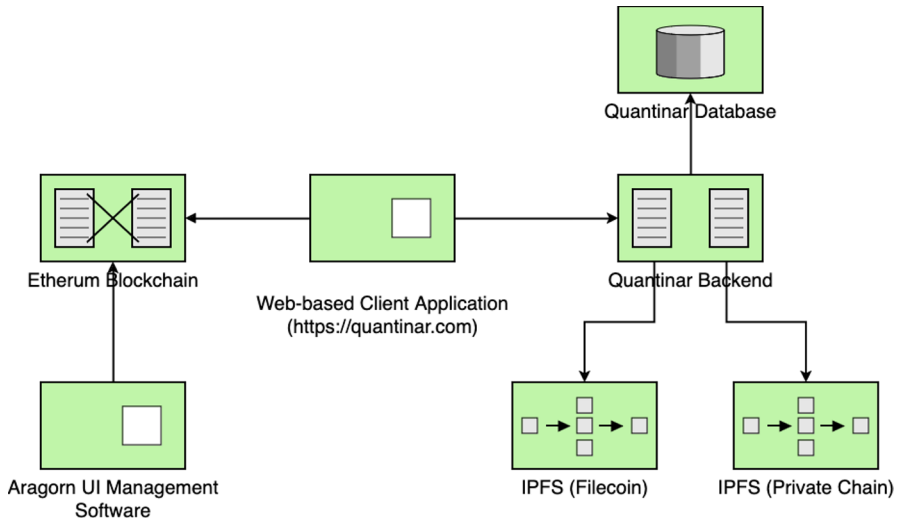


Fig. 11 Software Architecture Overview

forbidden items or spam. Articles are uploaded on a public IPFS chain like Filecoin's (Labs 2019), while presentations, videos, and other types of content will be uploaded on a private IPFS chain managed by the Quantinar DAO. More information about IPFS can be found under Sect. 3.2.

The Quantinar DAO will be hosted on the Ethereum blockchain, as it is one of the most stable and predictable technology. Moreover, the recent adoption of Proof of Stake (POS) and the upcoming implementation of sharding by Ethereum improves its competitiveness concerning other blockchains. Indeed, sharding, defined as the process which divides one blockchain network into several smaller networks, referred to as “shards”, improves the performance of blockchains that implement it by giving them a competitive advantage in terms of speed for transaction processing and data availability. On top, the planned launch of SoulBound tokens, announced in early 2022 by Vitalik Buterin (vitalik.ca/soulbound) comes in good time. SoulBound tokens are *special NFTs with immutable ownership and pre-determined immutable burn authorization*. Quantinar is a perfect application for SoulBound tokens via the various certifications obtained when passing a course.

Finally, the whole Web3 side of the platform is written using the Aragon framework (aragon.org), one of the most popular DAO frameworks on Ethereum. The centralized side of the infrastructure will be hosted on an OpenStack cloud fully installed and managed by the Quantinar Team.

3.2 Open access and IPFS

At the center of Quantinar is Open Access to its content. Nevertheless, it is not enough to guarantee Open Access to content if it is controlled by a centralized institution such as an online academic journal. Indeed, the access can be revoked at any

time, or even worse, ransomware attacks could take place which would render all of the data on the servers useless.

The InterPlanetary File System (IPFS) is a peer-to-peer protocol that distributes data storage in its network in a decentralized manner, firstly described in “IPFS—Content Addressed, Versioned, P2P File System” as *an ambitious vision of new decentralized Internet infrastructure, upon which many different kinds of applications can be built* (Benet 2014). It builds on top of common ideas collected from pieces of software like BitTorrent or Git, to create a protocol that manages Merkle DAGs containing file data over a network.

There have been multiple attempts at building an IPFS-based storage solution that is ready for solving real-world challenges like decentralizing medical data, as described by Kumar et al. (2021), and even more attempts of building IPFS networks for academic usages, like the share of databases used for research (Meng and Zhang 2021), some of which tackled issues like availability, immutability, transparency, and security, and even open access to academic research (Marjit and Kumar 2020).

Decentralization makes it difficult to restrict the network’s data access. On top of this, thanks to content addressing, files stored using IPFS are automatically versioned (<https://ipfs.io/>). Thus, by using a decentralized storage system such as IPFS, one cannot revoke access to the authors’ publications or delete an open peer-review article, as Quantinar’s content is shared across an IPFS network. Finally, at times of writing, Filecoin costs are extremely low compared to standard centralized cloud-based solutions (< 1\$/month/TB and 23\$ for Filecoin and AWS respectively, source [Filecoin](#) and [AWS](#)). Quantinar’s network and reward system is then truly resilient.

For the moment, there is no plan to implement a proprietary IPFS network. This is unnecessary since the papers should be stored on public chains, so they can be openly accessed. On top of that, a scalable and resilient IPFS network is required for the platform to take off. For these reasons, we propose the usage of the Filecoin network (Labs 2019). The capabilities of token generation of the Quantinar DAO can help support the filecoin storage on a *pay as you grow* basis.

Of course, private data use cases will be developed in a future phase of the platform that would require a private IPFS network with access control (as seen in (Steichen et al. 2018)). This will be designed specifically for holding private databases, original LaTeX files, or other information which might be seen as sensitive in the eyes of the researchers, companies, or universities. Thus, all of the actors will have the power to decide who can access this information. More research and development are required for developing such a feature, which is planned to happen in the second phase of the project.

3.3 Ownership and copyrights: Courselet NFT

Quantinar makes sure that the researchers keep the copyrights and ownership of their publication, CLs, DLs, or QLs. For that goal, Quantinar offers to create a non-fungible token (NFT) for each CL on the platform and transfer it to the CL author(s). An NFT is a unique cryptographic token created from a specific smart contract

standard (e.g. ERC-721 on Ethereum blockchain) that provides functionalities such as ownership transfer or ownership verification (see (Zinovyeva et al. 2023) for an extensive study of smart contracts applications). Thanks to this NFT, any authors can claim ownership of a specific courselet on the Quantinar platform by providing the unique hash of the NFT associated with it.

While smart contract and NFT makes it easy to verify ownership of a digital object on the blockchain, copyrights exist in the non-digital world and are governed by state law. Thus, to truly ensure copyright protection, each courselet will be secured with an Open Source license such as MIT or GNU. Finally, authors will keep ownership of the intellectual property (IP) on their work allowing them to publish their study in external academic journals.

Some information such as authors' identity, CL title, link to the CL content, review score, and link to reviews will be stored on-chain, while to reduce storage cost the CL content and actual reviews will be stored off-chain on Quantinar IPFS network defined in the previous Sect. 3.2. Having a courselet NFT with an immutable link to versioned content and reviews helps to open the iterative publication process during the peer-review feedback loop and protect the integrity of the authors' reputation score defined in 4.1.1. Thus, on top of the CL metadata, all contribution logs will be accessible directly on the blockchain ledger or on the IPFS network ensuring transparency.

4 Research quality control

4.1 Contributor reward

In the context of academic publications, the Bibliometrics research field has a long tradition and proposed many metrics for measuring the global productivity and impact of research in science and society. The most famous metric is probably the H-index (Hirsch 2005) which is an author-specific measure. It can be highly relevant in a scholar's career as it is often taken into consideration for allocating resources between researchers and funding. Because of many critics, mostly related to the relative easiness of the H-index manipulation (Bartneck and Kokkelmans 2011), researchers proposed alternative measures, in particular altmetrics which estimates the value of a publication at the article level based on various web data sources publicly available, e.g. social media such as Twitter (Altmetric 2022). Those metrics are highly valuable for journals and publishers and are often directly integrated into their publications. However, both bibliometrics and altmetrics remain weak indicators as they can easily be gamed (Karanatsiou et al. 2017). An interesting comparison between academic ranking methods in Economics is given by Zharova et al. (2023) who analyses the use of resources and scientific performance on the levels of individuals, research groups, and universities.

Quantinar offers a valuation system that measures the relative value of a contribution, or reputation, within the Qr ecosystem. The Qr reputation system is scalable in time with the size of the graph and the score reflects the inertia of highly valuable contributions. Indeed most of the results today can be attributed

to the labor provided yesterday and contributions that are highly valuable should be in the long run. The inertia of the reputation score of some contributor i , S_i^t over the periods t can be measured by the rate of change of the score assuming no change between the successive periods. Finally, the system must make sure that evaluations cannot be gamed in favor of malicious agents to be sustainable.

