Nuevos modelos de plataformas descentralizadas basados en tecnología blockchain

Oscar Lage Serrano

eman ta zabal zazu

Universidad del País Vasco
Euskal Herriko Unibertsitatea

Universidad del País Vasco Euskal Herriko Unibertsitatea

Facultad de Economía y Empresa

Directores:

Dra. Dña. María Saiz Santos

Dr. D. José Manuel Zarzuelo Zarzosa

Departamentos:

Economía Financiera II

Métodos Cuantitativos

Índice

Sección I: Síntesis 1

1. Introducción 3
2. Marco Teórico 9

2.1. Contexto Histórico: privacidad, hacktivismo y cypherpunks 10

2.2. La innovación disruptiva 16

2.3. Modelos de negocio de plataforma 18

2.4. La tecnología blockchain 20

Fundamentos de la tecnología blockchain 20

Smart Contracts 28

Principales ámbitos de aplicación de blockchain 31

3. Propósito de la Tesis 34
4. Metodología 38
5. Resultados y Discusión 45
6. Referencias Bibliográficas 59

Sección II: Conclusiones 65

7. Conclusiones 67
8. Futuras líneas de investigación 71

Sección III: Anexos 74

Trabajos Publicados o Aceptados 75

Artículo 1: Decentralized Industry 5.0: blockchain's contribution to industrial sustainability, resilience, and human-centricity 77

Artículo 2: Blockchain and the decentralization of the cybersecurity industry 100

Artículo 3: The Value and Applications of Blockchain Technology in Business: A Systematic Review of Real Use Cases 108

Artículo 4: Real business applications and investments in blockchain technology 125

Artículo 5: Decentralized platform economy: emerging blockchain-based decentralized platform business models 155

Otros artículos y capítulos de libro vinculados con la tesis 197

Índice de Figuras

Figura 1.1. Publicaciones sobre blockchain indexadas por año. Fuente: Scopus 3
Figura 5.1. Blockchain y la industria 5.0 48
Figura 5.2. Dendograma presentando los 6 clúster identificados. 52
Figura 5.3. Distribución de la inversión en blockchain por valor de negocio. Fuente: elaboración propia 53
Figura 5.4. Dendograma mostrando los tres clústeres identificados: hosted, federated y shared 56

Índice de Tablas

Tabla 3.1. Objetivos específicos y publicaciones asociadas 37
Tabla 4.1. Resumen de aproximación metodológica 38
Tabla 5.1. Resumen de resultados obtenidos 46
Tabla 5.2. Inversión por tamaño de empresa (porcentajes). Fuente: elaboración propia 49
Tabla 5.3. Inversión por sector (porcentajes). Fuente: elaboración propia 50
Tabla 9.1. Resumen de publicaciones y situación actual 76

Sección I: Síntesis

1. Introducción

En los últimos años ha aumentado significativamente el interés en la tecnología blockchain. La Comisión Europea ha promovido iniciativas como el EU Blockchain Observatory & Forum para comprender e impulsar la adopción de la tecnología en Europa. Muchos gobiernos han incluido la tecnología blockchain en sus agendas estratégicas, mientras que las empresas han creado asociaciones en torno a ella, como Alastria en España o INATBA a nivel europeo. Además, el mundo académico también ha mostrado un interés creciente en el tema, como se puede observar en la Figura 1.1, que muestra el número de publicaciones sobre tecnología blockchain indexadas en Scopus en los últimos años.

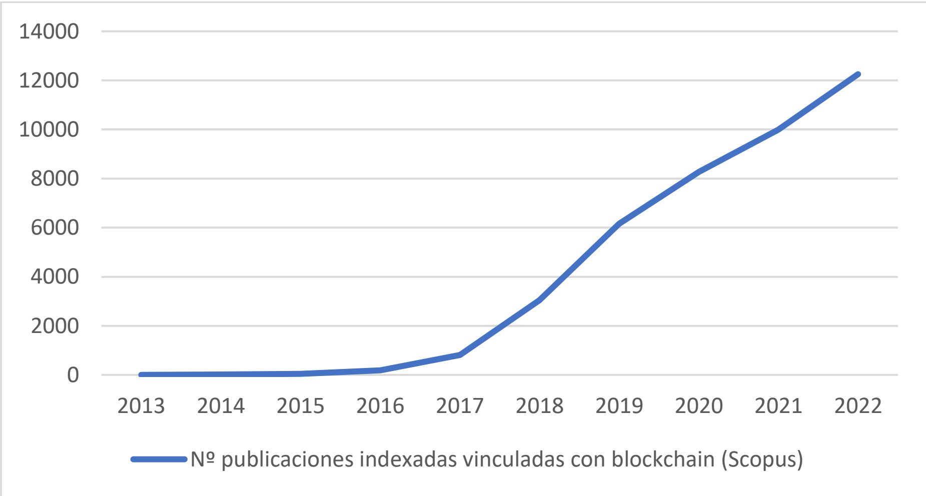

Figura 1.1. Publicaciones sobre blockchain indexadas por año. Fuente: Scopus

En una búsqueda del término "blockchain" realizada en Scopus el 24 de abril de 2023, se observó que había más de 37.000 documentos indexados en las áreas de "*Computer Science*" y "*Engineering*", mientras que en el área de "*Business, Management and Accounting*" había tan solo 5.326 documentos. De estos, casi la mitad (2.624) se publicaron desde 2021 hasta la fecha de la búsqueda. Estos resultados muestran que la academia está muy activa en el ámbito tecnológico, mientras que la investigación vinculada al ámbito empresarial es creciente pero muy inferior.

Esta mayor actividad en el ámbito tecnológico muy probablemente se deba a que la tecnología blockchain brinda grandes oportunidades en el ámbito tecnológico ofreciendo la posibilidad de descentralizar muchos de los procesos actuales. Dicha intermediación de procesos es precisamente la principal característica del modelo de negocio de plataforma, que surge como resultado de la influencia de Internet en la economía, y que en los últimos años ha experimentado una gran adopción (Rahman y Thelen, 2019). De hecho, durante las últimas dos décadas las empresas tecnológicas han implantado modelos de negocio de plataforma, que han adquirido popularidad y valor creciente, y liderado el ranking de las diez empresas con mayor capitalización bursátil (Hunter *et al.*, 2020).

Es natural preguntarnos sobre cómo la tecnología blockchain puede transformar o hacer evolucionar estos populares modelos de intermediación entre partes, ya que ofrece una alternativa de intermediación segura mucho más eficiente y económica que los modelos de plataforma tradicionales. Así pues, nos preguntamos si la adopción de blockchain podría transformar los modelos de negocio de plataforma, de manera similar a cómo Internet generó un nuevo modelo de negocio inicialmente bautizado como "*two-sided markets*" (Parker y Alstyne, 2005), precursor de los modelos actuales.

De Reuver *et al*. (2018) han elaborado una agenda de investigación que recoge los principales retos y líneas de investigación para evolucionar estas plataformas, anticipando que la naturaleza distribuida de blockchain podría traer nuevos desafíos. Los autores destacan que las estructuras de poder y las relaciones entre los participantes serán diferentes en los nuevos ecosistemas descentralizados basados en blockchain, y que es urgente incentivar la investigación sobre tecnologías descentralizadas para la innovación en las plataformas digitales.

Alt (2020) afirma que la tecnología blockchain será la infraestructura para los futuros mercados electrónicos, ya que actúa como intermediario seguro sin necesidad de terceros. Además, cuestiona si los proveedores de plataformas son necesarios y sugiere la transformación hacia mercados electrónicos completamente descentralizados. Wigang (2020) agrega que esta descentralización reduce los costos de mediación entre compradores y vendedores, lo que supone un gran beneficio para los usuarios de las plataformas.

Existe la posibilidad de que la economía de plataformas pueda transformarse en los próximos años con la llegada de blockchain y su capacidad para descentralizar los modelos de negocio. Es por ello que blockchain puede ser la tecnología disruptiva que evolucione el ecosistema empresarial de la misma manera que lo hizo Internet hace unas décadas (Crosby *et al*., 2016), generando en este caso un nuevo modelo de plataforma descentralizada.

La literatura actual presenta una evidente carencia de estudios basados en inversiones reales para la adopción de la tecnología blockchain. Además, es aún más relevante la falta de estudios que aborden la evolución de los modelos de negocio de plataformas por la influencia de la tecnología blockchain.

Como consecuencia el propósito principal de la tesis es *evaluar la influencia de blockchain en los principales sectores económicos y los modelos de negocio de plataforma*.

Con el objetivo de evaluar la influencia de blockchain en el entorno empresarial, se ha realizado un análisis bibliográfico y una síntesis de los resultados para identificar los ámbitos de oportunidad de esta tecnología. Además, se ha generado una base de datos de casos de uso reales de blockchain para cuantificar la inversión en esta tecnología. Utilizando la base de datos generada se han identificado los valores de negocio más demandados por el tejido empresarial y realizado un análisis cuantitativo de la inversión en blockchain por parte de las empresas.

Con el fin de evaluar la influencia de blockchain en los modelos de negocio de plataforma, se ha identificado un conjunto representativo de plataformas que utilizan esta tecnología. A partir de esta información, se ha generado una base de datos de plataformas descentralizadas. Siguiendo el método iterativo de diseño (Nickerson *et al*., 2013) se ha propuesto una taxonomía de plataformas descentralizadas, y mediante un análisis clúster se han identificado los arquetipos de plataformas descentralizadas y sus principales características.

Cabe matizar que en la literatura existe una gran controversia sobre el concepto de modelo de negocio ya que es un concepto en constante evolución (Shafer *et al*., 2005). En nuestro caso vamos a utilizar como base la definición de Osterwalder *et al.* (2005): "*Un modelo de negocio es una herramienta conceptual que contiene un conjunto de elementos y sus relaciones y permite expresar la lógica de negocio de una empresa específica.*"

Tras la investigación llevada a cabo, se ha constatado que la tecnología blockchain está siendo adoptada a nivel global en todos los sectores, lo que generará un gran impacto en la industria. Asimismo, se han analizado detalladamente los beneficios de esta tecnología en diferentes áreas, destacando sus amplias posibilidades tanto a nivel tecnológico como de negocio en diversos sectores industriales.

Otro resultado importante de la investigación es ofrecer información real sobre la inversión en tecnología blockchain ya que actualmente existe un vacío en la literatura al respecto. Se ha generado una base de datos detallada sobre la inversión en tecnología blockchain en distintas empresas y sectores, a partir de la cual se ha podido identificar que las empresas principalmente invierten en doce valores de negocio impulsados por esta tecnología. A pesar de que la descentralización de procesos y modelos de negocio, junto con el despliegue de smart contracts, son los valores más prometedores que ofrece la tecnología blockchain, solo representan el 6 % de la inversión de las empresas. El estudio nos revela que las empresas invierten principalmente en tecnología blockchain para satisfacer necesidades como la confiabilidad e integridad de la información, la identidad digital y la gestión de activos compartidos. Las empresas medianas y las TIC son las que más invierten en blockchain, representando respectivamente el 47,68% y el 39,25% de la inversión en función del tamaño de empresa.

Por último, los resultados más relevantes de la investigación son la taxonomía de las emergentes plataformas descentralizadas, la cual incluye la identificación de veintitrés propiedades de este novedoso modelo de plataforma, así como la clasificación de las plataformas descentralizadas en tres arquetipos (hosted, federated y shared), junto con sus principales características.

La investigación realizada sienta las bases para futuras líneas de investigación, así pues, se han identificado nueve áreas de trabajo relacionadas con la adopción de la tecnología blockchain en la industria 5.0 que deben ser estudiadas en detalle en el futuro, especialmente las vinculadas al enfoque centrado en las personas. La taxonomía de doce valores identificada puede servir de base para encontrar nuevas aplicaciones de la tecnología blockchain. Los tres arquetipos de plataformas identificados pueden ser objeto de estudios especializados para profundizar en su análisis, y se abre una línea de investigación sobre las plataformas descentralizadas de tipo compartido (*shared*) y sus modelos de negocio emergentes, que pueden impactar en los modelos de plataforma actuales al ofrecer servicios equivalentes, pero de forma abierta y sin intermediarios.

Los resultados de la tesis son una valiosa contribución a la literatura, ya que proporcionan información real sobre la inversión en blockchain en los principales sectores económicos. Asimismo, se identifican, describen y caracterizan los modelos emergentes de plataformas descentralizadas, confirmando las hipótesis de que de que la economía de plataformas puede experimentar una transformación en los próximos años gracias a la llegada de blockchain y su capacidad para descentralizar los modelos de negocio. Esto generará un gran impacto en los modelos de plataformas actuales.

Asimismo, esta tesis busca arrojar luz y establecer pautas para aquellos emprendedores que buscan un modelo de negocio futuro en el que las personas y las empresas puedan interactuar a través de redes blockchain que actúen como terceros de confianza. La investigación proporciona información valiosa y detallada sobre la inversión en blockchain en los principales sectores económicos y describe los modelos emergentes de plataformas descentralizadas. Estos resultados también pueden ayudar a los emprendedores a comprender mejor el potencial de la tecnología blockchain y a diseñar modelos de negocio innovadores y sostenibles en el futuro.

Por último, es importante destacar la relevancia de este nuevo conocimiento para los *policy makers*. En este sentido, la Organización para la Cooperación y el Desarrollo Económicos (OCDE) plantea interrogantes sobre cómo estas nuevas plataformas descentralizadas y sus activos digitales, también conocidos como tokens (de los cuales hablaremos en la siguiente sección), podrían transformar la sociedad, la economía e incluso la forma en que se recaudan los impuestos. Es fundamental que los *policy makers* estén al tanto de las posibilidades y desafíos que ofrece la tecnología blockchain, para poder desarrollar políticas públicas efectivas y promover el crecimiento económico sostenible en la era de la industria 5.0.

2. Marco Teórico

Crosby *et al*. (2016) señalaron que la llegada de Internet a las empresas fue una revolución sin precedentes que permitió la disrupción de los modelos de negocio tradicionales basados en una cadena de producción lineal, evolucionándolos hacia los actuales modelos de plataforma (Van Dyck *et al*., 2020). En sus orígenes, Parker y Alstyne (2005) definieron estas plataformas como modelos simples de intermediación entre la oferta y la demanda, pero con el tiempo se han vuelto cada vez más complejas.

La llegada de blockchain y su potencial influencia en los modelos de negocio de plataforma ha despertado el interés de la academia en los últimos años. Subramanian (2017) identificó el riesgo que la descentralización podría representar para estos modelos y ofreció alternativas más seguras y económicas. De Reuver *et al.* (2018) señalaron que la naturaleza distribuida de la tecnología blockchain presentaría nuevos retos en los modelos de plataforma y alentaron a la comunidad científica a investigar estas tecnologías emergentes. Más recientemente, Alt (2020) destaca la inminente adopción de la tecnología blockchain en la creación de futuras plataformas descentralizadas y se pregunta acerca de los modelos de negocio que prevalecerán en estos mercados.

Morkunas *et al*. (2019) analizan cómo blockchain podría afectar a los nueve elementos esenciales del Business Model Canvas (Osterwalder y Pigneur, 2010). Schulze *et al*. (2020) proponen una taxonomía de diez elementos para plataformas blockchain en general, mientras que Zutshi *et al*. (2021) identifican el desarrollo de modelos de gobernanza descentralizados como uno de los principales atractivos de estas plataformas. Schlecht *et al*. (2021) prevén un gran incremento de valor en los modelos de negocio gracias a la incorporación de blockchain, y Marikyan *et al*. (2021) analizan los riesgos y beneficios de las diferentes alternativas técnicas de las redes blockchain y su contribución a la innovación en los modelos de negocio.

Sin embargo, la literatura no cuenta con suficientes estudios que caractericen las plataformas descentralizadas y sus principales atributos. Estas plataformas representan una innovación disruptiva impulsada por la adopción de la tecnología blockchain en los modelos de negocio de plataforma, que ha sido motivada en gran medida por el movimiento global hacia la descentralización y la privacidad digital.

A continuación, analizamos el marco teórico que contextualiza la tesis doctoral. Para ello, se presentarán cuatro aspectos principales que ayudarán a comprender el contexto de esta evolución hacia las futuras plataformas descentralizadas. En primer lugar, se abordará el contexto histórico y político de la privacidad digital, lo que facilitará la comprensión del marco sociopolítico que está impulsando la innovación en los modelos de relación actuales. Luego, se analizarán los conceptos clave y características principales de la innovación disruptiva, particularmente en el caso de que blockchain permita la descentralización de los modelos de negocio de plataforma. Posteriormente, se profundizará en los modelos de negocio de plataforma, que son el objeto de estudio de esta innovación disruptiva. Finalmente, se presentará la tecnología blockchain como habilitadora de esta innovación disruptiva, la cual surge en el contexto histórico y político en torno a la privacidad digital.

2.1. Contexto Histórico: privacidad, hacktivismo y cypherpunks

"*Nineteen Eighty-Four*", escrita por George Orwell en 1949, es una novela política de ficción distópica que se ha convertido en una de las más populares del siglo XX. Ambientada en el Londres de 1984 y siguientes, describe una sociedad que practica la manipulación de la información y la vigilancia masiva de forma indiscriminada; así como otras prácticas de represión política y social.