Since the development of online P2P communities, multiple proposals have been made to ensure trust between members and the quality of members' contributions to develop sustainable P2P platforms. A well-known technique is the PageRank algorithm which the scaling factor is roughly linear in $\log(n)$ (Page et al. 1999). While it was originally built for ranking web pages in the context of improving search engines, it serves also as an indicator of the trustworthiness of a website. Since its publication, it has been widely studied (the reader can refer to (Chung 2014) for a short survey or (Langville and Meyer 2011)) and extended for example, EigenTrust (Kamvar et al. 2003) evaluates trust in a distributed-manner within P2P file-sharing communities. Some alternatives have been proposed such as PeerTrust (Xiong and Liu 2004) which evaluates the members' reputation based on specific contextualized parameters such as contribution feedback, number of contributions, and credibility of the feedback source. However, PageRank is not famous only because it was created by the founders of Google, but its simplicity, generality, guaranteed existence, uniqueness, and fast computation are the reasons that it is used in many other applications than Google's search engine and is still very popular today. In fact, Gleich (2015) shows how to apply PageRank to biology, chemistry, ecology, neuroscience, physics, sports, and computer systems. Thanks to PageRank, we can estimate the value of any contribution relative to the marginal value it brings to the community as a whole and engage the community by effectively rewarding Quantinar contributors for the labor they provided to produce their contribution.

To estimate the reputation of each member, we propose to use a modified version of PageRank named CredRank (credrank 2022), an algorithm developed for blockchain-based communities by SourceCred (sourcecred.io). The innovation of CredRank is to embed temporal information into the graph on which PageRank is computed. As we will explain in the next section, thanks to CredRank, only one PageRank invocation is necessary to obtain the reputation score defined by (4) for each Qr member at any period. This property of CredRank greatly improves the scalability of the reputation score evaluation over time. The inertia of past contributions can easily be controlled without having to run PageRank again and each period's importance can easily be evaluated.

SourceCred provides an algorithm for distributing rewards within a community that is sufficiently abstract to be used in any DAO thanks to the concepts of *Grain* and *Cred*. Cred refers to the reputation score defined in the next Sect. 4.1.1 which is mapped by a utility token that is not transferable and can be gained by contributing to the community. In the Quantinar DAO, the Cred token will be named QNAR. The second concept of SourceCred's algorithm is Grain, represented by the Quantlet token, QLET, in Quantinar DAO. This token is meant for the creation of an internal research-based economy and will be tradable on external exchanges. It will be used to pay contributors based on the QNAR score and gain access to premium

features of the platform such as private courselet components or consulting top-level researchers (see Sect. 4.1.2).

4.1.1 Reputation score evaluation

The first step for computing the QNAR-based reward a Qr user should receive for its contribution is to evaluate its reputation within the community thanks to the PageRank algorithm. Therefore the Qr ecosystem is mapped onto a graph with specific nodes of three types: the seed node s_0 , contributors, and contributions forming the sets \mathcal{C} and \mathcal{A} , respectively. The seed node mints the new QNAR tokens and distributes them proportionally according to the contributions in the graph. Finally, the minted tokens flow from the contributions to the contributors who eventually receive a part of the originally minted tokens relative to their participation in Quantinar's total value. The following non-exhaustive list of contributions will be mapped onto the graph: creating a CL, QL, or DL, viewing, citing, and reviewing a CL, enrolling as a student into a CL, creating a course linking other CLs, actively participating in the discord channels, voting in the DAO decision process and helping other community members with their research. It is already clear that not all contributions should be rewarded equally, as creating a CL requires much more labor than citing one. Thus weights are associated with each contribution type in a heuristic manner based on what the community values in Qr and determine how much QNAR is minted for each contribution (see Table 1b). SourceCred finds the equilibrium of the token distribution among community members, in other words, it finds the stationary distribution of the PageRank random walk associated with the community graph. Thanks to the contribution weights, the Qr community keeps full control of the distribution of the reward among contributions.

In detail, the source node s_0 , contributions, and community members are mapped onto a directed graph $G = (\mathcal{V}, \mathcal{E}, \mathcal{W})$ where $\mathcal{V} = \{s_0\} \cup \mathcal{A} \cup \mathcal{C} = \{v_i\}_{1 \leq i \leq n}$ is the set of n unique vertices mapping the seed node, contributions and contributors which are connected with m directed edges, $\mathcal{E} = \{e_{ij}\}_{(v_i, v_j) \in \mathcal{V}^2}$, where e_{ij} denotes the edge from parent vertex j to child vertex i and $\mathcal{W} = (w_{ij})_{e_{ij} \in \mathcal{E}}$ with $w_{ij} \geq 0$ is the set of m edges weights which are chosen by the community members in a heuristic manner. In our experiment, we used the weights according to Table 1 where w_{ij} is taken from 1a if $v_i \neq s_0$ else 1b. The weights have a strong influence on the PageRank computation and the final reward, thus they must ensure that contributions that require a lot of labor get rewarded more than simpler ones and that they get rewarded when they are validated or reviewed by the community. Indeed, if a contribution j has multiple children, its score should be propagated forward to the most important child.

Figure 12 shows such a graph, omitting s_0 for clarity, with 3 community members, John, Alice, and Bob, who are connected via the edges between their contributions and interactions. We can see that the rank of courselet $CL0$ will mostly be propagated to its author Alice ($1/(1 + 1/16 + 1/16) = 0.89$).

A simple definition of the PageRank score of vertex i is given in the original paper:

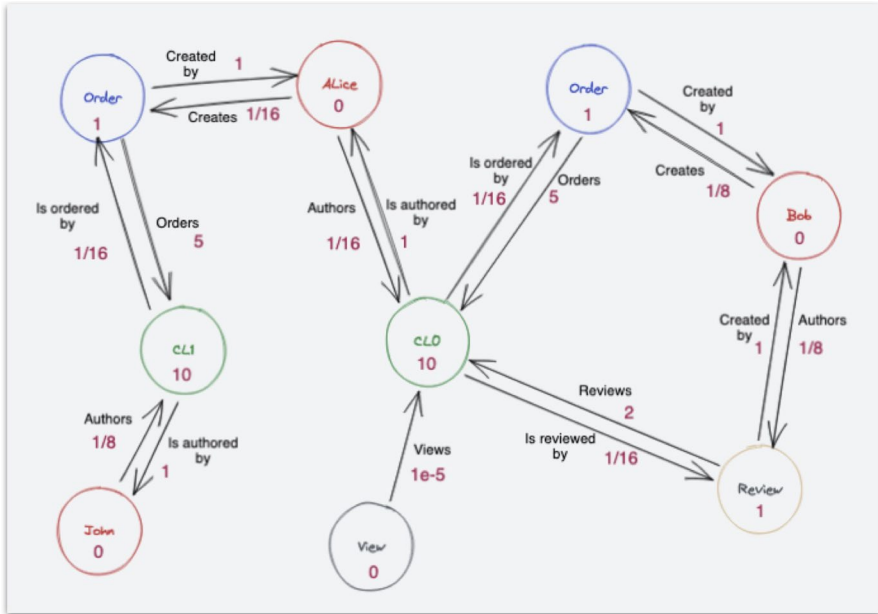


Fig. 12 Contribution graph. Notes: A user, John, creates a courselet, CL1. Another user, Alice, enrolls in CL1 and creates a courselet, CL2, which is reviewed by Bob

$$pr(v_i) = \sum_{j=1}^n A_{ij} \frac{pr(v_j)}{\sum_{k=1}^n A_{kj}} \tag{1}$$

where is A the adjacency matrix of the graph G . To avoid rank sink, Page et al. (1999) developed the random surfer model, where from any node, the user either continues to a children node with probability $1 - \alpha$ or the user jumps to a random node chosen based on the distribution in s with probability α . PageRank is then defined as the stationary distribution, pr , of a random walk, pr_t , on the graph G by the equation:

$$pr_{t+1} = \alpha s + (1 - \alpha)pr_t P \tag{2}$$

where pr_t is the row vector of vertex probabilities at time t , s is the n -vector $(1/n, \dots, 1/n)$, pr is the row vector of PageRank score $pr = (pr(v_i))_{1 \leq i \leq n}$, P is the transition probability matrix defined by $\forall 1 \leq i, j \leq n P(i, j) = \frac{w_{ij}}{d_i}$ where $d_i = \sum_j w_{ij}$ is the degree of v_i . The random surfer model ensures that the random walk on any graph G is strongly connected which guarantees the existence of the PageRank scores (from the fundamental theorem of Markov chains). PageRank can be estimated locally on large graphs (Lee et al. 2013) or globally using the power iteration method if the graph is small enough. Thanks to PageRank, we can easily evaluate

each node score by using the score of all parent nodes, that way, for each researcher, having highly valuable parents improves its score more than having less important ones. This evaluation motivates Qr's members to produce research of high quality.

Since contributions such as review or order are not at the source of Qr's value, the Personalized PageRank (PPR) is used by defining s as $s = (s_0, 0, \dots, 0) = (1, 0, \dots, 0)$ where s_0 is a *seed* node that corresponds to Qr itself or quantinar.com homepage from the point of view of the random surfer model. In that case, it can easily be observed that for any node v_i , its PPR, $pr(v_i)$, is equal to the success probability that a random walk starting at s_0 and independently terminating at each time step with probability α , hits v_i just before termination (Borgs et al. 2014). The PPR gives a contextualized ranking of Qr's contributions with respect to Qr's homepage.