Orwell introduce conceptos tan extendidos hoy en día como son el omnipresente y vigilante Gran Hermano o Hermano Mayor (de esta novela provienen los habituales eslóganes de "*Big Brother is watching you*"), la habitación 101, o la policía del Pensamiento.

La sociedad que presenta Orwell en su novela quizás sea demasiado ácida y exagerada en comparación con la sociedad actual. No obstante, hay quien cree que nuestra sociedad se parece demasiado a la sociedad descrita por Orwell, a quien consideran un visionario[1].

La vigilancia masiva

Mientras que en los cuarenta Orwell utilizaba su novela como medio para denunciar estas "posibles" prácticas, sería en los ochenta cuando se producen las primeras reacciones en contra por parte de la comunidad científica. En esos años, David Chaum[2] publica artículos como "*Blind signatures for untracable payments*" (Chaum, 1983) o "*Security without identification: Transaction systems to make big brother obsolete*" (Chaum, 1985), que precisamente ya hacían mención expresa al "Gran Hermano".

Durante esa década se publicó el libro "*The puzzle Palace*" (Bamford, 1982), donde se ofrece información sobre el funcionamiento de la *National Security Agency* (NSA) estadounidense y evidencias de proyectos de vigilancia masiva como la iniciativa Shamrock, que capturaba todos los telegramas que entraban o salían de EEUU. Realmente, Shamrock era el nombre en clave de Echelon hasta 1975, un proyecto mucho más ambicioso de lo que se publicaba en el libro de Bamford. En 1988 hubo varias filtraciones sobre el proyecto Echelon. La primera de ellas por M. Newsham, quien destapaba el uso del proyecto para la vigilancia de miembros del congreso de EE.UU; lo que fue publicado por el New Statesman bajo el titular "*Somebody's Listening*" (Campbell, 1988). El artículo describe Echelon como un programa informático que controla la recolección y distribución de tráfico de telecomunicaciones civil.

[1] Orwell no ha sido el único escritor que advertía de este tipo de prácticas a través de sus novelas. En 1920 Zamiatin publicó "Nosotros", una novela que a pesar de ser mucho menos mediática es considerada como la obra inspiracional de Orwell.

[2] Chaum desarrolló el primer protocolo de dinero digital criptográfico (DigiCash) y varios de los protocolos base de bitcoin

El programa Echelon, elaborado por Estados Unidos en colaboración con sus aliados (Reino Unido, Canadá, Australia y Nueva Zelanda) se creó realmente a finales de los sesenta con el objetivo de ejecutar tareas de espionaje durante la guerra fría. No obstante, el sistema comenzó a utilizarse a finales de los ochenta para la vigilancia masiva de organizaciones e individuos. Echelon hacía uso de un conjunto de satélites y estaciones base en tierra para recolectar, almacenar, y procesar todas las telecomunicaciones del mundo. Según el artículo "*Q&A: What you need to know about Echelon*" de la BBC (2001) a finales de los noventa Echelon era capaz de capturar hasta el 90% del tráfico de telecomunicaciones del mundo (llamadas telefónicas, faxes, mails, etc.).

La censura de la criptografía

Chaum y el resto de los precursores del movimiento Cypherpunk eran además conocedores de la presión ejercida por muchos gobiernos sobre la difusión de conocimientos criptográficos en medios públicos. La administración norteamericana llegó a considerar los algoritmos criptográficos como armamento (Pierce, 1984). Los autores de estos nuevos criptosistemas eran amenazados, en caso de la difusión de éstos, con ser procesados bajo la Ley de Control de Exportaciones de Armas. A pesar de todo, Chaum decidió apostar por la privacidad de las comunicaciones y comenzó su carrera de investigación en Berkeley precisamente en el ámbito de la criptografía y ciberseguridad.

La publicación del artículo "*New directions in cryptography*" (Diffie y Hellman, 1976) fue quizás el primer gran pulso por parte de la comunidad de criptógrafos al gobierno norteamericano, quien llegó a presionar al *Institute of Electrical and Electronics Engineers* (IEEE) para que no se publicara el artículo. De hecho, estos autores fueron apremiados por parte de diferentes instituciones públicas para retirar el artículo. Hellman ya había vivido una situación similar cuando años antes había intentado evitar que el Instituto Nacional de Estándares y Tecnología, NIST por sus siglas en inglés, estandarizara el uso del algoritmo *Data Encryption Standard* (DES) por sus graves problemas de seguridad. En el NIST eran conscientes de las vulnerabilidades del protocolo DES; pero, tal y como Hellman ha comentado varias veces en público, el NIST deseaba que el algoritmo seleccionado fuera suficientemente débil para que la NSA pudiera romperlo.

W. Diffie, M. Hellman y su estudiante de doctorado R. Merkle, y los autores del criptosistema RSA (Rivest, Shamir y Adlemen) percibieron como la NSA comenzó a clasificar sus artículos científicos como "*Top Secret*" y desde los órganos de inteligencia cada vez se hacía más presión para que sus "*papers*" fueran equiparados a armas de guerra.

El origen de los cypherpunks

En este contexto de vigilancia masiva, estandarización de algoritmos criptográficos no seguros e intimidación de expertos en ciberseguridad/criptógrafos, se comienza a fraguar el movimiento cypherpunk. En 1988 Timothy May recoge en "*The Crypto-Anarchist Manifesto*" el sentir de los precursores de este movimiento fraguado en pasillos de congresos científicos y eventos tecnológicos (Ludlow, 1996). El manifiesto fue compartido y discutido por May con otros fundadores del movimiento en las conferencias "*Crypto 88*" y la "*Hackers Conference*" de ese mismo año.

El manifiesto cripto-anarquista explica cómo la criptografía va a permitir a los ciudadanos y grupos interactuar entre ellos de forma anónima y privada sin necesidad de terceros. Incluso intercambiar mensajes y negociar contratos electrónicos sin compartir nunca la verdadera identidad legal entre las partes. Este manifiesto señala que la tecnología ya ha sido presentada en diferentes congresos científicos de Europa y EEUU bajo la monitorización de la NSA. El manifiesto, advierte que el Estado intentará retrasar la difusión de esta tecnología. Algunos de los argumentos serían los riesgos de seguridad nacional, el uso de esta tecnología por traficantes de drogas y evasores de impuestos, temores de desintegración social, comercialización libre de secretos nacionales y materiales ilícitos o robados, así como habilitar el establecimiento de mercados de asesinatos y extorsiones.

E. Hughes, T. May y J. Gilmore fundan en 1992 un pequeño grupo que comenzará a reunirse mensualmente en la empresa de Gilmore (Cygnus Solutions) en la Bahía de San Francisco, y a utilizar como foro "oficial" de discusión y coordinación del movimiento la "*Cypherpunk mailing list*"[3]. En la

[3] Después de la primera reunión, May comparte el manifiesto de 1988 de forma electrónica con el resto de la comunidad a través de la "Cypherpunk mailing list".

lista se intercalaban conversaciones sobre matemáticas, criptografía, ingeniería informática, política o filosofía. Tras dos años de funcionamiento la lista superaba los 700 subscriptores.

Un año más tarde se publica "*A Cypherpunk's Manifesto*" (Hughes, 1993). Este documento más extenso y detallado ha perdurado hasta el momento como el estandarte del movimiento cypherpunk. Este segundo manifiesto subraya que la privacidad es necesaria en la era electrónica, algo que no se puede esperar que los gobiernos proporcionen. Hughes señala en el manifiesto que la privacidad es tecnológicamente posible, y que el único obstáculo para alcanzarla es político.

La primera aparición mediática de los cypherpunks se produce en la revista Wired en 1993. Levy (1993) publica un artículo denominado "*Crypto Rebels*" en el que nuevamente se presenta un hipotético mundo en el que existe la privacidad, y se argumenta que la criptografía es el único medio para que se materialice. Además, el texto señala que existe un conflicto entre quienes quieren hacer accesible la criptografía y quienes la quieren restringir.

Levy queda tan impactado con el movimiento Cypherpunk que más adelante publicará el libro "*Crypto: How the Code Rebels Beat the Government – Saving Privacy in the Digital Age*" (Levy, 2001) detallando las "*Crypto Wars*", denominación bajo la que se conoce a la lucha de Estados Unidos y los gobiernos de sus países aliados en limitar el acceso público, a toda criptografía que la NSA no fuera capaz de romper.

Algunas de las contribuciones de los cypherpunks

Los cypherpunks han velado por la privacidad en el ámbito digital durante las últimas décadas. Un ejemplo es su influencia estratégica para impedir el despliegue del Chip Clipper por parte del gobierno de los EEUU. El chip, que utilizaba un algoritmo diseñado por la NSA, debía ser incorporado en los productos comerciales para cifrar las comunicaciones de todos los dispositivos de telecomunicaciones. Los fabricantes debían entregar en "garantía" la clave criptográfica de sus dispositivos por si alguna agencia del gobierno estimaba necesario interceptar y descifrar las comunicaciones.

La *Electronic Frontier Foundation* (EFF)[4] también se manifestó de forma contundente contra el uso del Chip Clipper y la "custodia" de claves por parte de la administración estadounidense. El esfuerzo común entre los cypherpunks y la EFF permitió desarrollar y difundir *software* criptográfico como *Nautilus* o *PGPfone* que permitiría añadir una capa extra de cifrado *software* a dichas comunicaciones.

La presión social, y la disponibilidad de herramientas que permitían mantener el anonimato de las comunicaciones, conllevó el abandono y retirada del Chip Clipper. Varios Cypherpunks y famosos expertos en ciberseguridad publicaron en 1997 un artículo señalando los riesgos de este tipo de prácticas. El artículo pretendía cerrar el caso y desincentivar la aparición de iniciativas similares (Abelson *et al.*, 1997).

Así mismo, la colaboración entre la EFF y varios participantes de la lista de correo cypherpunk permitió la construcción de un sistema informático que podía romper por fuerza bruta el algoritmo DES normalizado por el gobierno estadounidense. Con este sistema demostraron que la criptografía estándar para el uso de ciudadanos y empresas era insegura y podría ser descifrada en tan solo unos días.

A mediados de los noventa el activista Hal Finney[5], propuso a la lista de correos de Cypherpunks romper la versión internacional del navegador Netscape. Netscape lanzaba su *Initial Public Offering* (IPO) el 9 de agosto de 1995 y su crecimiento exponencial llamó la atención del público en general. Netscape se ratificó como el navegador de Internet más famoso de la época. Los cypherpunks aprovecharon esta popularidad para poner en evidencia la seguridad de este navegador, y en especial de su versión internacional que incorporaba criptografía todavía más débil debido a las limitaciones de exportación de criptografía en EEUU.

La comunidad Cypherpunk también ha dado soporte durante los últimos años a la iniciativa de creación de una entidad sin ánimo de lucro para el

[4] Organización sin ánimo de lucro cuyo objetivo es defender las libertades civiles en el uso de la tecnología

[5] Finney fue el protagonista de la primera transacción de bitcoins con Nakamoto, desarrollador clave de bitcoin, y para muchos puede ser el verdadero autor real de bitcoin.

mantenimiento de la red Tor[6]. La organización *The Tor Project* fue apoyada económicamente por la EFF en sus inicios y recibió el soporte de varios cypherpunks famosos entre los que se encuentran J. Appelbaum y R. Sandvik. Como puede observarse, los cypherpunks son un grupo de activistas que, a pesar de ser unos grandes desconocidos, han permanecido activos velando por la privacidad y seguridad de la información desde finales de los ochenta.

Para finalizar, cabe destacar la última gran contribución de la comunidad cypherpunk. El 31 de octubre de 2008 a las 20:10:00 CET un usuario, oculto tras el alias de Satoshi Nakamoto, compartía en la *Cryptography mailing list*[7] el diseño de Bitcoin (Nakamoto, 2008), es decir, el diseño de la primera red blockchain. Tras recibir feedback de la comunidad, el 3 de enero de 2009 Nakamoto creaba el primer bloque[8] y anunciaba en la misma lista que Bitcoin ya era una realidad. Nakamoto animaba al resto de activistas a descargarse el *software*, analizar su código fuente, y unirse a la red; todo ello con el objetivo de que Bitcoin se convirtiera en la primera red peer-to-peer[9] de intercambio de valor sin requerir entidades financieras ni emisores de monedas.

2.2. La innovación disruptiva

A mediados de los noventa Bower y Christensen, profesores de la Harvard Business School, publicaban "*Disruptive Technologies: catching the wave*" (Bower y Christensen, 1995), uno de los artículos científicos más citados en el ámbito de la innovación y que hoy en día sigue recibiendo cientos de citas anuales de investigadores en tecnología y ciencias empresariales.

---

[6] Red de comunicaciones distribuida que permite impedir que la navegación de un usuario pueda ser monitorizada por terceros.

[7] Última denominación conocida de la lista de correo de los cypherpunks.

[8] El primer bloque contenía el texto "*The Times 03/Jan/2009 Chancellor on brink of second bailout for banks*" refiriéndose a la rueda de prensa del Ministro de Hacienda del Reino Unido sobre un posible segundo rescate de la banca. Todo un reflejo de la crisis de confianza que estaba sufriendo el sistema financiero.

[9] Una red peer-to-peer, punto a punto o entre pares es una red de dispositivos (nodos) en los que no existe una jerarquía y se comportan como iguales entre sí.

Los autores señalan que la tecnología disruptiva es aquella que permite transformar y generar nuevos mercados económicos; tal y como ha ocurrido con la adopción de Internet en las últimas dos décadas. De hecho, la publicación reflexiona sobre cómo las empresas líderes de sus segmentos no son capaces de mantener el liderazgo ante la llegada de estas nuevas tecnologías disruptivas. En el manuscrito analiza diferentes ejemplos de empresas que no han sido capaces de idear nuevos modelos disruptivos y han ido perdiendo su liderazgo en unos pocos años.

Según los autores, los líderes de las empresas optan por invertir en el desarrollo incremental de las tecnologías existentes, en lugar de experimentar con tecnologías disruptivas que les permitirían conservar el liderazgo de sus mercados a largo plazo. El motivo principal es que éstas no satisfacen las necesidades a corto plazo de los mercados, y en especial de los clientes más rentables de estas compañías. Así pues, la cortoplacista cuenta de resultados, la falta de capacitación tecnológica, el temor a equivocarse a la hora de apostar por una tecnología novedosa, o incluso la falta de una toma de decisiones estratégicas son otros factores que impactan negativamente en la toma de decisiones.

Según el artículo, cada vez que surge una tecnología disruptiva solo la mitad de las empresas, dos tercios a lo sumo, son capaces de incorporar dichas tecnologías y adoptar nuevos modelos de negocio. De hecho, los autores señalan que aquellas compañías que las incorporan, y adoptan nuevos modelos, lo hacen con un retraso de alrededor de dos años de media. Durante ese tiempo, las compañías pioneras en la adopción de tecnologías disruptivas adquieren una gran madurez y conocimiento sobre nuevos mercados, o que han sido transformados sustancialmente. Este conocimiento adquirido constituye una barrera, infranqueable en la mayoría de casos, para el resto de las empresas. Por ello, en el artículo, los autores instan a los líderes a "subirse a la ola" de estas tecnologías disruptivas si quieren preservar el liderazgo de sus segmentos de mercado en el futuro.

Por todo ello, la innovación disruptiva, a diferencia de la innovación sostenible, es mucho más compleja de copiar o trasladar de un producto a otro. En su libro, "*The Innovator's Dilemma*", Christensen (1997) definía la innovación disruptiva como "*aquella innovación que basada en una* *tecnología disruptiva provee de un conjunto diferente de valores, genera un nuevo mercado y se apodera de otro existente*". Cabe mencionar que en esta clasificación también se definen dos tipos de innovación sostenible: evolutiva y revolucionaria. La innovación evolutiva supone una mejora natural de los productos o servicios del mercado actual, mientras que la innovación revolucionaria supone una mejora sustantiva del producto o servicio, pero sin llegar a implicar un cambio que transforme el mercado.

2.3. Modelos de negocio de plataforma

Durante el auge de las puntocom, un gran número empresas de nueva creación comenzaron a cotizar en el mercado de valores con excelentes resultados, pero sin seguir las pautas de éxito tradicionales (Ljungqvist *et al.*, 2003). A pesar de que estas startups estaban lejos de su umbral de rentabilidad fueron valoradas positivamente por los inversores, lo que les permitió acceder a capital sin gran esfuerzo.

Muchas de estas empresas quebraron, pero algunas como Amazon o eBay lograron sobrevivir al estallido de la burbuja económica generada e instaurar, durante las siguientes dos décadas, grandes imperios económicos. La cuestión es, ¿cuál fue el secreto de su supervivencia y éxito?

Tras analizar las empresas que sobrevivieron y disfrutaron de un gran éxito, Parker y Alstyne (2005) definieron un modelo formal que de forma pionera explicaba cómo las "*two-sided networks*", como ellos las denominaron, eran capaces de beneficiarse de las nuevas tecnologías de la información creando modelos de negocio cuyo principal valor era la intermediación entre dos, o más, lados de un mercado. Estas empresas, eran capaces de concebir nuevos mercados digitales poniendo en contacto la oferta y la demanda, y generando así un ecosistema a su alrededor. Poco después, en colaboración con Eisenmann, estos autores estudiaron la estrategia de las empresas que sustentan su propuesta de valor en estos mercados electrónicos, así como la propia dinámica de los ecosistemas generados (Eisenmann *et al.*, 2006).

Estos negocios son conocidos hoy en día como plataformas, y son los más exitosos de la economía. Una buena parte de las empresas más importantes del mundo, así como la mayoría de startups, se basan en este tipo de modelo de negocio de plataforma. Es por ello que los emprendedores tratan de promover iniciativas sustentadas en éstos, ya que parece ser un patrón clave para el éxito de cualquier negocio altamente escalable. Es decir, son negocios que podrían aumentar exponencialmente su base de clientes sin necesidad de realizar grandes inversiones iniciales.

El despliegue de Internet en los años 90 permitió digitalizar los modelos tradicionales de distribución y hacerlos más eficientes. Unos años más tarde, el verdadero cambio se produjo con la popularización de las plataformas basadas en Internet que sustituyeron a innumerables cadenas de suministro tradicionales. Este cambio fue muy ágil en el segmento de los servicios, pero todavía se está produciendo hoy en día en sectores como el de la fabricación (Van Dyck *et al.*, 2020). Sin lugar a duda, Internet ha sido la tecnología disruptiva de referencia en las últimas décadas; gracias a ella los emprendedores han sido capaces de idear nuevos negocios en un ejercicio de innovación disruptiva que ha transformado nuestros mercados en la actual economía de plataformas.

De Reuver *et al.* (2018) han elaborado una agenda de investigación que recoge los principales retos y líneas de investigación que permitirán evolucionar dichas plataformas. Los autores, anticipan que la naturaleza distribuida de los nuevos sistemas de información (blockchain) promoverá nuevos retos para el estudio de estas plataformas. Entre las nuevas líneas de estudio que proponen los autores, cabe destacar las siguientes:

- *¿Las plataformas digitales están aquí para quedarse?* Se debe considerar si existirán más o menos plataformas en el futuro, y especialmente cómo afectará la futura descentralización a estos mercados electrónicos.
- *¿Cómo deben diseñarse las plataformas?* Con la incorporación de nuevas tecnologías como el IoT, la computación en la nube o el blockchain, la arquitectura técnica y relacional de las plataformas tendrá que evolucionar en los próximos años.

- *¿Cómo transforman las plataformas digitales las industrias?* La emergente economía de plataformas exige investigar el impacto disruptivo que estas nuevas plataformas pueden tener en las organizaciones y sus modelos de negocio.

Los autores concluyen que las estructuras de poder y las relaciones entre los participantes serán diferentes en los nuevos ecosistemas descentralizados, es decir, basados en tecnología blockchain. También señalan la urgencia por incentivar la investigación sobre varios fenómenos emergentes, como las tecnologías descentralizadas, que están permitiendo la innovación en las plataformas digitales.

La tecnología blockchain será la infraestructura para creación de los futuros mercados electrónicos (Alt 2020). Esto se debe a que blockchain actúa como intermediario entre dos partes de forma ágil y sin requerir de terceros para garantizar la seguridad de las transacciones. Este mismo autor señala que *"...esto hace cuestionarse si los proveedores de plataformas siguen siendo necesarios y allana el camino hacia mercados electrónicos completamente descentralizados basados en blockchain..."*. Por su parte Wigang (2020) indica que esta descentralización contribuye a prescindir de los intermediarios y a reducir los costes de mediación entre compradores y vendedores.

La economía de plataformas puede transformarse en los próximos años con la llegada de blockchain y su capacidad para descentralizar los modelos de negocio. Blockchain puede ser la tecnología disruptiva que evolucione el ecosistema empresarial como lo hizo Internet hace unas décadas (Crosby *et al.*, 2016).

2.4. La tecnología blockchain

Fundamentos de la tecnología blockchain

La base tecnológica de Bitcoin, la primera criptomoneda digital totalmente descentralizada, es una arquitectura de ciberseguridad compleja y muy elaborada. De hecho, Nakamoto confesó que había comenzado con su diseño e implementación en 2007, aunque no fue hasta finales de 2008 cuando lo compartió con la comunidad. La tecnología desarrollada por Nakamoto, Bitcoin, ofrece una gran seguridad en el intercambio de activos digitales, que es el principal objetivo de una criptomoneda.

Durante cerca de dos años, Nakamoto fue integrando diferentes tecnologías y conceptos criptográficos ya descubiertos anteriormente, pero que nunca habían sido combinados en un mismo sistema. En este sentido, Nakamoto era como un chef que, provisto de ingredientes como un gran conocimiento sobre telecomunicaciones, matemáticas, y criptografía, se hallaba inmerso en la búsqueda de una arquitectura de ciberseguridad que permitiera gestionar de forma segura una moneda virtual descentralizada, su plato estrella.

El manuscrito compartido por Nakamoto era realmente un plato redondo y muy bien diseñado. Cuando la comunidad cypherpunk lo analizó surgieron dos tipos de reacciones. Algunos de los miembros de la comunidad, desalentados por anteriores intentos fallidos de lanzar una moneda digital descentralizada, rápidamente catalogaron Bitcoin como otro intento fallido. Estos miembros parecen caer en un sesgo cognitivo conocido como heurístico de accesibilidad, que consiste en estimar la probabilidad de un suceso según los recuerdos que la persona tiene sobre acontecimientos similares (Cortada de Kohan, 2008).

Por otro lado, otros se mostraron críticos pero esperanzados, examinando la lista de correo en la que se publicaba el *paper* puede observarse cómo las semanas posteriores a su publicación parte de la comunidad cypherpunk analizó minuciosamente Bitcoin, planteando dudas, o incluso intentando identificar posibles brechas de seguridad. A los lectores les preocupaba la seguridad de la criptomoneda, así como su descentralización efectiva; es decir, que el sistema no dependiera de ninguna entidad o grupos que pudiera ser coaccionado para influir, modificar, o cesar el mismo. Pero el trabajo previo de análisis y autocrítica realizado por su autor fue muy concienzudo, tanto que el resto de activistas no consiguieron identificar ninguna vulnerabilidad significativa en el diseño.

La red Bitcoin fue iniciada el 3 de enero de 2009. Poco después, Nakamoto compartió el código fuente para que el resto de la comunidad pudiera, por un lado, asimilar los detalles del diseño, y por otro, encontrar cuanto antes posibles vulnerabilidades en su implementación. Gracias a ello diferentes activistas comenzaron a ayudar con el desarrollo de nuevas funcionalidades y corrección de errores, permitiendo que Bitcoin fuera creciendo poco a poco.

Bitcoin es precisamente la primera red blockchain, el diseño original sobre el que se han creado otra serie de cadenas de bloques que dan soporte tanto a otras criptomonedas, como a redes y ecosistemas multipropósito en el que conviven aplicaciones de logística, energía, salud, o industria, entre otras.

Explicar los fundamentos básicos de la tecnología blockchain es precisamente el objetivo de este apartado, algo que no es trivial, y que incluso a los activistas técnicamente más avanzados les costó asimilar cuando analizaron por primera vez el *paper* de Bitcoin. De hecho, muchos de ellos reconocían que estudiar el código fuente de Bitcoin en enero de 2009 les ayudó a despejar las últimas cuestiones.

De cara a facilitar la asimilación de la tecnología se expondrá inicialmente una versión simplificada para, a continuación, indagar en algunos detalles de la tecnología blockchain. No obstante, esta sección no pretende entrar en detalles sumamente técnicos ni en aquellos específicos de un protocolo o plataforma concreta.

El objetivo es, por tanto, introducir la tecnología blockchain a un nivel suficiente para que el lector pueda comprender el resto del trabajo de investigación. Por ello, debemos exponer la tecnología blockchain de una forma sencilla antes de comenzar a profundizar en un mayor nivel de detalle.

Blockchain es una nueva tipología de registros digitales que, a diferencia de los tradicionales (p.ej. bases de datos) en los que una única organización vela por la coherencia y confiabilidad de la información albergada en el mismo, presenta una gobernanza compartida por una red o comunidad. Los miembros de la red analizan el formato y coherencia de cada transacción blockchain, requiriendo del consenso de la mayoría para registrarla, de forma inalterable, junto con el histórico de cambios y actualizaciones; maximizando así la auditabilidad y transparencia del sistema.

Blockchain es por tanto una plataforma de confianza distribuida. Es la primera tecnología que evita la necesidad de una autoridad central para asegurar la confiabilidad y transparencia de un sistema. Como consecuencia permite un nivel de eficiencia y certeza anteriormente inimaginable.

Esta nueva familia de registros permite que toda una comunidad, una red blockchain, comparta una versión exacta y sincronizada del registro. Todos los participantes disponen de la misma información en todo momento, lo que les permitirá evaluar y pronunciarse, en igualdad de condiciones, sobre la veracidad y coherencia de las transacciones propuestas por el resto de participantes. Por ejemplo, en una transferencia de activos cada miembro de la comunidad podrá verificar en su copia del registro si el emisor transfiere una cantidad igual o inferior al número de activos que posee.

Dentro de una red blockchain se deben distinguir los siguientes bloques fundamentales: la red de comunicaciones Peer-to-Peer, sus nodos, el propio registro o estructura de datos blockchain que alberga cada nodo, y la aplicación cliente o *wallet*.

Blockchain utiliza una *red distribuida peer-to-peer (P2P, en adelante)* para mantener la sincronización de todos los participantes similar a las utilizadas para el intercambio de archivos P2P como BitTorrent (Pouwelse *et al.*, 2005). Este diseño distribuido de comunicaciones permite evitar tanto un punto central en las comunicaciones como jerarquías en la red (todos los dispositivos conectados son iguales). De este modo se logra evitar la existencia de un punto único de fallo que pudiera interrumpir el servicio.

Los dispositivos conectados directamente a esta red P2P se denominan *nodos o pares de la red*. Estos nodos ejecutan un programa que permite recibir, validar, y propagar las transacciones. Todas las comprobaciones que realiza cada dispositivo de la red son efectuadas por este programa de forma automática, sin requerir de supervisión humana en ningún momento. No obstante, estos nodos pertenecen a diferentes agentes de la comunidad, de forma que no están bajo la gobernanza de una única persona o entidad. Estos nodos, además de enrutar y validar las transacciones, también almacenan, generalmente, el propio registro o estructura de datos en el que se guarda el histórico inalterable de todas las transacciones consensuadas.

Por último, el cliente o *wallet* es el programa informático que utiliza el usuario (humano o aplicación) para interactuar con la red blockchain (p. ej. realizar una transacción de activos o registrar una nueva medida de un dispositivo). Esta aplicación custodia la clave privada asociada a cada dirección de usuario en esa red. El usuario podrá tener varias direcciones o identidades diferentes en una misma red, al igual que puede disponer de diferentes cuentas en una entidad financiera.

En algunos casos este cliente (*wallet*) estará ubicado en el propio nodo de un usuario, pero la mayoría de los usuarios utilizará una *wallet* móvil, o similar, para realizar transacciones. Esto es debido a que muchos usuarios desean interactuar con la red (p. ej. realizar transacciones), pero no requieren de un dispositivo conectado permanentemente a la misma que valide las transacciones remitidas por todos los usuarios, y albergue una copia sincronizada del histórico de transacciones. Estos usuarios pueden conectarse puntualmente a la red para lanzar sus propias transacciones, convirtiéndose en nodos durante ese periodo; o hacerlo a través de otros participantes (nodos) que sí estén conectados directamente.

Principales beneficios de la aplicación de blockchain

Hughes *et al.* (2020) identifican en su análisis de la bibliografía diferentes beneficios que genera la implantación de la tecnología blockchain:

- *Desintermediación*: se reduce la necesidad de intermediarios o terceros de confianza en el proceso, y se evitan así procesos centralizados más complejos y costosos.
- *No-repudio*: se evita que las partes nieguen haber realizado una transacción ya que son firmadas en origen por sus promotores.
- *Confianza*: blockchain traslada la confiabilidad de los terceros de confianza a la tecnología y protocolos criptográficos.
- *Automatización*: se pueden tomar decisiones en base a la información registrada en blockchain, gracias a la certeza que genera la tecnología a las empresas.
- *Simplificación de los procesos*: se promueve la estandarización y transparencia, ya que todos los participantes deberán acordar una semántica y procedimientos comunes para trabajar en la red.
- *Mayor agilidad de procesos*: los procesos se realizan de modo más ágil en comparación con sistemas centralizados, que habitualmente están menos automatizados y tienen una mayor dependencia humana, debido a su falta de confianza en las fuentes de información.

- *Reducción de costes*: se reducen los costes gracias a la desintermediación y automatización de los procesos.

Tipologías de redes

La tipología de red blockchain en la que desplegar un proyecto es una decisión importante en el diseño de una solución basada en blockchain. La independencia y confiabilidad que brinda una red abierta y totalmente descentralizada como bitcoin es algo que la mayoría de apasionados de blockchain y la descentralización del poder admiran.

Esta confiabilidad es difícilmente igualable por las redes privadas, en las que existirá una gobernanza coordinada por todos los participantes de la red, o por un subconjunto de estos. La tecnología base empleada puede llegar a ser similar, incluso la misma, en cualquiera de los casos. No obstante, aunque en el ámbito tecnológico puedan no existir diferencias fundamentales, esta diferenciación sí se produce a nivel conceptual e ideológico.

La seguridad en las redes privadas ya no será íntegramente ofrecida por la propia tecnología con independencia de quienes participan en dicha red. La confianza en los participantes, las posibles relaciones entre estos, así como el modelo de coordinación y gobernanza, determinarán la confiabilidad de una blockchain privada.

De hecho, para quienes reniegan del sistema y corporaciones actuales, como es el caso de los cypherpunks, resulta difícil confiar en redes que no sean totalmente abiertas en las que la confianza la ofrezca el sistema y no recaiga parcialmente en un conjunto de participantes. Precisamente, en función del grado de control sobre la gobernanza y acceso a la red, podemos clasificar las redes como públicas, híbridas y privadas.

Las redes públicas, también conocidas como abiertas (*open*) o “no permisionadas” (*permisionless*), son las redes que respetan totalmente la ideología y diseño original de Nakamoto. Cuando Nakamoto diseñó bitcoin tenía como objetivo crear un sistema que no pudiera ser censurado ni controlado por ningún ente u organización. Las redes públicas están compuestas por decenas de miles de participantes en todo el mundo y en ellas todos son iguales; con independencia de su país, poder adquisitivo, raza, o religión.

En las redes públicas no existe una gestión de identidades controlada por algún ente u organización, nadie debe pedir permiso para crearse una o mil identidades, y tampoco deberá compartir su verdadera identidad para poder operar de forma segura con otros participantes de la red (p.ej. enviar o recibir bitcoins).

Precisamente, la gran novedad de la tecnología blockchain es que establece un sistema seguro, descentralizado y confiable en un entorno totalmente hostil. Una blockchain pública como bitcoin no necesita confiar ni en los sistemas que ejecutan la red blockchain, ni en ninguno de los usuarios de la red; creando así el primer sistema que no depende de terceros para constituir redes confiables.

En las redes híbridas o privadas siempre existe una mínima gestión de identidades y políticas de adhesión. Las comunidades híbridas, también conocidas como semi-públicas o públicas-permisionadas (*public-permissioned),* son aquellas en las que determinadas acciones están restringidas a un subconjunto de participantes previamente identificados. Este tipo de redes delegarán en estos participantes las operaciones y procesos de gobernanza más crítica.

Una de las características más habituales en las redes híbridas es ofrecer una lectura abierta de su registro, de su cadena de bloques. Esto significa que cualquier desconocido puede realizar una copia del registro, auditar las operaciones de la red (aunque no pueda ejecutar operaciones de forma anónima), e incluso verificar que la cadena de bloques no haya sido manipulada en ningún momento.

Esta tipología de redes no ofrece una gobernanza totalmente descentralizada. No podremos confiar exclusivamente en la tecnología, por lo que también deberemos depositar parte de nuestra confianza en los responsables de los nodos a quienes se les encomienda la gobernanza. No obstante, estas comunidades se exponen a la vigilancia y posible auditoría pública, lo que permite dotar de una mayor robustez al sistema.

En algunos casos, la regulación, junto con la incertidumbre y el cambio cultural necesario para adoptar una red pública, son las principales motivaciones para la constitución de redes híbridas o públicas permisionadas.

Finalmente, las redes privadas o permisionadas (*permissioned*) son aquellas cerradas a un conjunto de actores que tienen un interés transaccional conjunto, y que constituyen un gobierno relativamente centralizado que en la mayoría de casos está conformado por unos pocos nodos validadores. Esta gobernanza se define en la creación de la comunidad, y variará en función de la voluntad y necesidades de sus participantes.