Alas, the contribution graph defined above does allow us to study the PPR scores over time, in particular, the inertia of the score is not easily available. To overcome

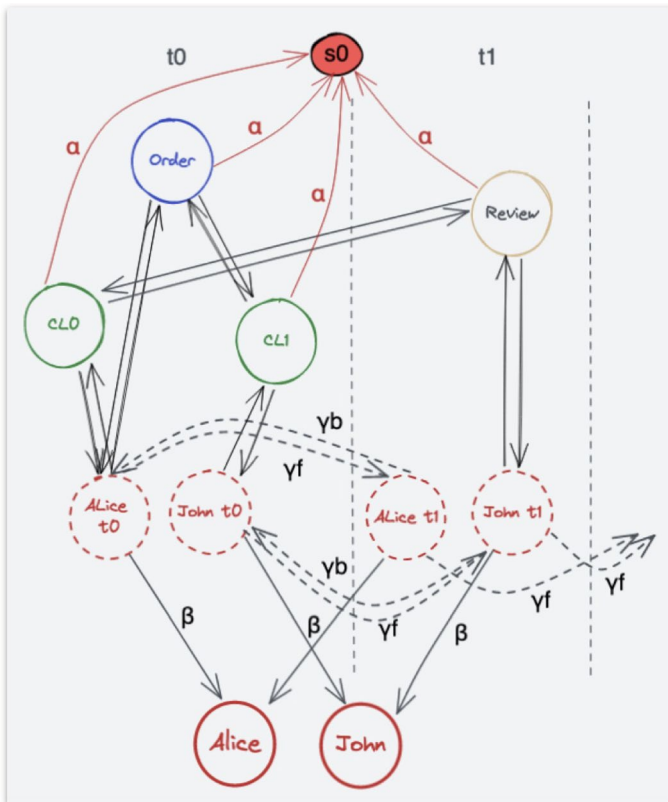


Fig. 13 Contribution graph over periods. Notes: At t_0 $Alice_{t_0}$ and Bob_{t_0} creates one courselet each, CL_0 and CL_1 , respectively. On top, $Alice$ enrolls in CL_1 . At t_1 , $John$ reviews CL_0 . It increases the score of $Alice_{t_0}$ and $John_{t_1}$. The current score of each user is aggregated in the global nodes $Alice$ and Bob

Table 1 Graph weights

Edge	Weight
<i>Edges weights</i>	
(view, courselet)	1e-5
(course, user)	1
(user, course)	1/8
(courselet, user)	1
(user, courselet)	1/8
(course, courselet)	1
(courselet, course)	1/8
(order, course)	5
(course, order)	1/16
(user, order)	1/16
(order, user)	1
(user, review)	1/8
(review, user)	1
(review, course)	2
(course, review)	1/16
<i>Seed-to-contribution weights</i>	
courselet	8
Review	1
Order	1
Course	0
View	0
User	0

that issue, we propose to use the latest CredRank algorithm from SourceCred to evaluate the scores on a discretized historical graph as it is represented in Fig. 13.

First, each vertex i is indexed by a timestamp t corresponding to its appearance in Qr and denoted as v_{it} . The history is then discretized in T fixed length periods (for example a week). Let us denote \mathcal{C} the set of vertices including all contributors and \mathcal{A} the set of vertices including all contributions. We define $\mathcal{A}_k = \{v_{it}, 1 \leq i \leq n, 1 \leq t \leq k, v_{it} \in \mathcal{A}\}$ as the set of vertices including all contributions until the date k . We can easily retrieve the set of new contributions during the period $k \geq 1$ with $\mathcal{A}_k^{new} = \mathcal{A}_k \setminus \mathcal{A}_{k-1}$ and $\mathcal{A}_0^{new} = \mathcal{A}_0$. At each period k , we create the epoch contributor nodes that authored the new contributions in \mathcal{A}_k^{new} , that is $\mathcal{C}_k^{new} = \{v_{ik}, 1 \leq i \leq n \text{ if } e_{ij} \in \mathcal{E}, v_i \in \mathcal{C}, v_j \in \mathcal{A}_k^{new}\}$. Thus the set of epoch contributor nodes until period k is defined as $\mathcal{C}_k = \bigcup_{1 \leq t \leq k} \mathcal{C}_t^{new}$. We add directed edges from the contributions in \mathcal{A}_k^{new} to their respective author(s) in \mathcal{C}_k^{new} . On top, webbing edges between previous and new epoch contributors are added with associated transition probability γ_f and γ_b connecting $\forall v_i \in \mathcal{C}_{k-1}, v_{ik-1}$ and v_{ik} forward and backward, respectively. The webbing edges ensure that the reputation gained at previous epochs has inertia over time. Finally, each epoch contributor node from \mathcal{C}_k is connected to its associated contributor node in \mathcal{C} with transition

probability β . Thanks to this graph, each contribution is connected to its associated contributor only through the epoch contributor node and not the global contributor node. That way, for any contributor i and period $k \geq 1$, the PageRank score at a previous period $k' < k$ is easily accessible at the epoch contributor v'_{ik} .

For any $k, 1 \leq k \leq T$, we define the epoch contribution graph as $G_k = (\mathcal{V}_k, \mathcal{E}_k, \mathcal{W}_k)$ where $\mathcal{V}_k = \{s_0\} \cup \mathcal{A}_k \cup \mathcal{C}_k \cup \mathcal{C}$, $\mathcal{E}_k = \{e_{ij}\}_{(v_i, v_j) \in \mathcal{V}_k^2}$ and $\mathcal{W}_k = (w_{ij})_{e_{ij} \in \mathcal{E}_k}$. The graph update is then given by:

$$G_k = (\mathcal{V}_{k-1} \cup \mathcal{V}_k^{new}, \mathcal{E}_{k-1} \cup \mathcal{E}_k^{new}, \mathcal{W}_{k-1} \cup \mathcal{W}_k^{new})$$

Before evaluating PageRank on such a graph, we need to compute the transition probability P to transform the contribution graph into a Markov chain. Given our definition, we have a mix of edges defined with weights and transition probability (α, β, γ_b , or γ_f). For any node v_i , the transition probability associated with an outbound edge e_{ij} is given if v_j is an epoch contributor node or a contributor node or the seed node (γ_b or γ_f, β , and α , respectively). For other outbound edges, it is trivial to transform the associated weight to a transition probability that keeps relative outbound weights' importance by setting it to the percentage of the remaining transition probability with the formula: $P(ij) = \frac{w_{ij}}{\sum_j w_{ij}}(1 - c_i)$ where c_i is the sum of the outbound predefined transition probability for node v_i , for example, $c_i = (\gamma_b + \gamma_f + \beta)$ if v_i is an epoch node contributor or $c_i = \alpha$ if v_i is a contribution. Having specific transition probabilities predefined allows us to keep a certain control on the reputation score dynamic. Indeed, from any contribution regardless of its outbound edges, the transition probability to the seed node is always equal to α ; similarly, from any epoch contributor node, regardless of its outbound edges in particular contributions, the transition probability to its global contributor node is always equal to β . The personalized PageRank scores, $pr(v_i)$ are obtained by solving (2) on G_k .

To compute the global score for any contributor $v_i \in \mathcal{C}$ at a given period k , a weighted sum that aggregates the previous epoch score with a discount factor, r , is used:

$$S_{ik}^* = \sum_{t=1}^k r^{k-t} pr(v_{it}) \tag{3}$$

Now, let us verify that r acts as a control parameter over the inertia of the score over the evaluation periods. We can easily show that if there is no change in the contribution graph, $\forall k, S_{i,k+1}^* - S_{ik}^* = -(1 - r)S_{ik}^* + \mathcal{O}(\gamma_f^k)$. Thus as r decreases the inertia of the score over the previous period decreases. The inertia is maximized for $r = 1$ and the score is roughly constant.

Since $pr(v_i)$ is a probability, S_i^* defined above can be very small as n increases. That is why SourceCred propose to normalize the score and scale it by the total amount of QNAR token minted at a given period. Any contribution node j that has a strictly positive weight $w_{s_0j} > 0$ associated with the inbound edge from the seed node s_0 will mint w_{s_0j} QNAR tokens. Let us denote $M_k = \sum_{j=1}^n w_{s_0j}$, the

following definition of the reputation score, the QNAR score, for any contributor i is then used:

$$S_i = \frac{S_i^*}{\sum_{j \in C} S_j^*} M_k \quad (4)$$

With definition (4), the reputation score will increase as the relative contributor page rank score and the total number of contributions that are valuable increase. Finally, this reputation system favors competition in the long term because to maximize one's reputation score, one needs to maximize the long-term value of one's contributions.