En general, las redes permisionadas son más cercanas a la forma tradicional de operar las redes corporativas. Como consecuencia, los proyectos que se basan en este tipo de planteamientos son más fáciles de "vender" internamente en las organizaciones, pero también son sustancialmente menores los beneficios aportados por los mismas.

Cuanto más reducido es el número de participantes en una comunidad, más centralizada está la gobernanza y, por tanto, resulta más factible vulnerar su seguridad. Podría incluso producirse una coalición entre las entidades que gobiernan la red, algo prácticamente imposible en una red pública y abierta compuesta por millares de participantes pseudo-anónimos.

Por todo ello, las redes privadas son muchas veces cuestionadas. Es por ello que en muchos casos se acuerda la existencia de participantes con intereses contrapuestos dentro de la propia comunidad; de cara a equilibrar el poder, y por tanto su gobernanza. En algunos casos también se incorporan a los reguladores en la red blockchain a fin de a ejercer su papel de terceros de confianza.

En definitiva, la misma tecnología puede ser implantada tanto en redes públicas totalmente abiertas y descentralizadas, como en sistemas híbridos, o incluso totalmente centralizados en una serie de participantes concretos. En la medida que esto ocurre la confiabilidad del sistema va evolucionando desde una confianza en la propia tecnología y la gobernanza descentralizada, a una confianza centralizada en una serie de instituciones y gobiernos que intervienen en una red privada concreta.

Smart Contracts

Los *smart contract*, o contratos inteligentes, son los programas nativos de blockchain. Al igual que cualquier plataforma tradicional (Windows, Android, IOS, etc.), blockchain también ofrece la posibilidad de desarrollar programas que, ejecutados en la plataforma (la red blockchain), dotarán a la misma de determinadas funcionalidades específicas a un caso de uso.

Es precisamente esta capacidad de ser programadas lo que ofrece una gran versatilidad a las redes blockchain; permitiendo a los desarrolladores crear y gestionar tokens (activos digitales que representan valor, por ejemplo, bitcoin), así como implementar cualquier lógica de negocio vinculada a la información de la propia red, por ejemplo, automatizando determinados procesos.

Estos programas serán interpretados por los nodos de la red y actuarán en muchos casos como tercero de confianza entre las partes, pudiendo incluso custodiar valor (tokens) como si una cuenta de *escrow* se tratara. Un ejemplo que ilustra este tipo de intermediación es la utilización de un contrato inteligente para la mediación de apuestas. Una vez depositado en el *smart contract* el valor que apuesta cada parte (tokens), ninguna de las partes tendrá influencia sobre el contrato inteligente. Así pues, el contrato se resolverá ejecutando estrictamente su programación, remitiendo el valor custodiado a la parte que haya ganado la apuesta.

Precisamente, un *smart contract* es un programa que ejecuta, de forma descentralizada, la lógica de negocio con la que haya sido programado. Debido a su carácter descentralizado, ninguna de las partes interesadas podrá influir en su resolución. El programa no se ejecutará en el servidor de una empresa, que podría ser "apagado" o manipulado al estar bajo el poder de una de las partes; ni tampoco se ejecutará en la empresa de un tercero sobre la que alguna de las partes podría ejercer presión. Un programa descentralizado se ejecuta en decenas de miles de ordenadores anónimos repartidos por la geografía mundial, por lo que este tipo de presiones o coaliciones para alterar su ejecución no es factible.

Habitualmente cuando se señala la inmutabilidad de estos programas y su ejecución totalmente agnóstica, sin capacidad de influencia por ninguna de las partes involucradas, se suele utilizar la expresión anglosajona "*Code is*

Law". Los *smart contract* siempre se ejecutarán tal cual fueron programados. Esto difiere sustancialmente de los contratos tradicionales en los que el poder, capacidad de influencia, o incluso un influyente despacho de abogados, puede retrasar la ejecución del contrato o realizar una interpretación favorable a alguna de las partes. Algunos investigadores como Hassan y De Filippi comienzan a reflexionar sobre el impacto de esta tecnología en el ámbito legal (Hassan y De Filippi, 2017).

No obstante, tal y como se ha comentado, los *smart contract* son contratos que se ejecutan de forma descentralizada y que automatizan reglas de negocio. Estas reglas de negocio se habrán desarrollado previamente por un programador con el objetivo de dar respuesta a una serie de requisitos y necesidades del caso de uso. Si bien la automatización de las relaciones contractuales entre dos o más partes es una de las lógicas que se pueden programar, las posibilidades son ilimitadas, ya que se trata de un código programable que se ejecuta en la red blockchain.

En cualquier caso, se debe retroceder a los orígenes, al movimiento cypherpunk, para encontrar la motivación y justificación del término; así como quizás una razón de peso para que a pesar de ser una denominación confusa se siga utilizando para enfatizar la capacidad de blockchain de eliminar desigualdades basadas en el poder y el liderazgo económico.

Origen y evolución de los smart contracts

El término de *smart contract* es anterior a Bitcoin y la tecnología blockchain. Debemos retroceder a 1994, en pleno auge del movimiento cypherpunk, para encontrar la primera referencia en un artículo publicado en la web de Nick Szabo denominado "*Smart Contracts*" (Szabo, 1994). Szabo siguió trabajando en el concepto durante los siguientes años, trabajo que se reflejó en diferentes artículos (Szabo, 1996; 1997).

No obstante, Szabo únicamente pudo definir la teoría, ya que aquello que él estaba ideando no era factible tecnológicamente. Era necesario un sistema descentralizado que permitiera ejecutar transacciones de valor. Es por ello que aunque el trabajo no se detuvo, fue perdiendo intensidad; permaneciendo aparcado hasta la llegada de bitcoin y su tecnología.

De hecho, el propio bitcoin ya es un dinero programable, admitiendo la agregación de cierta lógica al mismo. Esta lógica nos permite hacer realidad los primeros *smart contract* básicos que autorizan el desbloqueo de valor en base a un conjunto de instrucciones programadas mediante un lenguaje propio en la transacción bitcoin. Esta lógica, o conjunto de instrucciones que acompañan a una transacción bitcoin, permiten a la red interpretar las indicaciones vinculadas a dicho valor o transacción. Pero en bitcoin el lenguaje disponible para programar dicho dinero es muy limitado, el programador dispone de muy pocos recursos, reduciendo las posibilidades de dichos *smart contract*.

No obstante, tecnologías como Ethereum elevan los *smart contract* a otro nivel, basándose en lenguajes de programación mucho más ricos que habilitan la creación de programas avanzados y complejos; eliminando así las principales barreras y limitaciones del lenguaje de bitcoin.

Así pues, los programadores despliegan sus *smart contract* en redes como Ethereum donde estarán siempre disponibles, evitando cualquier tipo de censura o manipulación. No hay un punto central donde ejercer presión para alterar los datos o el programa. Este ordenador global que crean redes como Ethereum está formado por miles de ordenadores con una copia exacta de todos los programas y datos asociados.

La tokenización

Cuando se menciona que los *smart contract* pueden custodiar valor, o que blockchain permite gestionar valor de forma segura, estamos haciendo referencia a los tokens. Los tokens son precisamente fichas digitales que representan un valor. En función del token su valor asociado podrá representar el derecho al uso de una plataforma digital, energía, o incluso activos físicos como un coche o una casa, entre otros.

Se puede decir que bitcoin es el principal token existente, fue la primera criptomoneda, y por eso muchas veces se confunde el concepto de token con criptomoneda; denominando criptomoneda a cualquier tipo de token. No todos los tokens han sido concebidos como criptomonedas, es decir, diseñados para realizar transacciones de valor. Existen diferentes clasificaciones de tokens, una de las más populares en el ecosistema es la propuesta por MakerDAO (2020):

- *Platform Token*: permiten la ejecución del código de un *smart contract* en una plataforma orientada a dar servicio a aplicaciones descentralizadas, como el token ether (ETH) de Ethereum.
- *Security Token*: representa la propiedad legal de un activo físico o digital.
- *Transactional Token*: unidades de valor para el intercambio de bienes y servicios.
- *Utility Token*: integrado en el protocolo de la plataforma y usado para acceder a sus servicios.
- *Governance Token*: otorga a sus poseedores el derecho a voto en las plataformas de gobernanza compartida con la comunidad.

Los tokens son los activos nativos de blockchain. Independientemente del valor que representen, estos tokens serán gestionados de forma segura por los *smart contract* de la red a la que pertenezcan.

Los tokens podrán ser nativos de la propia red, como el activo bitcoin en la red Bitcoin, o creados por programadores mediante un *smart contract*. De hecho, una de las particularidades de plataformas de *smart contracts* avanzados como Ethereum es que mediante *smart contract* es posible crear y gestionar nuevos tokens personalizados. Gracias a ello los creadores de plataformas o servicios digitales podrán crear sus propios tokens, que serán utilizados por los usuarios para consumir sus servicios.

Principales ámbitos de aplicación de blockchain

Blockchain, al igual que otras tecnologías de la información, es una tecnología de aplicación transversal, es decir, su implantación será generalizada en sectores muy diversos. No obstante, tal como sucedió con otras tecnologías como Internet, la velocidad de adopción de blockchain diferirá según cada sector. Las industrias más digitalizadas serán, sin lugar a duda, las que primero se beneficiarán de las características de la tecnología blockchain (Hughes *et al*., 2019).

El sector **financiero** fue el primero que comenzó a experimentar con la tecnología blockchain, seguramente por el riesgo que le suponía la aparición de las criptomonedas, y bitcoin en particular (Crosby *et al*., 2016; Treleaven *et al*., 2017; Morkunas *et al*., 2019). Tras analizar el funcionamiento de esta tecnología, los grandes *players* (la banca principalmente) han comprendido cómo blockchain puede ayudarles en la mejora de procesos existentes, en donde están realizando un mayor esfuerzo en la actualidad. De hecho, un conjunto de actores está promoviendo, en paralelo al sector tradicional, un ecosistema de finanzas descentralizadas conocido como DeFi (*Decentralized Finance*). Esta descentralización podría tener un gran impacto sobre el sector financiero tradicional (Zetzsche *et al.*, 2020), cuyo estudio precisamente forma parte de los objetivos de esta tesis.

En la actualidad las **industrias manufacturera** y **energética** desarrollan numerosas pruebas de concepto para comprender qué beneficios aporta blockchain tanto en la operación de su red industrial, como en el funcionamiento de sus mercados (Van Dyck *et al*., 2020). Estas industrias demandan una red de operaciones más robusta y que su disponibilidad no dependa de la posibilidad de fallo de un único punto del sistema, tal y como ocurre con los servidores centralizados en la actualidad (por ejemplo, la gestión de identidad o el SCADA). Con relación al funcionamiento de sus mercados la tecnología blockchain está permitiendo experimentar con relaciones automatizadas entre máquinas, así como con la compraventa de energía entre particulares (Lage, 2019b).

La trazabilidad es una característica demandada tanto por estas dos industrias como por el **sector agroalimentario** (Lage, 2019a). Blockchain ofrece una trazabilidad mucho más segura y neutra en la que ningún actor de la cadena de suministro pueda influir, y en la que ningún participante pueda alterar el registro de trazabilidad.

Por último, otra de las primeras industrias en la adopción de la tecnología blockchain es la **industria de la ciberseguridad** (Lage *et al.,* 2019). Seguramente sea la industria que mejor entiende la tecnología blockchain y por ello ha comenzado a utilizarla para dar seguridad a los servicios propios y de terceros. De hecho, expertos en ciberseguridad están estudiando cómo aplicar blockchain para hacer más seguros los pilares de las redes de comunicaciones actuales cuya principal vulnerabilidad es precisamente la existencia de un punto único de fallo en sus diseños.

La industria de la ciberseguridad, al igual que la industria financiera, es un sector totalmente digitalizado. Por este motivo, al igual que están emergiendo las finanzas descentralizadas (DeFi), cabría la posibilidad de que pueda emerger una nueva industria de ciberseguridad descentralizada. Este nuevo ecosistema descentralizado permitiría que los profesionales puedan ofrecer sus servicios de forma global y coordinada, sin requerir de estructuras empresariales de coordinación y gestión (Lage *et al.,* 2021).

3. Propósito de la Tesis

La adopción de los modelos de negocio de plataforma por parte de las empresas ha crecido exponencialmente en los últimos años. Estos modelos de negocio son el resultado de la influencia de Internet en la economía (Rahman y Thelen, 2019), y su principal distintivo es, precisamente, la mediación entre la oferta y la demanda de un producto o servicio. Así pues, podríamos señalar que las empresas que conforman la economía de plataformas tienen como principal propuesta de valor la intermediación e intercambio seguro de valor entre dos o más partes.

A diferencia de las cadenas de suministro tradicionales, en la que los actores deben poseer un activo físico para ofrecer un servicio (p.ej. hoteles, taxis, etc.), las plataformas no requieren de la pertenencia de activos físicos, y así disminuyen sus costes operativos, lo que facilita su crecimiento exponencial (p. ej. Booking, Uber, Airbnb, entre otras).

Las empresas tecnológicas, quienes mayoritariamente implantan este tipo de modelos de negocio, han adquirido una popularidad y valor creciente en las últimas dos décadas, llegando a liderar el ranking de las 10 empresas con mayor capitalización bursátil (Hunter *et al.*, 2020). Casi todas ellas (Amazon, Apple o Alphabet, entre otras) lo han logrado al explotar modelos de negocio de plataforma, y como consecuencia las plataformas forman parte de nuestro día a día.

Es natural reflexionar sobre el potencial impacto de blockchain en este tipo de modelos de negocio, ya que ofrece precisamente una intermediación segura entre las partes, que precisamente constituye hoy en día la base de estos modelos. Blockchain es, por tanto, una tecnología con el potencial de transformar radicalmente el modelo de negocio estrella del siglo XXI. Gracias a ella incluso un pequeño grupo de voluntarios puede llegar a crear, de forma altruista, aplicaciones capaces de ofrecer un servicio y valor semejante al que ofrecen las multinacionales, cuya principal propuesta de valor es precisamente la intermediación entre las partes. De hecho, en la actualidad podemos encontrar multitud de empresas como Facebook, Google, Amazon, Dropbox, Airbnb, o Uber, que podrían verse afectadas por la aparición de plataformas descentralizadas construidas por estos pequeños grupos.

Este potencial recuerda a la influencia que Internet ha tenido en nuestra economía. Un ejemplo es precisamente la creación de la Wikipedia. Internet permitió a la comunidad la creación de una enciclopedia libre y abierta, que acabó radicalmente con el modelo de negocio de las enciclopedias. La Wikipedia es una enciclopedia libre mucho más extensa que la enciclopedia Encarta de Microsoft (discontinuada en 2009), y con 30 veces más artículos que en la última edición de la Encyclopedia Britannica (únicamente en versión online desde 2012). Internet demostró, en este y otros casos, que era una tecnología disruptiva, capaz de transformar los modelos de negocio tradicionales como los de la Encyclopedia Britannica y Encarta.

Al igual que Internet ha transformado nuestra economía y modelos de negocio, se considera que blockchain puede transformar los modelos de negocio de plataforma. Es decir, que el impacto de la tecnología blockchain en la economía podría ser similar al de Internet, lo que convierte a blockchain en una de esas pocas tecnologías que por su carácter disruptivo pueden transformar los modelos de negocio existentes.

Actualmente, la mayoría de los estudios académicos están centrados en la evolución tecnológica de blockchain, o en la identificación de casos de uso específicos para los principales sectores de actividad económicos. Pero, en paralelo, están surgiendo startups y proyectos basados en la tecnología blockchain. Éstos nos recuerdan a las startups de la burbuja puntocom, de las cuales surgió un nuevo modelo de negocio inicialmente bautizado como "*two-sided markets*" (Parker y Alstyne, 2005). Tal y como analizábamos con mayor detalle en el apartado 2.3, este modelo ha ido evolucionando en las últimas dos décadas hasta convertirse en el modelo de negocio de plataforma; que es el modelo más utilizado, el que mayores beneficios genera en la cadena de valor[10].

Por todo ello, nos hemos marcado como **objetivo principal** de la tesis *evaluar la influencia de blockchain en los principales sectores económicos y los modelos de negocio de plataforma*.

Para la consecución del objetivo principal, proponemos los siguientes objetivos más específicos:

- Objetivo 1: Identificar los ámbitos de oportunidad de blockchain en el tejido empresarial.
- Objetivo 2: Cuantificar la inversión en tecnología blockchain y determinar su adopción en el ámbito empresarial.
- Objetivo 3: Identificar y realizar una taxonomía de las propiedades más relevantes de las nuevas plataformas descentralizadas, que emergen gracias a tecnología blockchain.
- Objetivo 4: Clasificar los nuevos arquetipos de plataformas descentralizadas e identificar las principales características de cada uno de estos arquetipos.

[10] 8 de las 10 empresas más importantes del mundo se basan en el modelo de negocio de plataformas (Hunter et al., 2020).

Los objetivos específicos previamente mencionados se tratan en detalle en las publicaciones que se describen en la siguiente tabla.

Tabla 3.1. Objetivos específicos y publicaciones asociadas

Objetivo principal de la tesis	
Evaluar la influencia de blockchain en los principales sectores económicos y los modelos de negocio de plataforma	
Objetivos específicos	**Publicaciones**
O1. Identificar ámbitos de oportunidad de blockchain en el tejido empresarial	• A1: Lage, O., Saiz-Santos, M., & Zarzuelo, J. M. (2023). Decentralized Industry 5.0: blockchain's contribution to industrial sustainability, resilience, and human-centricity. *Dyna* • A2: Lage, O. y Saiz-Santos, M. (2021). Blockchain and the decentralisation of the cybersecurity industry. *Dyna, 96*(3), artículo 239.
O2. Cuantificar la inversión en tecnología blockchain y determinar su adopción en el ámbito empresarial	• A3: Lage, O., Saiz-Santos, M. y Zarzuelo, J. M. (2021). The value and applications of blockchain technology in business: A systematic review of real use cases. En J. Prieto, A. Partida, P. Leitão y A. Pinto *(eds.), III International Congress on Blockchain and Applications* (pp. 149-160). Springer. • A4: Lage, O., Saiz-Santos, M. y Zarzuelo, J. M. (2022). Real business applications and investments in blockchain technology. *Electronics, 11*(3), artículo 438.
O3. Identificar y realizar una taxonomía de las propiedades más relevantes de las nuevas **plataformas descentralizadas**	• A5: Lage, O., Saiz-Santos, M. y Zarzuelo, J. M. (2022). Decentralized platform economy: Emerging blockchain-based decentralized platform business models. *Electronic Markets, 32*(3), 1707-1723.
O4. Clasificar los nuevos arquetipos de plataformas descentralizadas e identificar sus principales características	

4. Metodología

Conscientes del desafío que supone responder a los objetivos específicos que nos hemos marcado, hemos optado por establecer una aproximación metodológica determinada para cada uno de los diferentes objetivos, tal y como muestra la Tabla 4.1.

Tabla 4.1. Resumen de aproximación metodológica

<table>
<tr><th colspan="2">Objetivo principal de la tesis</th></tr>
<tr><td colspan="2">Evaluar la influencia de blockchain en los principales sectores económicos y los modelos de negocio de plataforma</td></tr>
<tr><th>Objetivos específicos</th><th>Metodología</th></tr>
<tr><td>O1. Identificar ámbitos de oportunidad de blockchain en el tejido empresarial</td><td>• Análisis bibliográfico (literatura científica + literatura gris)
• Síntesis de resultados</td></tr>
<tr><td>O2. Cuantificar la inversión en tecnología blockchain y determinar su adopción en el ámbito empresarial</td><td>• Generación de base de datos de casos de uso reales basados en el ERP de Tecnalia
• Identificación de los valores de negocio demandados por las empresas
• Análisis cuantitativo de la inversión empresarial</td></tr>
<tr><td>O3. Identificar y realizar una taxonomía de las propiedades más relevantes de las nuevas plataformas descentralizadas</td><td rowspan="2">• Identificación de plataformas descentralizadas
• Generación de base de datos de plataformas descentralizadas
• Propuesta de taxonomía basada en el método iterativo de diseño propuesto por Nickerson et al. (2013)
• Propuesta de arquetipos de plataformas descentralizadas mediante análisis clúster.</td></tr>
<tr><td>O4. Clasificar los nuevos arquetipos de plataformas descentralizadas e identificar sus principales características</td></tr>
</table>

A continuación, se presentan las diferentes aproximaciones metodológicas dispuestas según los objetivos específicos asociados. Para un mayor detalle de cada una de las aproximaciones se sugiere la consulta de los trabajos de investigación asociados en la sección III Anexos.

- **Objetivo 1**

De cara a identificar diferentes ámbitos de oportunidad de la tecnología blockchain en el tejido empresarial, se ha seguido una método analítico-sintético. Es por ello que se combina el análisis sistemático de la literatura con el objetivo de descomponer el problema en unidades más pequeñas y concretas, con el estudio de estos componentes y la posterior síntesis de los resultados obtenidos.

El análisis de la literatura ha sido desarrollado siguiendo las especificaciones de Keele (Keele 2007) para análisis sistemáticos de la literatura (Systematic Literature Review o SLR). Las directrices presentadas por Keele se fundamentan en la metodología aplicada por los investigadores de medicina y ciencias sociales en el análisis de la literatura, y han sido adaptadas a los retos específicos del ámbito de las plataformas *software*.

La primera fase del análisis consiste en la planificación de la revisión de la literatura. En este paso, se establece la necesidad, la pregunta de investigación y el protocolo a seguir para desarrollar la SLR. A continuación, se identifican las fuentes, los principales estudios, y se procede a la recopilación y monitorización de los datos.

Tras evaluar otras opciones se ha seleccionado Scopus como fuente de información al ser la mayor base de datos de abstracts y citas de literatura revisada (*peer-review*). Sobre ésta se han realizado las diferentes búsquedas avanzadas que permiten identificar, de la forma más precisa posible, los diferentes *papers* a analizar (véase anexo “Artículo 1: Decentralized Industry 5.0: blockchain’s contribution to industrial sustainability, resilience, and human-centricity”).

De acuerdo con las directrices de Keele, se ha elaborado una primera selección en función de los títulos y *abstracts* de los diferentes trabajos identificados en las búsquedas, desechando aquellos que no están directamente vinculados con nuestra investigación. Igualmente, en una segunda iteración, se ha desarrollado una lectura completa de los manuscritos resultantes con el objetivo de descartar aquellos que no aportan datos a nuestro análisis, clasificando y analizando aquellos que sí alcanzan el nivel de calidad exigido por nuestro estudio y aportan información relevante.

De forma complementaria, se ha realizado un análisis de las posibilidades de descentralización en el sector de la ciberseguridad, empleando un método analítico-sintético basándose en el estado del estado del arte.

Finalmente, siguiendo el tercer paso de la metodología, se han presentado los resultados. Debido a la naturaleza de nuestro estudio, hemos realizado una síntesis descriptiva, aplicando las recomendaciones de Keele para el formato de artículo de revista o conferencia.

En los anexos "Artículo 1: Decentralized Industry 5.0: blockchain's contribution to industrial sustainability, resilience, and human-centricity" y "Artículo 2: Blockchain and the decentralisation of the cybersecurity industry", puede consultarse con mayor detalle la aplicación de la presente metodología y los resultados obtenidos.

- **Objetivo 2**

Además de estudiar el teórico potencial de blockchain, debemos analizar el valor de negocio real aportado y conocer la inversión que las empresas están realizando en la tecnología.

Para ello, se ha diseñado un método de investigación mixto. Este método combina un análisis cualitativo de la documentación asociada con proyectos de aplicación de blockchain en el ámbito empresarial con un análisis estadístico (cuantitativo) de la información recopilada a partir del análisis cualitativo.

No existen, o al menos no conocemos, bases de datos que puedan utilizarse para el estudio, por lo que el análisis de los proyectos se ha desarrollado en función de los contratos con empresas del grupo de investigación en ciberseguridad y blockchain de Tecnalia. Se han seleccionado 104 proyectos blockchain contratados durante el periodo 2017-2020 en el *Enterprise Resource Planning* (ERP) corporativo. La información básica de los contratos de esos proyectos ha sido extraída a una hoja de cálculo para analizarla posteriormente.

El siguiente paso ha sido cumplimentar nuestra base de datos, compilando la información de los contratos, reportes y acuerdos de consorcio relativos a los 104 proyectos.

Se ha realizado un análisis cualitativo de la documentación de cara a identificar las palabras clave que definen la motivación de cada una de las inversiones blockchain analizadas. Una vez aisladas estas palabras clave se han normalizado y agrupado para identificar los valores o aplicaciones que motivan la inversión de las empresas.

Finalmente, se han analizado los resultados siguiendo técnicas estadísticas, así como un análisis clúster de los resultados para poder encontrar vínculos entre los diferentes valores identificados.

En los anexos "Artículo 3: The Value and Applications of Blockchain Technology in Business: A Systematic Review of Real Use Cases" y "Artículo 4: Real business applications and investments in blockchain technology", puede consultarse con mayor detalle la aplicación de la presente metodología y los resultados derivados de dicha investigación.

- **Objetivos 3 y 4**

Blockchain está haciendo posible la creación de nuevas plataformas descentralizadas. Es conveniente conocer las propiedades más significativas de estas plataformas que están emergiendo en diferentes sectores.

Además, estas nuevas plataformas presentan diferentes formas de colaborar con la comunidad como, por ejemplo, recompensar a los usuarios por el valor generado en estas. Es deseable conocer si existen diferentes modelos de plataforma y cuáles son sus principales características.

Para desarrollar la investigación asociada con estos objetivos se ha desarrollado una aproximación común basada en un enfoque de investigación multimétodo que consta de tres fases: identificación de plataformas descentralizadas y creación de la base de datos, desarrollo de una taxonomía, y, finalmente, realización de un análisis clúster para distinguir los arquetipos de plataformas descentralizadas y sus propiedades.

Fase 1: base de datos

El punto de partida es la selección de las fuentes de información sobre las que se identificarán las plataformas descentralizadas del estudio. Se han seleccionado tres fuentes de datos complementarias que, además, habitualmente son utilizadas para realizar diferentes investigaciones: Crunchbase, CoinMarketCap y Github.

La primera de ellas es Crunchbase, que es la mayor base de datos de Ventures (Marra *et al.*, 2015) y garantiza resultados de alta calidad con respecto a startups y empresas invertidas de forma tradicional. Se ha ejecutado una búsqueda compleja de empresas del sector blockchain sobre esta y se han analizado los cien primeros resultados. Después de su análisis, se han seleccionado las organizaciones que tienen interés para nuestra investigación y se han descartado las iniciativas que ofrecen servicios o consultoría blockchain en lugar de crear plataformas descentralizadas.

Los resultados se han complementado con la información de CoinMarketCap, que es el sitio web de seguimiento de precios de criptoactivos más popular del mundo. El objetivo de esta segunda fuente de datos es integrar, en el resultado de la búsqueda anterior, proyectos financiados mediante *Initial Coin Offering* (ICO); es decir, proyectos que han optado por la emisión de un token blockchain como método de financiación. De los cien primeros resultados se han seleccionado aquellos tokens que pertenecen a proyectos de plataforma y cuya misión es el intercambio de valor en plataformas descentralizadas, descartando todos los tokens que representan una criptomoneda.

Finalmente, para identificar proyectos totalmente libres creados por la comunidad, incluso sin ningún soporte financiero, se ha realizado una última búsqueda de proyectos blockchain en Github; que es la plataforma de desarrollo de proyectos *software* colaborativos más grande del mundo. Se han seleccionado aquellos resultados que permiten la creación de plataformas descentralizadas y descartado todos los proyectos de desarrollo de tecnología base (proyectos Hyperledger, Ethereum, etc.).

Fase 2: taxonomía de plataformas descentralizadas

Para abordar esta segunda fase, hemos seguido el método iterativo de diseño de taxonomías propuesto por Nickerson *et al.* (2013), que integra perspectivas conceptuales y empíricas. La metodología requiere de una aproximación combinada de ambas perspectivas (conceptual y empírica) entre las que se realizarán diferentes iteraciones.

En las iteraciones conceptuales, analizamos en detalle un subconjunto de las plataformas seleccionadas para identificar sus propiedades. Además, estas propiedades se han agrupado en dimensiones, siempre que ha sido posible, mediante la creación de etiquetas para conjuntos de características relacionadas (Baley, 1984).

Para abordar las iteraciones empíricas e identificar nuevas características, nos hemos basado en la literatura existente, ya que las plataformas descentralizadas heredan propiedades generales de las plataformas tradicionales y los atributos específicos de la tecnología blockchain.

Como resultado de las diferentes iteraciones entre las dos aproximaciones se ha obtenido la taxonomía de las plataformas descentralizadas, que es clave para el estudio posterior de la materia.

Fase 3: arquetipos de plataformas descentralizadas

Esta última fase está dedicada a la elaboración de un análisis clúster de cara a identificar los diferentes arquetipos de plataformas descentralizadas. El análisis clúster es una técnica estadística que nos permite agrupar las plataformas, minimizando la varianza dentro del grupo y maximizándola entre grupos (Blashfield y Aldenderfer, 1988).

El primer paso ha sido la selección de las variables de agrupación. Siguiendo un enfoque deductivo, se utilizan las dimensiones de la taxonomía creada en la fase anterior como variables de agrupación. Hemos completado la base de datos cumplimentando las dimensiones de cada una de las plataformas seleccionadas teniendo en cuenta la información pública disponible sobre cada proyecto (página web, libro blanco, información publicada en redes sociales y entrevistas/artículos de los principales medios de comunicación especializados).

Tras la selección de las variables, hemos escogido el algoritmo de agrupación adecuado, en particular, la agrupación jerárquica; utilizado el método de Ward como técnica de aglomeración en el análisis (Ward, 1963); y calculado la distancia euclidiana sobre los valores ponderados como medida de la relación entre los valores (Žiberna *et al*., 2004).

En el anexo "Artículo 5: Decentralized platform economy: emerging blockchain-based decentralized platform business models. Electronic Markets" puede consultarse en detalle las tres fases de la metodología y los resultados derivados de dicha investigación.

5. Resultados y Discusión

En los últimos años la tecnología blockchain está adquiriendo cada vez más relevancia tanto en el ámbito tecnológico como académico, tal y como ya adelantábamos en la introducción de esta tesis (Figura 1.1).

Por esa razón, hemos evaluado la influencia de la tecnología blockchain en los principales sectores económicos, así como en los modelos de negocio de plataforma, que es donde esta tecnología ha tenido una mayor aplicación hasta la fecha.

En la Tabla 5.1 se exponen, de forma esquemática, los principales resultados obtenidos durante la investigación, cuya información ampliada puede consultarse en las publicaciones asociadas con estos.

Tabla 5.1. Resumen de resultados obtenidos

Objetivo principal de la tesis			
Evaluar la influencia de blockchain en los principales sectores económicos y los modelos de negocio de plataforma			
Objetivos específicos	**Metodología**	**Resultados**	**Publicaciones asociadas**
O1. Identificar ámbitos de oportunidad de blockchain en el tejido empresarial	• **Análisis bibliográfico** (literatura científica + literatura gris) • **Síntesis** de resultados	• Identificación de oportunidades y retos motivados por la descentralización de la industria de la ciberseguridad. • Identificación de ámbitos de oportunidad en la industria 5.0 gracias a la adopción de la tecnología blockchain.	• A1: Lage, O., Saiz-Santos, M., & Zarzuelo, J. M. (2023). Decentralized Industry 5.0: blockchain's contribution to industrial sustainability, resilience, and human-centricity. *Dyna* • A2: Lage, O. y Saiz-Santos, M. (2021). Blockchain and the decentralisation of the cybersecurity industry. *Dyna, 96*(3), artículo 239.
O2. Cuantificar la inversión en tecnología blockchain y determinar su adopción en el ámbito empresarial	• **Generación de base de datos** de casos de uso reales basados en el ERP de Tecnalia • **Identificación de los valores de negocio** demandados por las empresas • **Análisis cuantitativo de la inversión** empresarial	• Clasificación de 12 valores de negocio en los que las empresas están invirtiendo. • Análisis de la inversión en blockchain por diferentes factores	• A3: Lage, O., Saiz-Santos, M. y Zarzuelo, J. M. (2021). The value and applications of blockchain technology in business: A systematic review of real use cases. En J. Prieto, A. Partida, P. Leitão y A. Pinto *(eds.), III International Congress on Blockchain and Applications* (pp. 149-160). Springer. • A4: Lage, O., Saiz-Santos, M. y Zarzuelo, J. M. (2022). Real business applications and investments in blockchain technology. *Electronics, 11*(3), artículo 438.

Objetivos específicos	Metodología	Resultados	Publicaciones asociadas
O3. Identificar y realizar una taxonomía de las propiedades más relevantes de las nuevas **plataformas descentralizadas**	• **Identificación de plataformas** descentralizadas • **Generación de base de datos** de plataformas descentralizadas • **Propuesta de taxonomía** basada en el método iterativo de diseño propuesto por Nickerson *et al.* (2013) • **Propuesta de arquetipos** de plataformas descentralizadas mediante análisis clúster.	• Taxonomía de las 22 características que definen una plataforma descentralizada • Identificación y especificación de las 3 tipologías de plataformas descentralizadas: hosted, federated y shared	• A5: Lage, O., Saiz-Santos, M. y Zarzuelo, J. M. (2022). Decentralized platform economy: Emerging blockchain-based decentralized platform business models. *Electronic Markets, 32*(3), 1707-1723.
O4. Clasificar los nuevos arquetipos de plataformas descentralizadas e identificar sus principales características			

- **Objetivo 1**

Con respecto al **primer objetivo**, el trabajo de investigación realizado nos ha permitido identificar los diferentes beneficios y oportunidades de la aplicación de blockchain en los principales sectores económicos.