4.1.2 A reputation based reward

SourceCred proposes three types of grain-generation strategies based on the QNAR scores: *immediate*, *balanced* and *recent*. The *immediate* strategy mints one QLET, for each QNAR gained in the past week. The *balanced* strategy mints QLET based on the weights that are given to each action inside the DAO at any moment. For example, if creating a courselet changed its weight from w to w' , the QLET target will be recalculated for each author and they will be paid accordingly from the future payoff to match the new total QNAR score incorporating the weight change. The last strategy of generating QLET is *recent*. This strategy refers to a discounted reward based on previous period QNAR scores.

Since the concept of a decentralized P2P platform is new, the Quantinar DAO will use the *balanced* strategy. In the long run, this strategy is more equitable for all the contributors and allows for a continuous fine-tuning of weights used for QNAR/QLET generation by the whole community.

4.2 QNAR dynamics

Quantinar has already implemented certain features and collected some statistics. To illustrate the dynamics of the CredRank algorithm for the platform, we made an experiment using the production SQL dataset from the Quantinar platform and Google Analytics statistics of [quantinar.com](https://www.quantinar.com) from the inception date on 2021-09-13 to 2022-10-25. This dataset includes the following contributions:

- CL publication as an author
- CL order (ordering a courselet as a user, in most cases the CLs are free)
- CL review (grading or commenting on a courselet as a user)
- CL page view
- Course publication as an author

The graph is created with the contributions {"course", "courselet", "order", "review", "view"} and user nodes. The edge weights and seed-to-contribution minting weights are defined respectively in Table 1a and b.

It is worth noticing that publishing a course does not mint any QNAR. Indeed, as courses contain courselet(s), only publishing a courselet should mint additional QNAR. On top, as Quantinar offers the users to create courses from courselet(s) that they did not author, a possible malicious behavior could appear: creating courses that contain courselet(s) with high reputation to steal it from the original courselet and artificially increase one’s QNAR score. A simple mechanism to avoid this issue would be to add a new node for any linked courselet that does not have any inbound edge from the original one, but one outbound edge from the linked courselet to its original. That way, the instant reward of linking a courselet can only be positive for the original author.

Finally, we define the following transition probabilities using default values from SourceCred: $\alpha = 0.1$, $\beta = 0.4$, and $\gamma_f = \gamma_b = 0.1$. This choice is governed by the aim to guarantee that the score of each contribution is influenced by earlier dependencies and that the score of each contributor has some inertia over time. The effect of those parameters on the reputation score has been studied by the SourceCred team (Conte [actualizing Cred](#), github.com/sourcecred/research) and it is future research in the context of Quantinar. However, their impact on the QNAR score can be described analytically.

Indeed, for any node v_i in the graph, the contribution from a connected parent v_j with score $pr(v_j)$ and $n - 1$ nodes between v_i and v_j , is bounded by $(1 - \alpha)^n pr(v_j)$. $1 - \alpha$ corresponds to the rate at which the contribution value propagates itself to neighbors in the graph. Thus, decreasing α shifts the credit from the most immediate to further children’s contributions. A small α is required if one attributes more value to the most foundational work. γ_f and γ_b influences mostly the contributors reputation. Indeed, we can easily show that for small γ_f and γ_b , $\exists M > 0$ and $\forall t > M$, the score of the epoch contributor node v_{it} is given by $pr(v_{it}) = \frac{1}{1-\gamma_f\gamma_b} (C_{it} + \gamma_f C_{it-1} + \gamma_f^2 C_{it-2}) + \mathcal{O}(\gamma_f^3)$, where \mathcal{A}_t^{new} is the set of new contributions at period t and $C_{it} = \sum_{v_j \in \mathcal{A}_t^{new}} \pi_{ji} pr(v_j)$, the share of the epoch contributor score that comes from its new contributions only. We provide a short demonstration:

At epoch t , we have $pr(v_{it}) = \gamma_f pr(v_{i,t-1}) + \sum_{v_j \in \mathcal{A}_t^{new}} \pi_{ji} pr(v_j)$, where v_{it} is an epoch contributor node and \mathcal{A}_t^{new} is the set of new contribution at t . Developing the recurrence to previous epoch nodes, we have $\forall t > k, \forall k \geq 1, pr(v_i)^{t-k} = \gamma_f pr(v_{i,t-k-1}) + \gamma_b pr(v_{i,t-k+1}) + C_{it-k}$, thus $\forall t \geq 3, pr(v_{it}) = \frac{1}{1-\gamma_f\gamma_b} \left\{ \gamma_f^t pr(v_{i0}) + \gamma_b \sum_{k=0}^{t-3} \gamma_f^{k+2} pr(v_{i,t-k-1}) + \sum_{k=0}^{t-1} \gamma_f^k C_{it-k} \right\}$. The result is derived using $\gamma_f < 1$.

Thus, γ_f controls the inertia of the previous epoch scores within an evaluation period. Increasing γ_f shifts the value from the most recent to older contributions.

Before looking at the QNAR score, an example of the contribution graph at 2021-10-12 is presented in Fig. 14a.

We can observe one contributor that, at that time, participates the most in the Q2 ecosystem as the user publishes multiple CLs into various courses that are ordered multiple times by different users. By doing so, the user increases its Pagerank score, which is visualized with a larger node size in the figure. Figure 14b shows the

Fig. 14 PageRank Contribution graph ▶

contributors' sub-graph with their associated QNAR score on 2022-10-18, as the full contribution graph is too large at that date. Two contributors act as central members and have the largest QNAR score. We can also observe a community within Quantinar at the left of the graph which seems tightly influenced by the left central node on the graph.

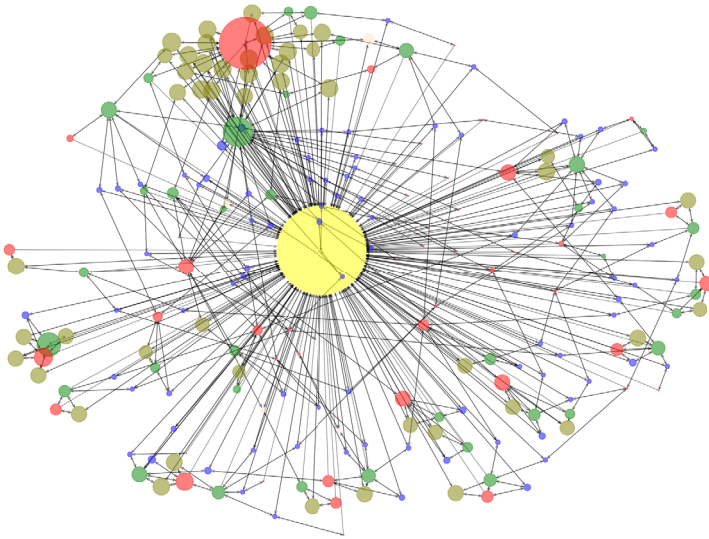
Using the temporal graph presented in the previous paragraph, we evaluate the QNAR score using a slow decay rate ($r = 0.95$). Figure 15a and b show the weekly minted QNAR and cumulative minted QNAR, respectively. In Fig. 15a, we observe that Qr alternates between a period of high productivity and a period where new contributions are less frequent. This behavior justifies the use of the temporal graph since periods do not have the same importance. Finally, Qr's value, measured in terms of QNAR, presents an up-trend since the beginning of 2022, which has strengthened in the second half of 2022, showing relative traction for Quantinar.


On top, we can observe in Fig. 16 that the score behaves as expected for the top user: the score on 2022-10-18 is mostly influenced by the contributions from previous periods. As past contributions become more popular, the share of the past epoch nodes' score within the total score will increase, which motivates community members to appreciate the long-term value of their contributions. Indeed, the weeks 2022-03-29, 2022-05-31, and 2022-08-23 are the most important for the user on 2022-10-18 and contribute roughly 10, 20, and 22% in the final score, respectively.

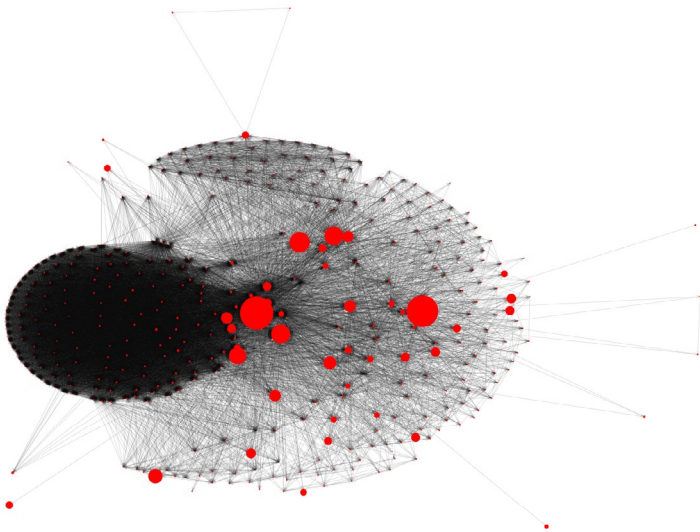
Figure 17a shows the final weekly QNAR scores per user and Fig. 17b their relative score. We observe that the score behaves as expected. The QNAR has inertia over time which guarantees that the contributions from the previous period still have values today. Nevertheless, contributors need to consistently add contributions to keep up with new active contributors, which can be observed when comparing the olive and pink curves in Fig. 17b. Indeed, as the evaluation period is more recent, the score of the early contributor in olive decreases at an inversely exponential rate from September 2021, as the user probably reduced its contribution to Quantinar. On the other hand, the user corresponding to the pink curve starts to be very active in March/April 2022 and his score increases drastically until he reached the highest score in mid-July 2022.

At the latest evaluation date, the top 4 users in terms of CL creation also belong to the top 4 users in terms of QNAR reward which demonstrates that Qr rewards researchers first. However, the user corresponding to the olive curve is the top contributor in terms of CL creations (see Fig. 4), but only the 4th in terms of QNAR reward, as its important contributions are too old to be the most valuable in recent periods thanks to the discount factor r in (3).


Finally, Fig. 17a shows that the user score is quite volatile, as it is a function of the periodic minted QNAR presented in Fig. 15a. We could propose to smooth it to have a more stable score across evaluation periods.

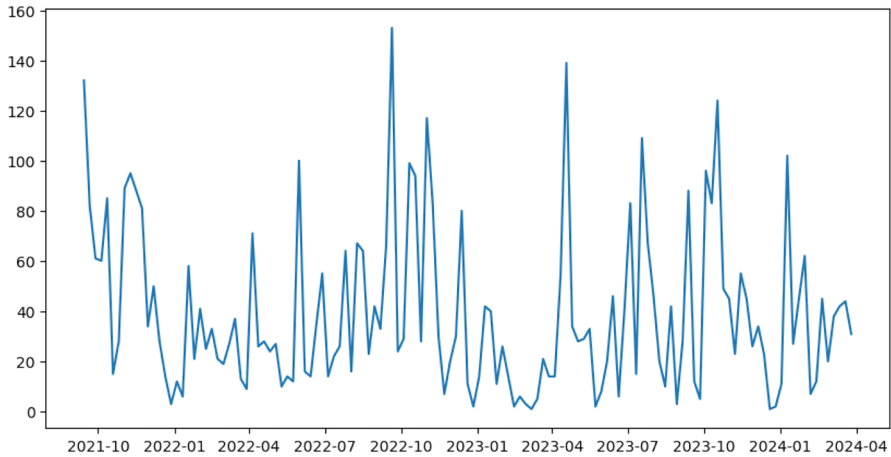


(a) PageRank Contribution graph at 2021-10-19: **seed**, **contributor**, **course**, **courselet**, **review**, **order**. The node size is proportional to the associated PageRank score  Quantinar-rep

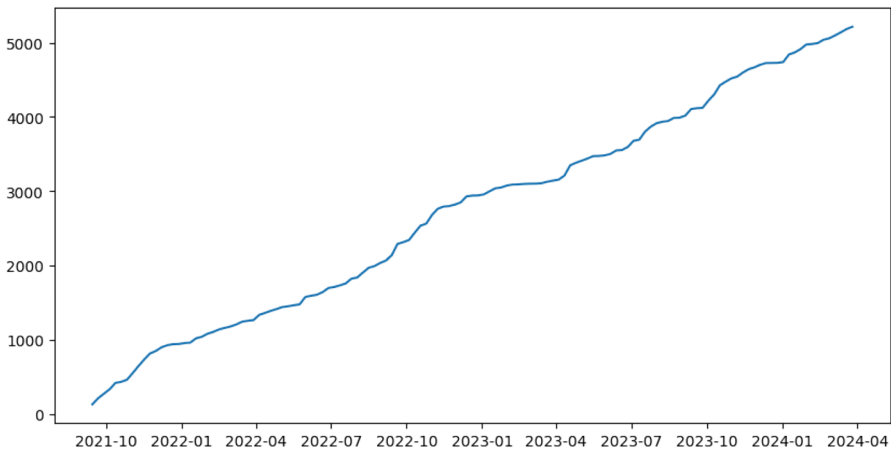


25


(b) Contributor subgraph at 2022-10-18. The node size is proportional to the associated QNAR score. An edge is created between two users if they are linked through at least one contribution  Quantinar-rep



(a) Minted QNAR per weekly period



(b) Cumulative minted QNAR

Fig. 15 QNAR supply dynamics  [Quantinar-rep](#)

4.3 QLET dynamics

We have described how the users interact within the quantinar to gain QNAR. However, it is important to discuss also how the users can use and earn QLET.

QLET will be denominated in USD or another fiat currency on external cryptocurrency exchanges, to create a research-based economy within Quantinar connected to the market. Discussing the pricing methodology of QLET is outside the scope of this article and requires an extended study. Let us propose two possibilities:

Quantinar could fix the price of QLET to 1 USD. In that case, QLET are minted to the users for their contributions to the platform. Quantinar additionally mints

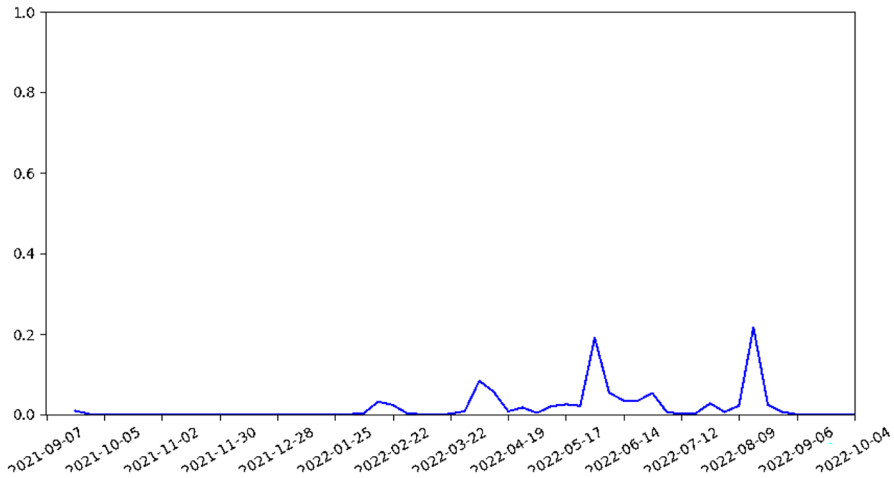

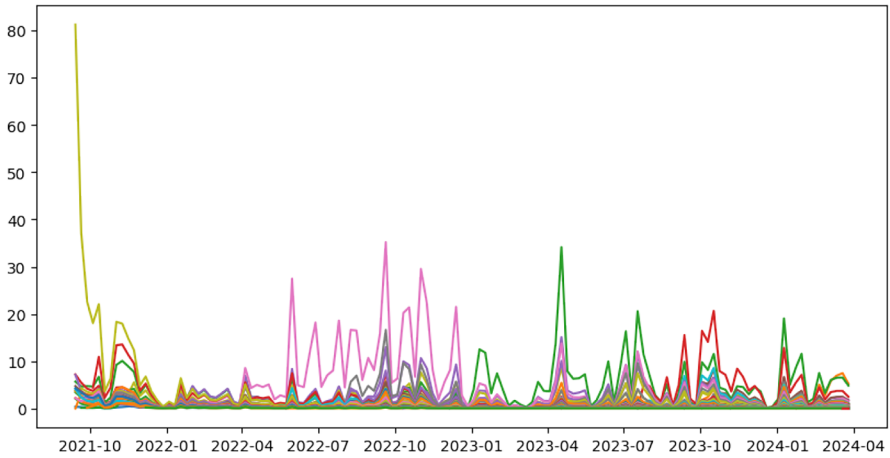


Fig. 16 Example of epoch relative importance in QNAR score (in % of the total score). The relative epoch importance is presented for the top user at the latest date  [Quantinar-rep](#)

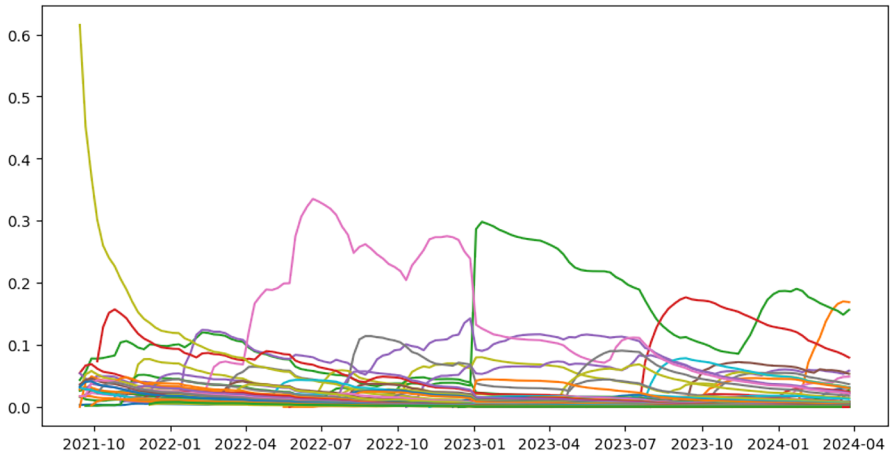
QLETs to sell them to the new users that arrive on the platform so they can buy the goods sold on Quantinar, such as CLs, Qs, DLs, and other research materials. Thus, the inflation rate of QLET will depend on the contributors and the users' demand for contributions. The contributors earning QLET will sell their tokens at 1 USD on an external exchange. The price should be stable at around 1 USD since no one will have an interest in buying QLET on an external exchange at a higher price. However, having a fixed price in USD might introduce a large inflation risk within the platform. Indeed, users can only gain more QLETs by contributing to the platform or by increasing the QLET price of their courselets. However, creating a CL is difficult as it must have a high quality to pass the peer review process. Thus, greedy authors might favor increasing their CLs' price instead of increasing their number of contributions. This effect might be accentuated for authors that benefit from significant demand for their CLs, as for central nodes in Fig. 14b.