En primer lugar, debemos destacar el cambio que la descentralización producida por la adopción de blockchain va a suponer para sectores altamente digitalizados. Al estudiar la adopción de blockchain en la industria de la ciberseguridad, identificamos iniciativas descentralizadas que pretenden ofrecer servicios alternativos a los que actualmente ofrecen las empresas de servicios de ciberseguridad.

Igualmente, cabe destacar la influencia de la tecnología blockchain en la emergente industria 5.0 promovida por la Comisión Europea. En la Figura 5.1 se presentan los principales beneficios del despliegue e implantación de blockchain en la industria 5.0.

Figura 5.1. Blockchain y la industria 5.0

Hemos clasificado estos beneficios en función de los tres pilares de la Industria 5.0: sostenibilidad industrial, resiliencia industrial y centralidad de las personas. Con relación a la sostenibilidad industrial, destacamos cómo el blockchain permitirá una mejor gestión, trazabilidad y fomento de actividades sostenibles y de la reducción de emisiones. Blockchain nos permitirá crear una industria más resiliente tanto en lo referente a la gestión de la cadena de suministro como a la ciberseguridad de la industria. Finalmente, en relación con la centralidad de las personas, blockchain nos permitirá mejorar la privacidad en las interacciones con los usuarios y trabajadores, así como mejorar su experiencia.

- **Objetivo 2**

Con relación al **segundo objetivo**, determinar la adopción e inversión empresarial en tecnología blockchain, hemos identificado los doce valores de negocio en los que las empresas están invirtiendo, analizando dicha inversión en función de diferentes factores.

Así pues, los doce valores de negocio que presentan una mayor oportunidad y, por tanto, están captando una mayor inversión en tecnología blockchain por parte de las empresas serían:

- Descentralización de procesos
- Descentralización de modelos de negocio
- Trazabilidad y procedencia de activos
- Trazabilidad/certificación de procesos y cumplimiento regulatorio
- Transparencia de procesos
- Gestión de procesos/activos compartidos
- Confiabilidad e Integridad del dato
- Automatización de procesos
- Contratos inteligentes
- Identidad digital
- Soberanía del dato y los servicios
- Transacciones Machine-to-Machine (M2M) y *Machine Economy*

Si analizamos la inversión en cada uno de dichos valores en función del tamaño de la empresa (Tabla 5.2), podemos observar cómo la confiabilidad e integridad del dato es el valor más demandado con independencia del tamaño de la empresa, ya que representa entre el 16,96 % y el 21,51 % de la inversión. Por otro lado, la automatización de procesos es el único aspecto en el que algunos de los segmentos no invierten, concretamente, las micro- y pequeñas empresas[11]. Seguramente, esto se debe a que las grandes y medianas empresas se gestionan a partir de procesos más complejos en los que blockchain, claramente, aporta un mayor nivel de automatización, por lo que la inversión presenta una mayor rentabilidad.

Tabla 5.2. Inversión por tamaño de empresa (porcentajes). Fuente: elaboración propia

[11] Según el Anexo I del Reglamento (UE) nº 657/2014 de la Comisión Europea la categoría de microempresas, pequeñas y medianas empresas (pymes) está constituida por las empresas que ocupan a menos de 10, 50 y 250 personas y cuyo volumen de negocio general anual no excede de 2, 10 y 43 millones de euros respectivamente.

Tamaño	Decentraliz. procesos	Dec. mod. negocio	Trazabilidad Activos	Trazabilidad procesos	Transparen. Procesos	Gest. activos compartidos	Confianza e integridad	Automatiz. procesos	Contratos inteligentes	Ident. digital	Soberanía dato	Machine Economy
Micro	14,96	9,16	4,60	9,92	2,12	4,28	16,96	-	5,81	12,11	9,50	10,58
Peq.	8,11	2,44	8,03	13,00	4,11	8,04	21,53	-	5,34	13,11	8,11	8,17
Med.	8,50	1,49	6,36	15,33	3,23	12,04	17,32	5,91	5,53	9,61	6,42	8,25
Gran	15,14	2,45	6,45	7,23	1,89	5,22	21,51	11,03	1,13	14,32	4,20	9,42

Las microempresas son las que están apostando más activamente en la descentralización de modelos de negocio y la *Machine Economy*. Esto se debe a que la mayoría de las microempresas que invierten en blockchain son *startup* que buscan escenarios con mayor riesgo e incertidumbre, tratando de construir valor a medio/largo plazo.

También se debe señalar que la micro- y gran empresa está invirtiendo más activamente en la descentralización de procesos, al contrario que la pequeña y mediana empresa, que presenta un mayor interés en la trazabilidad de procesos.

A su vez la Tabla 5.3 nos muestra el porcentaje de inversión en cada uno de los doce valores por sector. Observamos cómo el sector de la construcción está principalmente apostando por la trazabilidad de procesos, la gestión de activos compartidos y la confiabilidad e integridad de la información. No se han identificado inversiones por parte del sector en los valores más cercanos a la descentralización, es decir, la descentralización de procesos, modelos de negocios, los contratos inteligentes o la *Machine Economy*.

Tabla 5.3. Inversión por sector (porcentajes). Fuente: elaboración propia

Sector	Decentraliz. Procesos	Dec. Mod. Negocio	Trazabilidad Activos	Trazabilidad Procesos	Transparen. Procesos	Gest. Activos compartidos	Confianza e Integridad	Automatiz. Procesos	Contratos Inteligentes	Ident. Digital	Soberanía Dato	Machine Economy
Cons.	-	-	10,78	22,21	10,78	22,21	22,21	6,51	-	5,31	-	-
eGov	9,93	-	-	24,34	5,26	24,34	13,98	1,75	-	16,04	4,35	-
Energ.	3,74	4,23	15,42	15,38	1,68	13,77	15,79	10,77	3,82	-	-	15,42

Finan.	0,69	1,38	0,69	22,14	8,46	22,83	10,49	22,14	11,18	-	-	-
Ind4.0	4,08	0,90	4,31	4,66	0,79	10,79	20,90	10,57	1,83	6,44	15,84	18,89
Salud	13,53	5,89	5,90	12,39	-	17,88	17,88	5,19	-	12,69	8,64	-
Mobil.	11,20	6,81	7,99	7,99	3,60	14,80	14,80	14,80	-	11,20	-	6,81
TIC	9,03	1,94	2,25	7,35	0,33	4,34	17,64	10,29	3,48	19,23	11,75	12,36

Los gobiernos están invirtiendo, principalmente, en tecnología blockchain para la trazabilidad de procesos y gestión de activos compartidos, seguido por el despliegue de la identidad digital para sus ciudadanos, así como la descentralización de sus procesos.

El sector energético está intensivamente invirtiendo en trazabilidad de procesos y activos, así como en la automatización de procesos. Además, debido al proceso de descentralización del sector, también está apostando por la confiabilidad e integridad de la información, en la gestión de activos compartidos y en la *Machine Economy*.

La industria financiera está focalizada en mejorar sus procesos mediante la adopción de tecnología blockchain, por lo que su inversión está muy centrada en la gestión de activos compartidos, la automatización de procesos y la trazabilidad.

La industria manufacturera está realizando inversiones en tecnología blockchain para aumentar la confiabilidad e integridad de los datos, su soberanía y la *Machine Economy*. En un segundo nivel, podemos destacar cómo las empresas industriales apuestan por la gestión de activos compartidos y la automatización de procesos mediante blockchain.

El sector salud invierte principalmente en la gestión de activos compartidos, la identidad digital y la confianza e integridad del dato mediante tecnología blockchain. Todo ello alineado con una visión centrada en el paciente en la que los servicios de salud empoderan al mismo en la gestión de sus datos de salud.

En el caso de la movilidad, la inversión en blockchain se está destinando principalmente a la gestión de activos compartidos, la identidad digital, la confiabilidad del dato y la automatización de procesos.

El sector de las tecnologías de la información y la comunicación (TIC) está claramente vinculado con la identidad digital y la confiabilidad del dato, principalmente, por su interés en adoptar un nuevo modelo de identidad descentralizada, Self-Sovereign Identity (SSI). Además, las TIC están apostando también por la soberanía del dato y la *Machine Economy*, debido a su vinculación con líneas estratégicas como son la economía del dato y los ecosistemas IoT respectivamente.

En la Figura 5.2 se pueden observar las relaciones existentes entre las inversiones en cada uno de los doce valores de la tecnología blockchain identificados. Gracias a la visualización del análisis clúster en formato dendograma, es posible distinguir seis clústeres diferentes.

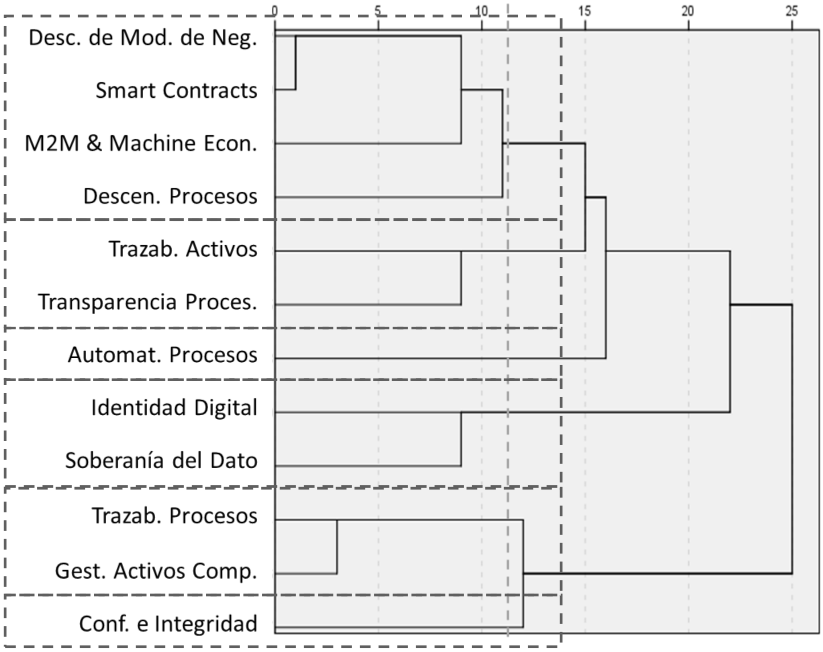

Figura 5.2. Dendograma presentando los 6 clúster identificados.

Cabe destacar la estrecha relación entre la descentralización de modelos de negocio, el uso de *smart contract*, la descentralización de procesos y la *Machine Economy*. Así pues, los proyectos más disruptivos presentan varias de estas características.

Por otro lado, hay una relación estrecha entre la trazabilidad de activos y la transparencia de procesos, ya que, para realizar la transparencia de los procesos, hace falta tener una trazabilidad de estos. Igualmente, la trazabilidad de procesos es la base para la gestión de activos compartidos y la identidad digital es necesaria para la soberanía del dato. Por eso, es habitual que, en muchos casos, estos valores de la tecnología blockchain estén vinculados en los proyectos analizados.

Al examinar las inversiones agregadas por cada uno de los valores (Figura 5.3), podemos observar cómo la inversión en confiabilidad e integridad del dato representa el valor más demandado de la tecnología blockchain con un 18 % de la inversión global.

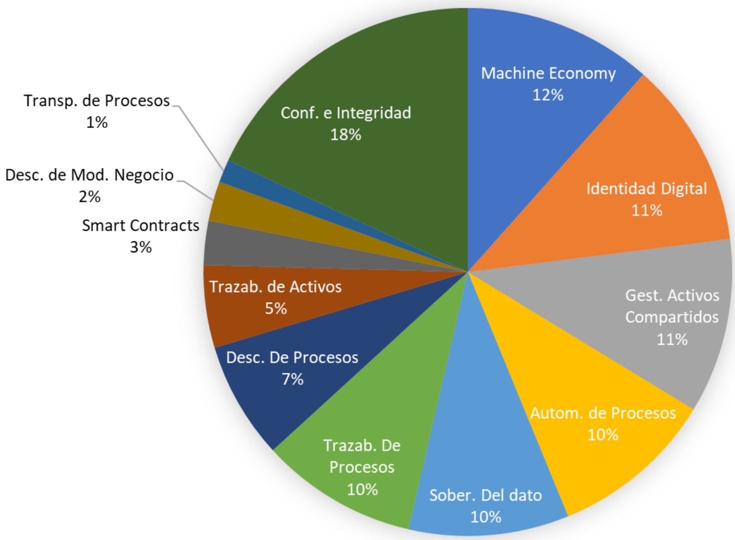

Figura 5.3. Distribución de la inversión en blockchain por valor de negocio. Fuente: elaboración propia

La *Machine Economy* es el siguiente valor con una mayor inversión en tecnología blockchain. Esta tendencia del ámbito del IoT representa el 12 % de la inversión global, probablemente, debido a la alta inversión en proyectos TIC y de Industria 4.0. Los siguientes valores con una mayor inversión son la identidad digital y la gestión de activos compartidos. Cada uno representa el 11 % de la inversión global en blockchain. Estos cuatro valores suponen más de la mitad de la inversión en blockchain de los proyectos analizados, concretamente, un 56 %.

Sorprendentemente, las tres funcionalidades de blockchain que han recibido menos inversión por parte de los proyectos analizados son la transparencia de procesos, la descentralización de modelos de negocio y los contratos inteligentes. Juntos representan únicamente el 6 % de la inversión analizada, seguidos por la trazabilidad de activos que representa un 5 % de la inversión en tecnología blockchain. Estos valores se señalan habitualmente como los de mayor valor en el ámbito empresarial, pero vemos que las empresas no están apostando activamente en ellos; esto se debe, probablemente, a que están realizando inversiones de un riesgo más controlado. En los próximos años podremos ver cómo las empresas invertirán en los valores de mayor potencial, y riesgo, en un ejercicio de innovación disruptiva que transformará los actuales modelos de negocio.

Precisamente, aunque el total de la inversión es muy bajo, 2 % de la inversión total, casi todos los sectores están realizando ciertas pruebas de descentralización de modelos de negocio mediante pequeñas inversiones. Parte de esta inversión está destinada a la experimentación de nuevas plataformas descentralizadas que pueden constituir un nuevo modelo de negocio, transformando el modelo de plataforma que impera hoy en día.

- **Objetivo 3**

De cara a identificar las propiedades más relevantes de estas nuevas plataformas descentralizadas (**objetivo tercero**), hemos seguido el método propuesto por Nickerson *et al.* (2013). Se ha desarrollado una taxonomía de las características de estas nuevas plataformas descentralizadas. Para facilitar su comprensión, las características de las plataformas descentralizadas han sido clasificadas en cinco grupos:

- **Componentes de interacción**
    - **N.º de roles** que interactúan en la plataforma
    - **Intercambio de información como objetivo primario** de las interacciones en la plataforma
    - **Filtros** de contenido para mejorar la experiencia de usuario
    - **Interacción directa** entre usuarios
    - **Intercambio interno de bienes** dentro de la propia plataforma
    - **Pagos** en la plataforma
    - **Selección de miembros**

    - **Efecto red directo** con la incorporación de nuevos participantes
- **Apertura de la plataforma**
    - **Tipo de colaboración** (Propietaria, Licenciamiento, *Joint Venture*, Compartida)
    - **Código abierto**
    - **Gobernanza compartida**
    - **Participación de desarrolladores** externos
    - **Participación de usuarios** en la definición de la plataforma.
- **Tokenomics**
    - **Uso** de tokens
    - **Tipo** de tokens (Plataforma, Security, Transaccional, Utilidad, Gobernanza)
- **Propiedades de mercado**
    - Mercado **B2B**
    - Mercado **B2C**
    - **Control de precios**
    - **Control de términos contractuales**
    - **Estrategia de monetización** (pago por transacción, acceso, acceso mejorado, filtro mejorado, Free&Open)
    - **¿Quién paga?** (Todos, un lado financia al otro, nadie)
- **Estrategia de marketing**
    - **Estrategia de lanzamiento** (Follow the rabbit, Piggyback, seeding, producer evangelism, micromarket)
    - **Crecimiento viral**

En el apartado "Artículo 5: Economía de plataformas descentralizadas" puede consultarse una explicación detallada de cada uno de los elementos de la taxonomía.

- **Objetivo 4**

Finalmente, se han clasificado los modelos de plataformas descentralizadas e identificado sus principales características, respondiendo al **cuarto objetivo** de esta investigación. Para ello, se han estudiado las 82 plataformas descentralizadas identificadas en función de dicha taxonomía. Mediante un análisis clúster se han identificado tres tipologías de plataformas descentralizadas (Figura 5.4), que, por sus características, hemos denominado: *hosted*, *federated* y *shared*.