The second possibility is to make QLET a floating currency denominated in USD. In that case, we let the market decide the exchange rate based on supply and demand. Quantinar only mints QLET against contributions, thus, the inflation rate of QLET depends only on the growth rate of contributions to the platform.


Let us assume that we have only one type of contribution that mints new QNAR in the contribution graph defined in the previous section, for example: creating a courselet. Let us assume that the courselets are fungible (which is obviously not true in reality) and have a fixed price in QLET of 1 QLET, but that the QLET has a price in USD of P_t . On top, we assume that P_t follows the dynamics of the cryptocurrency market as a whole, which can be represented by the cryptocurrency index CRIX (Trimborn and Härdle 2018). Finally, we assume that the number of contributors



(a) QNAR user score



(b) Relative QNAR user score

Fig. 17 QNAR score dynamics using a weekly period and discount rate $r = 0.95$  Quantinar-rep

is stable, that is we have no shock in the production of courselets. Contributors will adapt their interactions within the platform as the exchange rate of QLET varies:

In periods of uptrends of the exchange rate, the reward value in USD of the contributions increases which will incentivize users to contribute more, thus increasing the supply of QLET available on the market. On top, there will be more available courselets in the platform which introduces downward pressure on the courselet price, lower demand for QLET in the market, and eventually a downtrend in the exchange rate.

In periods of downtrends, the reward value in USD of the contributions decreases which will dissuade researchers from contributing to the platform. However, the cost of consumption within the platform decreases relatively to the USD which will increase the demand for QLET either by a choc in demand or by inflation of the courselet prices coming from the price adaption of the contributors.

Formally, we can express the supply curve of contributions for the period t as: $P_t = a + bQ_t$ where Q_t is the quantity of courselets produced during the period t . We know that creating a new courselet is hard and takes a lot of time, thus it is inelastic to price. We assume an elasticity of 0.1, that is a change in 10% in the price will only introduce a change of 1% in the quantity of courselets produced. Knowing the elasticity, we deduce that $b = 10$. Let us assume that at the launch of Quantinar, $P_0 = 50$ USD, which is aligned with the median price on Coursera (Shi et al. 2018), and $Q_0 = 100$, hence $a = -950$. For each period t , the quantity of courselets produced is given by $Q_t = P_t/10 + 95$, represented in Fig. 18, where $P_t = P_{t-1} \times (\text{CRIX}_t - \text{CRIX}_{t-1})/\text{CRIX}_{t-1}$.

As expected, as P_t goes up, the contributors are incentivized to create more courselets, but in periods of downtrends, they contribute relatively less to the platform. If the demand for QLET vanishes completely as users totally lose interest with platform, then the reward value in USD will tend towards 0. The contributors will probably leave the platform as the cost of creating a courselet will be too large.

4.4 An auction based open peer-review (OPR)

An open peer-review process using IPFS and decentralization has already been conceptualized by Tenorio-Fornés et al. (2019). Such a process ensures the seven traits of the open peer-review process identified by Ross-Hellauer (2017):

- **Open identities:** Authors and reviewers are aware of each other's identities.
- **Open reports:** Review reports are published alongside the CL and versioned using IPFS.
- **Open participation:** The wider community can contribute to the review process. This is ensured by an open call for review from the CL's author.
- **Open interaction:** Direct reciprocal discussion between author(s) and reviewers, and/or between reviewers, is allowed and encouraged. Since the authors' and reviewers' identities are revealed to each other, they are encouraged to chat in a specific Discord channel which is open for reading the community.
- **Open pre-review manuscripts:** CLs are made immediately available on Quantinar in advance of any formal peer review procedures.
- **Open final-version commenting:** Review or commenting on final publications is allowed directly on the CL page on Quantinar.
- **Open platforms:** Quantinar is open by design.

In Quantinar, on top of addressing the above issues, we propose a new peer-review process that motivates community members to review publications in a time-effective and fair manner.

Let there be a smart contract, a computer program intended to automatically govern and execute the rules of the following game and manage the associated cash flow. The game is defined with stake owner S_i with stakes s_i , paper proposer P , paper acceptance status S (Accepted, Denied), auction type T maturity M , payoff function f , voting function v , token QNAR, inflation rate I . The goal of the game is to find a majority-driven and fair peer review for a proposed paper and to encourage publication. While the latter can be achieved through token rewards, due process is designed for the former. A majority-driven and fair review is to be defined as one that is simultaneously qualified and aligned with the majority of the network. Since the majority of decision-makers are not necessarily objectively right, an incentive structure must be created that assigns a larger weight to those decision-makers, who have a history of being right or publish knowledge that is deemed right (this assessment can be made with the help of the reputation score, see Sect. 4.1).

The inflation rate, time to maturity, auction type, and payoff function are defined as global variables, whose status can be set by the DAO. The payoff function is in its simplest form a function that sums all bids and assigns a positive (negative) bid-weighted share to each winner (loser). Additionally, each participant receives token units according to the inflation rate after each iteration. A multitude of auction types is possible. Auctions are conducted in terms of a First-price sealed bid, implemented in a smart contract (Proebsting 2018). Other classes of auctions might be employed in the future.

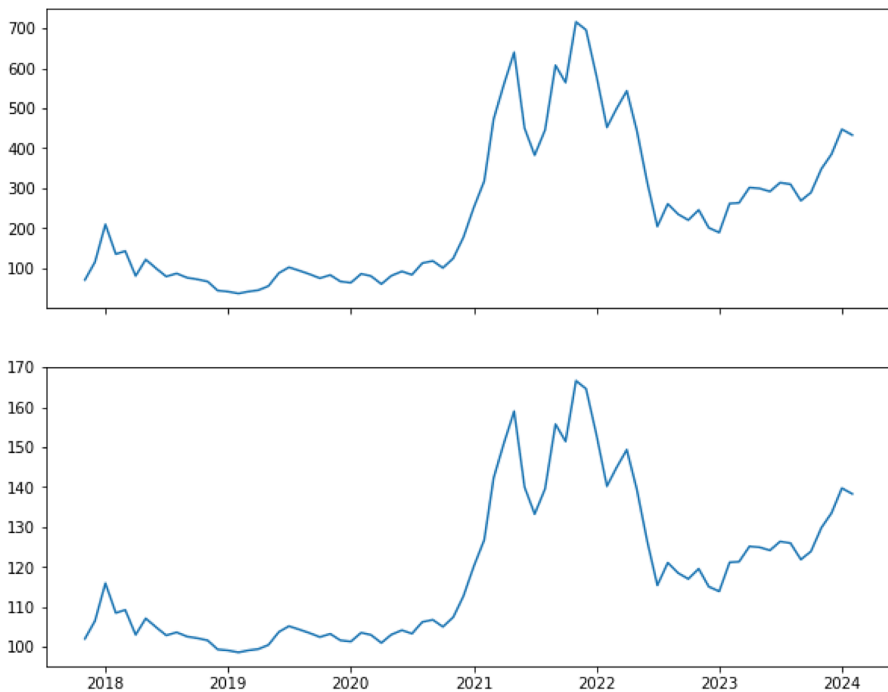


Fig. 18 QLET_USD exchange rate, P_t (top) and quantity of CLs produced at time t , Q_t (bottom)

Let there be a proposal for a new paper by proposer P. To counteract spam and incentivize reviewer participation, the proposer must submit a small initial bid. Yet the proposer is excluded from reviewing his/her paper, thus only profiting if the paper is accepted and adds value to the network. The acceptance of the proposal is treated as an auction that inherits above defined global variables. Stake Owners S_1, S_2, S_3 , of Token QNAR are allowed to participate in the auction. Let's assume that each Stake Owner enters the auction as a player. Having reviewed the paper each on their own, the players must decide on the Acceptance Status S in a blind auction. They submit a bid, which is a subset of their stake, encrypted with their public key and their voting decision (Accepted or Denied) as input to a smart contract. When the auction closes at maturity, all players must publicly disclose their bid. Since their public keys are known, verification of their bid is trivial. In case of a false claim, the player automatically loses their (locked up) bid. Due to the strict negative payoff, there cannot be any incentive to make a false claim.

$$r = \frac{\sum_{j \in \mathcal{L}} S_j}{\sum_{i \in \mathcal{W}} S_i}$$

$$P(S_i) = \frac{S_i}{\sum_{j \in \mathcal{W}} S_j} * r$$

where $P(S_i)$ is defined as the profit of Staker S_i . The index \mathcal{L} and \mathcal{W} correspond to stakes on a game's losing or winning side. The ratio of the sum of stakes on either side of the bet balances diminishes the bet's payoff if a structural imbalance exists.

As an example, use a voting function v for the acceptance status, e.g. meaning that "Accepted" is assigned 1 and "Denied" is assigned -1. Then, at the close of the auction, the voting decision is defined according to the sign of the bid-weighted average of votes. Let player S_1, S_2 vote "Accepted" with a stake of 1 and 2 QNARs, whereas player S_3 votes "Denied" with 2 QNARs. Then the sum of bids is 5 QNARs. The voting decision is $1 + 2 - 2 = 1$. The potential payoff for the winners is restricted by the ratio of stakes on each side of the game. This is an optional function that aims to dampen the effects of a strong imbalance of betting forces. It achieves this goal by decreasing the marginal payoff for each Staker to join the stronger side. The sum of bids is then distributed proportionally to the players S_1 , who receives $(1/3) \times 5$, and S_2 , who receives $(2/3) \times 5$.

The rate of minted tokens determines the general degree of incentive that potential reviewers have; which is independent of their abilities. Since only people who participate in reviews receive additional tokens, non-participants bear the cost of inflation. Hence the rate of minted tokens should be decided by the network. To prevent proposers to employ trivial strategies to profit from minting, an anti-spam strategy needs to be enforced. We suggest that each proposer is required to submit a minimum bid with each paper. The bid size should also be decided by the network.

4.4.1 Simulation

A simulation study is conducted to assess the minimum amount of participants required for a stable system, their time of survival, and expected changes in wealth (stakes) conditional on the initial distributions. The aggregate behavior of stakers is simulated. Inflation per iteration is 1 QNAR. A staker's acceptance or denial of a paper is a Bernoulli-distributed random variable with a predefined acceptance probability, assumed to be 0.5, 0.1, or 0.05. For each type of initial stake distribution, Pareto and uniform, stakers' performances are evaluated for a set of 5, 10, 50, 100, and 1,000 participants after the rounds 10, 100, 1,000, 10,000, and 100,000. One round is counted as the proposal of a paper, meaning the submission and subsequent acceptance or denial of a paper. We compute the Sharpe ratio of the final wealth of the stakers ($SR = \mu/\sigma$) where μ is the average wealth of the stakers and σ is its standard deviation. We find the system to be stable for as few as 5 players for all acceptance probabilities. On top, when it is assumed to be 0.5, we did not observe an impact of the initial distribution of the stakers' wealth on the distribution of the Sharpe ratio. However, this is not the case when the acceptance probability is assumed to be 0.1 or 0.05. We report the results only for an acceptance probability of 0.05. For 0.1, the results are similar, but we observe a slightly larger variance in the Sharpe ratio's distribution.

Figure 19 shows that under a uniform initial distribution, Sharpe ratios are generally high and positive when there are few stakers and the acceptance probability is small, equal to 0.05. Sharpe Ratios decrease with growing competition, yet stay positive even for a large number of stakers.

Under an initial Pareto distribution, the Sharpe ratios for a few players and a few rounds are also high and positive, as it is shown in Fig. 20. Yet, with a growing amount of rounds and players the Sharpe ratios rise to a level of 3. This constitutes a high incentive for additional players to join the network with growing size. These observations indicate that reviewers are incentivized to offer their expertise. This incentive holds under real-world, unfair distributions such as of the Pareto type.

5 Conclusion

We propose a P2P platform, Quantinar, designed to accompany all players in the education and research system in their knowledge accumulation. Quantinar incentivizes academic publications based on an open and decentralized infrastructure that favors research findings' transparency and reproducibility. Quantinar is intended for students, practitioners, and researchers alike. We cater to the need for sound statistical and quantitative education in the modern world but do not restrict the educational themes on the platform. We aim to encourage a new scientific publication standard consisting of a triptych of CL, DL, and QL (knowledge, data, and code), allowing for vertical learning and ensuring the research findings' reproducibility. Quantinar members interact with other user-generated content within the

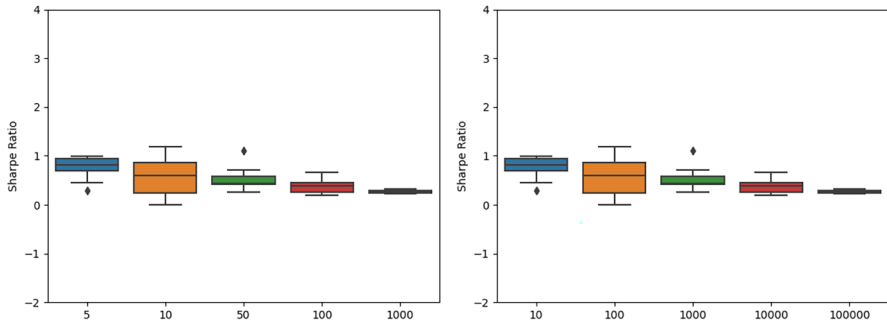


Fig. 19 Initial wealth follows an uniform distribution: Sharpe Ratio conditional on the amount of stakers (left) and on the amount of rounds (right) [Quantinar-Staking-Simulation](#)

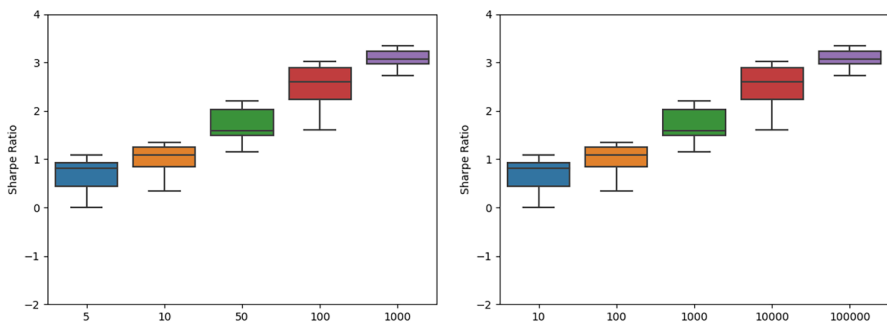


Fig. 20 Initial wealth follows a Pareto distribution: Sharpe Ratio conditional on the amount of stakers (left) and on the amount of rounds (right) [Quantinar-Staking-Simulation](#)

C5 framework to create a consumer-prosumer spiral and encourage communication between researchers. Consumers and prosumers are motivated to participate via a token-based reward, which reflects their interactions within and contributions to the platform thanks to SourceCred's CredRank, a flexible data-driven reputation system inspired by the personalized PageRank algorithm. This reputation system ensures that the community decides which contributions to reward and that users maximizing the long-term value of their contributions obtains more rewards than shortsighted publications. Finally, we propose a new open peer-review process to assess the quality of submitted content. Independent reviewers are allowed to review and vote on paper proposals. The voters' stake partly supports the voting process, which facilitates honest reviews, counteracts spam, and incentivizes reviewers. This process reduces the presence of malpractices, such as a positive publication bias, to which traditional journals might be converging without radical changes.

Acknowledgements The European Cooperation in Science & Technology COST Action [CA19130]; Grant CAS: XDA 23020303 and DFG IRTG 1792 gratefully acknowledged. This paper is supported through the European Cooperation in Science & Technology COST Action grant CA19130 - Fintech and Artificial Intelligence in Finance - Towards a transparent financial industry; the project "IDA Institute of Digital Assets", CF166/15.11.2022, contract number CN760046/23.05.2024 financed under the Romania's National Recovery and Resilience Plan, Apel nr. PNRR-III-C9-2022-I8; and the Marie

Skłodowska-Curie Actions under the European Union's Horizon Europe research and innovation program for the Industrial Doctoral Network on Digital Finance, acronym DIGITAL, Project No. 101119635.

Funding Open Access funding enabled and organized by Projekt DEAL.

Open Access This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit <http://creativecommons.org/licenses/by/4.0/>.