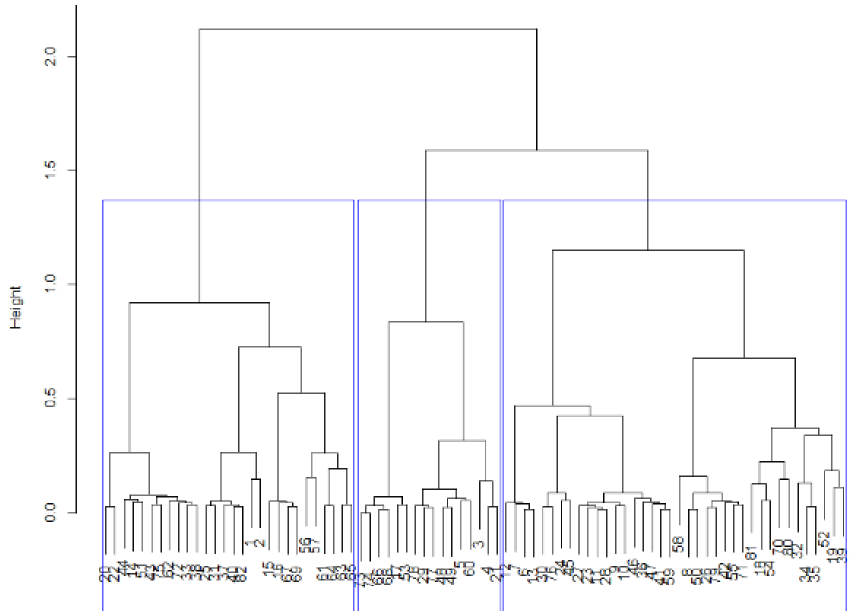

Figura 5.4. Dendograma mostrando los tres clústeres identificados: hosted, federated y shared

Estos tres nombres tratan de representar los rasgos más significativos de cada uno de estos segmentos, bautizados como resultado del análisis sobre las características más significativas de cada uno de los grupos.

Hosted (gestionadas)

Las plataformas descentralizadas de tipo gestionado (*hosted*) son las más tradicionales. Estas plataformas, a pesar de implementar una tecnología descentralizada como blockchain, mantienen las características típicas de una plataforma centralizada. Las plataformas gestionadas destacan principalmente por basarse en modelos propietarios (60,71 %) o de licenciamiento (39,29 %), algo que descartan los otros dos tipos de plataformas, que prefieren modelos de *joint venture* y compartidos con la comunidad.

La apertura del código a terceros es muy inferior al resto de las plataformas descentralizadas. En el caso de las gestionadas (*hosted*), únicamente el 39,29 % de las plataformas son *open-source*, mientras que en los otros dos tipos ronda el 100 %. Además, no implementan mecanismos de gobernanza compartida y la involucración de desarrolladores y usuarios externos en la definición y creación de la plataforma es muy inferior al resto (64,29 % y 28,57 %, respectivamente); como consecuencia son el único tipo de plataforma descentralizada que no utiliza tokens de gobernanza.

Federated (federadas)

Las plataformas descentralizadas de tipo federado reflejan, principalmente, el trabajo de colaboración entre una *startup* promotora y la comunidad. En su gran mayoría, estas *startup* quieren crear un modelo de plataforma que sustituye a una o a varias plataformas tradicionales (centralizadas). Es por ello por lo que proponen un nuevo modelo de relación con la comunidad: la cocreación de una plataforma descentralizada en la que el poder y la gobernanza sea compartido entre la comunidad y la *startup* promotora. En algunos casos, la *startup* promotora puede ser una fundación sin ánimo de lucro, siendo los fundadores recompensados por su idea y liderazgo mediante una cantidad relevante de tokens.

Muchas de estas plataformas federadas pretenden crear alternativas a redes sociales; por esta razón, el intercambio de información es el principal objetivo de la red (75 %), y todas presentan un intercambio de bienes en la propia plataforma (100 %).

Con respecto al modelo de relación y apertura a la comunidad, todas las plataformas federadas optan por un modelo de *joint venture* con la comunidad (100 %), lo que refleja claramente su vocación de colaboración. Además, su desarrollo se comparte en formato *open-source* (97,37 %), hay una gobernanza totalmente compartida con la comunidad (87,50 %) y se involucra a desarrolladores externos (93,75 %) y usuarios (43,75 %) en la creación de la plataforma.

Estas plataformas federadas destacan por utilizar principalmente tokens de utilidad (81,25 %) para crear una economía alrededor del uso de la plataforma, así como tokens de gobernanza (75 %) para gestionar la colaboración con la comunidad. En algunos casos, ambas funcionalidades recaen sobre un mismo token que da derecho a los usuarios a consumir servicios, así como participar en las decisiones de la plataforma.

Además, cabe señalar que estas plataformas destacan por utilizar una estrategia de *producer evangelism* más alta que la media (31,25 % frente al 16 % de media), además de una estrategia de crecimiento viral (31,25 % frente al 15,85 % de media).

Shared (compartidas)

Las plataformas compartidas (*shared*) son aquellas que en su mayoría están creadas por la propia comunidad, aunque a veces también puede existir una fundación que facilite su operación. Estas plataformas destacan claramente por su nivel de apertura, evidentemente, motivado por ser la propia comunidad la que en la mayoría de los casos se encarga de su desarrollo y gestión.

Así pues, en las plataformas compartidas, prevalecen los modelos de explotación compartidos y abiertos (97,37 %), la apertura de código en formatos *open-source* (97,37 %), y una gobernanza compartida con la comunidad (81,58 %). Además, la involucración de la comunidad de desarrolladores es prácticamente total (97,37 %) en las plataformas compartidas y hay un alto índice de involucración de usuarios (28,95 %), aunque por debajo de las plataformas federadas (43,75 %). Estas plataformas compartidas presentan habitualmente tokens de plataforma (39,47 %), además de tokens de gobernanza (52,63 %) y utilidad (44,74 %).

Por último, cabe destacar que el 21,05 % de estas plataformas compartidas no presentan un modelo de monetización evidente. Son Free&Open y nadie paga de forma directa o indirecta por sus servicios; esta es, sin duda, la característica más novedosa de este tipo de plataformas compartidas. Así pues, ese 21,05 % de las plataformas compartidas son creadas, operadas y disfrutadas por la propia comunidad, ofreciendo servicios que hasta la fecha son provistos por grandes empresas cotizadas como Dropbox o Uber, entre otras.

6. Referencias Bibliográficas

Alt, R. (2020). Electronic markets on blockchain markets. *Electronic Markets, 30*(2), 181-188. https://doi.org/10.1007/s12525-020-00428-1

Abelson, H., Anderson, R., Bellovin, S. M., Benaloh, J., Blaze, M., Diffie, W., Gilmore, J., Neumann, P. G., Rivest, R. L., Schiller, J. I. y Schneier, B. (1997). The risks of key recovery, key escrow, and trusted third-party encryption. *World Wide Web Journal, 2*(3), 241-257.

Bailey, K. D. (1984). A three-level measurement model. *Quality & Quantity, 18*(3), 225-245. https://doi.org/10.1007/BF00156457

Bamford, V. J. (1982). *The puzzle palace.* Houghton Mifflin Harcourt.

BBC. (2001, 29 de mayo). Q&A: What you need to know about echelon. *BBC News*. http://news.bbc.co.uk/2/hi/science/nature/1357513.stm

Benčić, F. M. y Žarko, I. P. (2018, July). Distributed ledger technology: Blockchain compared to directed acyclic graph. En A. M. Tjoa (presidente), *2018 IEEE 38th International Conference on Distributed Computing Systems (ICDCS)* (pp. 1569-1570). IEEE. https://doi.org/10.48550/arXiv.1804.10013

Blashfield, R. K. y Aldenderfer, M. S. (1988). The methods and problems of cluster analysis. En J. R. Nesselroade y R. B. Cattell *(eds.), Handbook of multivariate experimental psychology* (pp. 447-473). Springer.

Bower, J. L. y Christensen, C. M. (1995). Disruptive technologies: Catching the wave. *Harvard Business Review, 73(1)*, 43-53.

Campbell, D. (1988, 12 de agosto). Somebody's listening. *The New Statesman,* 10-12. https://bit.ly/3Vhn3Yj

Chaum, D. (1983). Blind signatures for untraceable payments. En D. Chaum, R. L. Rivest y A. T. Sherman (eds.), *Advances in Cryptology Proceedings of Crypto 82* (pp. 199-203). Springer.

Chaum, D. (1985). Security without identification: Transaction systems to make big brother obsolete. *Communications of the ACM, 28*(10), 1030-1044. https://doi.org/10.1145/4372.4373

Christensen, C. M. (1997). *The innovator's dilemma: When new technologies cause great firms to fail.* Harvard Business School Press.

Cortada de Kohan, N. (2008). Los sesgos cognitivos en la toma de decisiones. *International Journal of Psychological Research, 1*(1), 68-73.

Crosby, M., Pattanayak, P., Verma, S. y Kalyanaraman, V. (2016). Blockchain technology: Beyond bitcoin. *Applied Innovation Review, 2*(6-10), 71.

De Reuver, M., Sørensen, C. y Basole, R. C. (2018). The digital platform: a research agenda. *Journal of Information Technology, 33*(2), 124-135. https://doi.org/10.1057/s41265-016-0033-3

Diffie, W. y Hellman, M. (1976). New directions in cryptography. *IEEE Transactions on Information Theory, 22*(6), 644-654. https://doi.org/10.1109/TIT.1976.1055638

Eisenmann, T. R., Parker, G. y Van Alstyne, M. W. (2006). Strategies for two-sided markets. *Harvard Business Review, 84*(10), 92.

Hassan, S. y De Filippi, P. (2017). The expansion of algorithmic governance: From code is law to law is code. Field actions science reports. *The Journal of Field Actions,* (17), 88-90.

Hughes, E. (1993, 9 de marzo). *A cypherpunk's manifesto.* Activism. http://www.activism.net/cypherpunk/manifesto.html

Hughes, L., Dwivedi, Y. K., Misra, S. K., Rana, N. P., Raghavan, V. y Akella, V. (2019). Blockchain research, practice and policy: Applications, benefits, limitations, emerging research themes and research agenda. *International*

Journal of Information Management, *49*, 114-129. https://doi.org/10.1016/j.ijinfomgt.2019.02.005

Hunter, R., Bellin, M., Liu, K., Picard, N. y Ethridge, D. (2020). *Global Top 100 companies by market capitalisation*. PricewaterhouseCoopers (PwC). https://www.pwc.com/gx/en/audit-services/publications/assets/pwc-global-top-100-companies-2021.pdf

Keele, S. (2007). *Guidelines for performing systematic literature reviews in software engineering* [EBSE Technical Report EBSE-2007-01; version 2.3]. Software Engineering Group School of Computer Science and Mathematics.

Lage, O. (2019). Blockchain: aplicaciones en la industria alimentaria. *ACTA/CL,* (69), 13-17.

Lage, O. (2019). *Blockchain: from industry 4.0 to the machine economy*. En C. Thomas, P. Fraga-Lamas y T. M. Fernández-Caramés (eds.), *Computer Security Threats (pp. 87-96)*. IntechOpen. https://doi.org/10.5772/intechopen.88694

Lage, O., de Diego, S., Urkizu, B., Gómez, E. y Gutiérrez, I. (2019). Blockchain Applications in Cybersecurity. En C. Thomas, P. Fraga-Lamas y T. M. Fernández-Caramés (eds.), *Computer Security Threats (pp. 76-86)*. IntechOpen. https://doi.org/10.5772/intechopen.90061

Lage, O. y Saiz-Santos, M. (2021). Blockchain and the decentralisation of the cybersecurity industry. *Dyna*, *96*(3), artículo 239. https://doi.org/10.6036/10188

Levy, S. (1993). *Crypto rebels*. Wired. https://www.wired.com/1993/02/crypto-rebels

Levy, S. (2001). *Crypto: How the code rebels beat the government – Saving privacy in the digital age*. Penguin.

Ljungqvist, A. y Wilhelm, W. J. Jr. (2003). IPO pricing in the dot-com bubble. *The Journal of Finance*, *58*(2), 723-752. https://doi.org/10.1111/1540-6261.00543

Ludlow, P. (1996). *High noon on the electronic frontier. Conceptual issues in cyberspace*. The MIT Press.

Lyons T, Courcelas L., Grandsenne J., Carrel E. y Timsit K. (2018). *Blockchain innovation in Europe.* EU Blockchain Observatory and Forum Thematic Report. https://amc.law/wp-content/uploads/2018/08/Blockchain-Innovation-in-Europe.pdf

MakerDAO. (2020, 16 de agosto). *The different types of cryptocurrency tokens explained.* https://blog.makerdao.com/the-different-types-of-cryptocurrency-tokens-explained

Marikyan, D., Papagiannidis, S., Rana, O. y Ranjan, R. (2021). Blockchain in a business model: Exploring benefits and risks. En D. Dennehy, A. Griva, N. Pouloudi, Y. K. Dwivedi, I. Pappas, y M. Mäntymäki (eds.), *Responsible AI and analytics for an ethical and inclusive digitized society. I3E 2021* (pp. 555-566). Springer. https://doi.org/10.1007/978-3-030-85447-8_46

Marra, A., Antonelli, P., Dell'Anna, L. y Pozzi, C. (2015). A network analysis using metadata to investigate innovation in clean-tech-Implications for energy policy. *Energy Policy, 86(C),* 17-26. https://doi.org/10.1016/j.enpol.2015.06.025

Morkunas, V. J., Paschen, J. y Boon, E. (2019). How blockchain technologies impact your business model. *Business Horizons, 62*(3), 295-306. http://dx.doi.org/10.1016/j.bushor.2019.01.009

Nakamoto, S. (2008). *Bitcoin: A peer-to-peer electronic cash system*. Bitcoin. https://bitcoin.org/bitcoin.pdf

Nickerson, R. C., Varshney, U. y Muntermann, J. (2013). A method for taxonomy development and its application in information systems. *European Journal of Information Systems, 22*(3), 336-359. https://doi.org/10.1057/ejis.2012.26

Orwell, G. (2013). *Nineteen eighty-four*. Penguin.

Osterwalder, A., Pigneur, Y. y Tucci, C. L. (2005). Clarifying business models: Origins, present, and future of the concept. *Communications of the Association for Information Systems, 16*(1), artículo 1. https://doi.org/10.17705/1CAIS.01601

Osterwalder, A., y Pigneur, Y. (2010). *Business model generation: a handbook for visionaries, game changers, and challengers (Vol. 1)*. John Wiley & Sons.

Parker, G. G. y Van Alstyne, M. W. (2005). Two-sided network effects: A theory of information product design. *Management Science, 51*(10), 1494-1504. https://doi.org/10.1287/mnsc.1050.0400

Pierce, K. J. (1984). Public cryptography, arms export controls, and the first amendment: A need for legislation. *Cornell International Law Journal, 17*(1), artículo 5.

Pouwelse, J., Garbacki, P., Epema, D. y Sips, H. (2005). The bittorrent p2p file-sharing system: Measurements and analysis. En M. Castro y R. van Renesse (eds.), *Peer-to-Peer Systems IV. IPTPS 2005* (pp. 205-216). Springer. https://doi.org/10.1007/11558989_19

Rahman, K. S. y Thelen, K. (2019). The rise of the platform business model and the transformation of twenty-first-century capitalism. *Politics & Society, 47*(2), 177-204. http://dx.doi.org/10.1177/0032329219838932

Schlecht, L., Schneider, S. y Buchwald, A. (2021). The prospective value creation potential of Blockchain in business models: a Delphi study. *Technological Forecasting and Social Change, 166(1),* artículo 120601. http://dx.doi.org/10.1016/j.techfore.2021.120601

Schulze, T., Seebacher, S. y Hunke, F. (2020). Conceptualizing the Role of Blockchain Technology in Digital Platform Business. En H. Nóvoa, M. Drăgoicea y N. Kühl (eds.), *Exploring Services Science. 10th International Conference, IESS 2020, Porto, Portugal, February 5–7, 2020, Proceedings* (pp. 150-163). Springer. http://dx.doi.org/10.1007/978-3-030-38724-2_11

Shafer, S. M., Smith, H. J. y Linder, J. C. (2005). The power of business models. *Business Horizons, 48*(3), 199-207. http://dx.doi.org/10.1016/j.bushor.2004.10.014

Subramanian, H. (2017). Decentralized blockchain-based electronic marketplaces. *Communications of the ACM, 61*(1), 78-84. https://doi.org/10.1145/3158333

Szabo, N. (1994). *Smart contracts* [manuscrito inédito]. http://web.archive.org/web/20080524040140/http://szabo.best.vwh.net/smart.contracts.html

Szabo, N. (1996). Smart contracts: building blocks for digital markets. *Extropy, 18(16)*.

Szabo, N. (1997). Formalizing and securing relationships on public networks. *First Monday, 2*(9). https://doi.org/10.5210/fm.v2i9.548

Treleaven, P., Brown, R. G. y Yang, D. (2017). Blockchain technology in finance. *Computer, 50*(9), 14-17. https://doi.org/10.1109/MC.2017.3571047

Van Dyck, M., Luettgens, D., Diener, K. y Pollok, P. (2020). From pipeline to platform: Managing risks of openness in an emerging industrial ecosystem. *Academy of Management Proceedings, 2020*(1), artículo 16878. http://dx.doi.org/10.5465/AMBPP.2020.16878abstract

Ward, J. H. Jr. (1963). Hierarchical grouping to optimize an objective function. *Journal of the American Statistical Association, 58*(301), 236-244. https://doi.org/10.1080/01621459.1963.10500845

Wigand, R. T. (2020). Whatever happened to disintermediation? *Electronic Markets, 30*(1), 39-47. https://doi.org/10.1007/s12525-019-00389-0

Zamyatin, Y. (1920). *Nosotros.* Seix Barral.