References

- Albright J (2017) Welcome to the era of fake news. *Media Commun* 5(2):87–89. <https://doi.org/10.17645/mac.v5i2.977>
- Altmetric (2022) Altmetric. <https://www.altmetric.com>, accessed: 2022-06-17
- Bartneck C, Kokkelmans S (2011) Detecting h-index manipulation through self-citation analysis. *Scientometrics* 87(1):85–98. <https://doi.org/10.1007/s11192-010-0306-5>
- Benet J (2014) IPFS - content addressed, versioned, P2P file system. CoRR abs/1407.3561. , [arXiv:1407.3561](https://arxiv.org/abs/1407.3561)
- Borgs C, Brautbar M, Chayes J et al (2014) Multiscale matrix sampling and sublinear-time pagerank computation. *Internet Math* 10(1–2):20–48. <https://doi.org/10.1080/15427951.2013.802752>
- Borke L (2017) Dynamic clustering and visualization of smart data via d3-3d-lsa. PhD thesis, Humboldt-Universität zu Berlin, Wirtschaftswissenschaftliche Fakultät, <https://doi.org/10.18452/18307>
- Bruns SB, Ioannidis JPA (2016) p-curve and p-hacking in observational research. *PLOS ONE* 11(2):1–13. <https://doi.org/10.1371/journal.pone.0149144>
- Buterin V (2013) Ethereum white paper: A next generation smart contract & decentralized application platform. <https://github.com/ethereum/wiki/wiki/White-Paper>
- Buterin V (2014) Daos, dacs, das and more: An incomplete terminology guide. <https://blog.ethereum.org/2014/05/06/daos-dacs-das-and-more-an-incomplete-terminology-guide/>
- Chung F (2014) A brief survey of pagerank algorithms. *IEEE Trans Netw Sci Eng* 1(1):38–42. <https://doi.org/10.1109/TNSE.2014.2380315>
- credrank (2022) Credrank. <https://discourse.sourcecred.io/t/credrank-scalable-interpretable-flexible-attrition/654>, Accessed 2022-06-17
- Ellison G (2011) Is peer review in decline? *Econ Inq* 49(3):635–657. <https://doi.org/10.1111/j.1465-7295.2010.00261.x>
- Fett D, Küsters R, Schmitz G (2014) An expressive model for the web infrastructure: Definition and application to the browser id sso system. In: 2014 IEEE Symposium on Security and Privacy, pp 673–688, <https://doi.org/10.1109/SP.2014.49>
- Gleich DF (2015) Pagerank beyond the web. *SIAM Rev* 57(3):321–363. <https://doi.org/10.1137/140976649>
- Harvey C (2017) Presidential address: the scientific outlook in financial economics. *J Fin* 72(4):1399–1440. <https://doi.org/10.1111/jofi.12530>
- Heckman JJ, Moktan S (2020) Publishing and promotion in economics: the tyranny of the top five. *J Econ Lit* 58(2):419–70. <https://doi.org/10.1257/jel.20191574>
- Hirsch JE (2005) An index to quantify an individual's scientific research output. *Proc Nat Acad Sci* 102(46):16569–16572. <https://doi.org/10.1073/pnas.0507655102>
- Ioannidis JPA (2005) Why most published research findings are false. *Medicine*. <https://doi.org/10.1371/journal.pmed.0020124>

- Kamvar SD, Schlosser MT, Garcia-Molina H (2003) The eigentrust algorithm for reputation management in p2p networks. In: Proceedings of the 12th International Conference on World Wide Web. Association for Computing Machinery, New York, NY, USA, WWW '03, p 640-651, <https://doi.org/10.1145/775152.775242>
- Karanatsiou D, Misirlis N, Vlachopoulou M (2017) Bibliometrics and altmetrics literature review: performance indicators and comparison analysis. *Perform Meas Metrics*. <https://doi.org/10.1108/PMM-08-2016-0036>
- Kerr NL (1998) Harking: hypothesizing after the results are known. *Personalit Social Psychol Rev* 2(3):196–217. https://doi.org/10.1207/s15327957pspr0203_4
- Kumar S, Bharti AK, Amin R (2021) Decentralized secure storage of medical records using blockchain and ipfs: a comparative analysis with future directions. *Secur Priv* 4(5):e162. <https://doi.org/10.1002/spy2.162>
- Labs P (2019) Filecoin: A decentralized storage network. <https://ethereum.org/en/whitepaper/>
- Langville AN, Meyer CD (2011) Google's PageRank and Beyond: The Science of Search Engine Rankings. Princeton University Press, Princeton,. <https://doi.org/10.1515/9781400830329>
- Lee CE, Ozdaglar A, Shah D (2013) Computing the stationary distribution locally. In: Burges C, Bottou L, Welling M, et al (eds) *Adv Neural Inf Process Syst*, vol 26. Curran Associates, Inc., <https://proceedings.neurips.cc/paper/2013/file/99bcfcd754a98ce89cb86f73acc04645-Paper.pdf>
- Marjit U, Kumar P (2020) Towards a decentralized and distributed framework for open educational resources based on ipfs and blockchain. In: 2020 International Conference on Computer Science, Engineering and Applications (ICCSEA), pp 1–6, <https://doi.org/10.1109/ICCSEA49143.2020.9132841>
- Meng N, Zhang S (2021) University education resource sharing based on blockchain and ipfs. In: Atiqzaman M, Yen N, Xu Z (eds) *Big Data Analytics for Cyber-Physical System in Smart City*. Springer Singapore, Singapore, pp 1808–1813
- MouseBelt (2019) Mousekyc. <https://github.com/mousebelt/mousekyc>
- Page L, Brin S, Motwani R, et al (1999) The pagerank citation ranking: Bringing order to the web. Technical Report 1999-66, Stanford InfoLab, <http://ilpubs.stanford.edu:8090/422/>, previous number = SIDL-WP-1999-0120
- Proebsting T (2018) Writing a sealed-bid auction contract. <https://programtheblockchain.com/posts/2018/03/27/writing-a-sealed-bid-auction-contract/>, accessed: 2022-09-22
- RedHat (2014) Keycloak. <https://www.keycloak.org/>
- Ross-Hellauer T (2017) What is open peer review? a systematic review. *F1000Research*. <https://doi.org/10.12688/f1000research.11369.2>
- Rowland F (2002) The peer-review process. *Learn Publish* 15(4):247–258. <https://doi.org/10.1087/095315102760319206>
- Shi Y, Li X, Haller A, et al (2018) Knowledge pricing structures on mooc platform - a use case analysis on edx. In: Pacific Asia Conference on Information Systems, <https://api.semanticscholar.org/CorpusID:53233047>
- Spier R (2002) The history of the peer-review process. *Trends Biotechnol* 20(8):357–8. [https://doi.org/10.1016/s0167-7799\(02\)01985-6](https://doi.org/10.1016/s0167-7799(02)01985-6)
- Spilak B, Härdle WK (2021) Tail-risk protection: Machine learning meets modern econometrics. In: Lee CF, Lee AC (eds) *Encyclopedia of Finance*. Springer International Publishing, Cham, p 1–37, https://doi.org/10.1007/978-3-030-73443-5_94-1
- Spilak B, Härdle WK (2022) Does non-linear factorization of financial returns help build better and stabler portfolios? arXiv preprint [arXiv:2204.02757](https://arxiv.org/abs/2204.02757)
- Steichen M, Fiz B, Norvill R, et al (2018) Blockchain-based, decentralized access control for ipfs. In: 2018 IEEE International Conference on Internet of Things (iThings) and IEEE Green Computing and Communications (GreenCom) and IEEE Cyber, Physical and Social Computing (CPSCom) and IEEE Smart Data (SmartData), pp 1499–1506, https://doi.org/10.1109/Cybermatics_2018.2018.00253
- Tenorio-Fornés A, Jacynycz V, Llop-Vila D, et al (2019) Towards a decentralized process for scientific publication and peer review using blockchain and IPFS. In: Proceedings of the 52nd Hawaii International Conference on System Sciences
- Trimborn S, Härdle WK (2018) Crix an index for cryptocurrencies. *Journal of Empirical Finance* 49:107–122. <https://doi.org/10.1016/j.jempfin.2018.08.004>, <https://www.sciencedirect.com/science/article/pii/S0927539818300616>

-
- Vicente-Saez R, Martinez-Fuentes C (2018) Open science now: a systematic literature review for an integrated definition. *J Bus Res* 88:428–436
- Ware M (2011) Peer review: recent experience and future directions. *New Rev Inf Netw* 16(1):23–53. <https://doi.org/10.1080/13614576.2011.566812>
- Xiong L, Liu L (2004) Peertrust: supporting reputation-based trust for peer-to-peer electronic communities. *IEEE Trans Knowl Data Eng* 16:843–857. <https://doi.org/10.1109/TKDE.2004.1318566>
- Zharova A, Härdle WK, Lessmann S (2023) Data-driven support for policy and decision-making in university research management: a case study from Germany. *Eur J Oper Res* 308(1):353–368. <https://doi.org/10.1016/j.ejor.2022.10.016>
- Ziman JM (1968) *Public Knowledge: An Essay Concerning the Social Dimension of Science*. Cambridge University Press, London
- Zinovyeva E, Reule RCG, Härdle WK (2023) Understanding smart contracts: Hype or hope? In: *Fin-Tech Research and Applications*. World Scientific (Europe), chap 1, p 3–91, https://doi.org/10.1142/9781800612723_0001

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.