Zetzsche, D. A., Arner, D. W. y Buckley, R. P. (2020). Decentralized finance. *Journal of Financial Regulation, 6*(2), 172-203. https://doi.org/10.1093/jfr/fjaa010

Žiberna, A., Kejžar, N. y Golob, P. (2004). A comparison of different approaches to hierarchical clustering of ordinal data. *Metodološki zvezki, 1*(1), 57-73. https://doi.org/10.51936/tivd4881

Zutshi, A., Grilo, A. y Nodehi, T. (2021). The value proposition of blockchain technologies and its impact on Digital Platforms. *Computers & Industrial Engineering, 155,* artículo 107187. https://doi.org/10.1016/j.cie.2021.107187

Sección II: Conclusiones

7. Conclusiones

A partir del análisis sistemático tanto de la literatura, como de dos bases de datos elaboradas con este propósito, se han obtenido las siguientes conclusiones que se han dividido en apartados en función de los objetivos a las que hacen referencia:

1. **Impacto de la tecnología blockchain y aplicaciones (Objetivo 1)**
    1.1. Blockchain tiene un gran impacto en la economía. Se han analizado proyectos que implementan la tecnología blockchain en los principales sectores de actividad y, de forma similar, a otras tecnologías disruptivas como internet, vemos que la adopción de la tecnología blockchain se está desarrollando de forma global en todos los sectores. (Artículos 3 y 4)
    1.2. La investigación revela varios beneficios de blockchain en relación con el impulso de una industria sostenible. Blockchain aporta valor en la gestión de la sostenibilidad de la cadena de suministro, la trazabilidad, el comercio de emisiones y energético, los programas de gestión activa de la demanda, los programas de economía circular, así como en la incentivación de los comportamientos sostenibles mediante tokens blockchain que podrán ser canjeados por los usuarios por productos y servicios de su interés. (Artículo 1)
    1.3. Con respecto a la resiliencia industrial, es decir, la capacidad de adaptación y resistencia ante cualquier adversidad o cambio, la adopción de blockchain en el sector manufacturero ayuda a fomentar tanto la resiliencia de la cadena de suministro como la cibernética, ya que es una tecnología que ofrece integridad e inmutabilidad de las transacciones por diseño, generando como consecuencia una mayor confiabilidad entre las partes. (Artículo 1)

1.4. En lo que respecta a la adaptación de la industria a las personas, blockchain aporta interacciones que preservan la privacidad, así como una experiencia de usuario mejorada a través de la interoperabilidad de los sistemas industriales. (Artículo 1)

1.5. La tecnología blockchain ofrece grandes posibilidades a nivel tecnológico en el campo de la ciberseguridad, siendo especialmente útil para prevenir el punto único de fallo presente hoy en día en diferentes servicios críticos. Evitar este punto único de fallo en los sistemas de información puede suponer una mayor seguridad de los servicios digitales, aumentando así la disponibilidad de estos. (Artículo 2)

1.6. Blockchain puede a nivel de negocio impulsar la descentralización de la industria de la ciberseguridad. Ya existen los primeros avances en la creación de servicios de ciberseguridad descentralizados en los que los miembros de la comunidad responden de forma colectiva a la demanda. (Artículo 2)

2. Demanda e inversión real en tecnología blockchain (Objetivo 2)

2.1. La investigación revela que existe muy poca información real sobre la inversión en tecnología blockchain. Precisamente, una de las aportaciones de esta tesis es la creación de una base de datos con información detallada de más de cien contratos de validación y despliegue de tecnología blockchain en diferentes empresas y sectores. (Artículos 3 y 4)

2.2. Las empresas actualmente invierten en doce valores de negocio inducidos por la tecnología blockchain. Estos doce valores son los siguientes: descentralización de procesos, descentralización de modelos de negocio, trazabilidad de activos, trazabilidad/certificación de procesos, transparencia, gestión de activos compartidos, confiabilidad e integridad, automatización de procesos, contratos inteligentes, identidad digital, soberanía del dato y los servicios, y Machine Economy. (Artículos 3 y 4)

2.3. A pesar de que la descentralización de procesos y modelos de negocio, junto con el despliegue de smart contracts, son los valores más prometedores que ofrece la tecnología blockchain, solo representan el 6 % de la inversión de las empresas. (Artículos 3 y 4)

2.4. Las empresas que invierten en tecnología blockchain dan respuesta predominantemente a las siguientes necesidades: confiabilidad e integridad de su información, identidad digital y la gestión de activos compartidos. (Artículos 3 y 4)

2.5. La inversión que las empresas están realizando en valores más cortoplacistas y menos disruptivos (innovación sostenible) podría indicar que las empresas están tomando decisiones pragmáticas y se encuentran en un proceso de aprendizaje. Esto puede confirmar el hecho de que todavía estamos en fases iniciales de adopción de la tecnología blockchain, y las empresas necesitan aprender sobre la tecnología antes de emprender inversiones de mayor riesgo e incertidumbre. (Artículos 3 y 4)

2.6. Las empresas medianas (47,68 %) y las TIC (39,25 %) son las que más están invirtiendo en la tecnología blockchain. (Artículos 3 y 4)

3. Plataformas descentralizadas: taxonomía, arquetipos y nuevos modelos de negocio (Objetivos 3 y 4)

3.1. Las plataformas descentralizadas se definen en función de una taxonomía de veintitrés propiedades (véase apartado “5. Resultados/Discusión”), constituidas por una combinación de las propiedades de los modelos de plataforma y las redes blockchain. (Artículo 5)

3.2. Tres modelos de plataformas descentralizadas están emergiendo en la actualidad: hosted, federated y shared. (Artículo 5)

3.3. Las plataformas de tipo gestionado (hosted) representan, mayoritariamente, ecosistemas de plataforma que sacan provecho de la tecnología blockchain para alcanzar una mayor eficiencia en sus procesos, pero mantienen los rasgos de las plataformas tradicionales. Estas plataformas gestionadas (hosted) presentan, principalmente, los mismos modelos de colaboración tradicionales (propietarios y licenciamiento), con un modelo de colaboración cerrado (ya que no comparten la gobernanza a terceros), y presentan un nivel inferior de cooperación con los desarrolladores. Este tipo de entidades utilizan, principalmente, un token de utilidad que les permite monetizar su plataforma a través de un cargo por transacción u ofreciendo una curación de contenidos mejorada. (Artículo 5)

3.4. Las plataformas de tipo federado (federated) son utilizadas, fundamentalmente, por startups que crean su ecosistema en colaboración con la comunidad (joint venture) y son mucho más abiertas que las gestionadas (hosted). En muchos casos, tienen tres características singulares: el intercambio de información en la plataforma es su principal objetivo, ofrecen una curación de contenidos mejorada como una de sus principales estrategias de monetización y el producer evangelism es su estrategia de marketing prioritaria. Estas plataformas federadas apuestan claramente por el uso de tokens de utilidad y gobernanza; el primero, para incentivar a los prosumidores (usuarios que producen y consumen) y el segundo (que puede ser el mismo token con dos tipos de uso diferentes), para compartir la gobernanza con la comunidad. (Artículo 5)

3.5. Las plataformas de tipo compartido (shared) son las más disruptivas, comparten la gobernanza con la comunidad, no tienen una estrategia de monetización clara o visible y forman un ecosistema totalmente gratuito en el 21,05 % de los casos analizados. La falta de estrategia de monetización podría suponer un estímulo para la creación de nuevos modelos de negocio innovadores, teniendo en cuenta que algunos de estos modelos emergentes se están orientando fundamentalmente en el ahorro de recursos más que en la generación de nuevos ingresos. El modelo de plataforma compartido es, por tanto, el más disruptivo y el que amenaza inequívocamente la economía actual, sustentada en gran medida en modelos de negocio de plataforma. (Artículo 5)

3.6. Cerca de dos tercios de las plataformas evaluadas, concretamente los modelos federados y compartidos, proponen nuevos enfoques de relación con la comunidad, así como nuevos modelos de negocio. Los resultados sugieren diferentes motivaciones de los desarrolladores y emprendedores que cooperan por un objetivo común. (Artículo 5)

8. Futuras líneas de investigación

Se han identificado nueve áreas de trabajo relacionadas con la adopción de la tecnología blockchain en la industria 5.0 que deberán de ser estudiadas con mayor detalle en los próximos años, a medida que la industria 5.0 se vaya consolidando. Dentro de las nueve líneas de investigación (véase Figura 5.1) se deben, así mismo, destacar aquellas vinculadas a la aplicación de blockchain a la centralidad de las personas en la industria, ya que es un ámbito totalmente nuevo en el sector y de vital importancia para su futuro.

A su vez, la taxonomía de doce valores identificada (véase Artículo 4: Aplicaciones reales e inversión en blockchain), podrá servir de base para encontrar nuevas aplicaciones de la tecnología blockchain que no hayan sido consideradas en la literatura. Es decir, investigadores expertos en diferentes sectores podrán utilizar dicha taxonomía como guía para la identificación de nuevas aplicaciones de la tecnología blockchain en sus respectivos dominios.

Los tres arquetipos de plataformas que hemos identificado pueden servir como punto de partida para futuros estudios sobre la evolución y transformación de las plataformas descentralizadas en relación a los cambios en los mercados y la tecnología. Además, estos arquetipos también pueden ser objeto de estudios especializados para profundizar en su análisis.

De hecho, otra de las principales líneas de investigación que se abre con este trabajo es el análisis detallado de las plataformas descentralizadas de tipo compartido (*shared*) y sus modelos de negocio emergentes. Además, será necesario el estudio de cómo este modelo de negocio de plataforma descentralizada puede impactar en los modelos de plataforma actuales al ofrecer servicios equivalentes, pero de forma absolutamente abierta. En consecuencia, el servicio de estas plataformas descentralizadas de tipo compartido será ofrecido en muchas ocasiones sin ningún tipo de cuotas ni intermediarios, constituyendo un ahorro significativo de costes para los usuarios de estas emergentes plataformas descentralizadas.

Implicaciones para la gestión o práctica empresarial

Debemos destacar que como resultado de la investigación se ha descubierto que, aunque la descentralización de los modelos de negocio actualmente solo representa el 2 % de la inversión en tecnología blockchain, todos los sectores, excepto la construcción y los gobiernos, experimentan con la creación de nuevos modelos de plataforma descentralizados. Por eso sería conveniente analizar cómo evoluciona esta inversión en la descentralización de los modelos de negocio para comprender cómo se desarrolla la transición hacia nuevos modelos descentralizados.

Así mismo, los *practitioners* pueden utilizar los tres arquetipos de plataformas descentralizadas como modelos de referencia para diseñar sus propias plataformas. Esto dependerá de los objetivos que busquen y del modelo de relación deseado con la comunidad, ya que los tres arquetipos difieren en la forma en que involucran a la comunidad. Por último, para establecer su propio esquema de relación con la comunidad, los *practitioners* deben analizar y utilizar como base los nuevos modelos de relación emergentes en las plataformas de tipo federado y compartido.

Limitaciones del estudio

Es preciso analizar las limitaciones del propio estudio ya que éstas siempre abren paso a futuras líneas de investigación. Consideramos que la muestra de inversiones en proyectos blockchain es suficientemente representativa, y que una muestra mayor solo podría variar ligeramente los resultados. Sin embargo, es importante señalar que la muestra podría estar sesgada geográficamente debido a que la mayoría de las inversiones provienen de empresas europeas. Además, la adopción de la tecnología blockchain se encuentra en una etapa temprana, lo que significa que los investigadores podrían identificar nuevas aplicaciones en el futuro que no se han considerado en la muestra de inversiones en proyectos blockchain utilizada en nuestro estudio. Por lo tanto, sería recomendable realizar un nuevo estudio a medio plazo para identificar nuevas aplicaciones y analizar la evolución de la inversión en blockchain por parte de las empresas.

Es importante recordar que nos encontramos en una fase muy prematura en el desarrollo de las plataformas descentralizadas. En los próximos años, estos nuevos mercados descentralizados evolucionarán, al igual que los mercados electrónicos surgidos durante el auge de las puntocom evolucionaron de redes de dos partes iniciales a modelos multiparte más complejos en la actualidad. Los arquetipos de plataformas descentralizadas que hemos identificado podrían transformarse en el futuro, a medida que las plataformas descentralizadas se establezcan en la economía. Además, se espera que las propias tecnologías descentralizadas evolucionen para ofrecer nuevas oportunidades.

Sección III: Anexos

Trabajos Publicados o Aceptados

La divulgación de resultados de esta tesis doctoral ha sido en formato de 5 artículos de alto impacto. A continuación, en la Tabla 9.1, se expone la calidad de estos trabajos.

Tabla 0.1. Resumen de publicaciones y situación actual

Publicación	Año	Revista	Calidad de la revista	Situación
A1: Lage, O., Saiz-Santos, M., & Zarzuelo, J. M. (2023). Decentralized Industry 5.0: blockchain's contribution to industrial sustainability, resilience, and human-centricity. Dyna,	2023	DYNA	JCR JCI Q3	Aceptado
A2: Lage, O. y Saiz-Santos, M. (2021). Blockchain and the decentralisation of the cybersecurity industry. *Dyna, 96*(3), artículo 239.	2021	DYNA	JCR JCI Q3	Publicado
A3: Lage, O., Saiz-Santos, M. y Zarzuelo, J. M. (2021). The value and applications of blockchain technology in business: A systematic review of real use cases. En J. Prieto, A. Partida, P. Leitão y A. Pinto (eds.), III International Congress on Blockchain and Applications (pp. 149-160). Springer.	2021	Lecture Notes in Networks and Systems	Scopus Q4	Publicado
A4: Lage, O., Saiz-Santos, M. y Zarzuelo, J. M. (2022). Real business applications and investments in blockchain technology. Electronics, 11(3), artículo 438.	2022	Electronics	JCR JCI Q2	Publicado
A5: Lage, O., Saiz-Santos, M. y Zarzuelo, J. M. (2022). Decentralized platform economy: Emerging blockchain-based decentralized platform business models. Electronic Markets, 32(3), 1707-1723.	2022	Electronic Markets	JCR JCI Q1	Publicado

Artículo 1: Decentralized Industry 5.0: blockchain's contribution to industrial sustainability, resilience, and human-centricity

Lage, O., Saiz-Santos, M., & Zarzuelo, J. M. (2023). Decentralized Industry 5.0: blockchain's contribution to industrial sustainability, resilience, and human-centricity. *Dyna*, https://doi.org/10.6036/10804

Índices de impacto: JCR JIF Q3, JCR JCI Q3, Scopus Q3

Decentralized Industry 5.0: blockchain's contribution to industrial sustainability, resilience, and human-centricity

Oscar Lage[a,b]*, María Saiz-Santos[b] and José Manuel Zarzuelo[b]

[a]*TECNALIA, Basque Research and Technology Alliance (BRTA), Derio, Spain;*

[b]*Faculty of Economics and Business Administration, The University of the Basque Country, Bilbao, Spain*

* Correspondence: Oscar.Lage@tecnalia.com

Abstract

The emerging concept of Industry 5.0 presents new challenges related to sustainability, resilience, and worker welfare in industrial companies; challenges that are vital for industrial and social development in the coming years. We believe that blockchain can help to face these challenges thanks to the trust and security it provides in complex ecosystems such as industrial supply chains. To verify this hypothesis, this paper performs a Systematic Literature Review (SLR) based on two stages. A first stage focused on the analysis of publications related to blockchain and Industry 5.0. Being such a novel term and with limited literature, we complemented the analysis with a second stage in which we analyzed the benefits of blockchain on each of the three pillars of Industry 5.0: sustainability, resilience, and human-centricity. The results of the SLR confirm our initial hypothesis and provide details on how, and to what extent, blockchain can add value to each of the

three challenges of Industry 5.0, empowering at least nine use cases that will contribute to those challenges.

Keywords: blockchain, industry 5.0, sustainability, resilience, human-centricity, human centric

INTRODUCTION

More than a decade has passed since the concept of "Industry 4.0" was introduced at the Hannover Fair (Germany) in 2011. Industry 4.0 has grown in popularity and been implemented to varying degrees in the industrial sector over the past decade [1], becoming a priority for governments and policy makers.

In its conception, Industry 4.0 was not only focused on economic benefit, it was presented with a close connection to "green production", sustainable supply chain management, and an energy-efficient industry. However, the industry has prioritized digitization and artificial intelligence for increased efficiency, flexibility, and economic gains at the expense of social and environmental sustainability principles [2].

We are currently facing a new paradigm shift and the European Commission has recently presented a new evolution of the industry called Industry 5.0 [2]; that is mainly focused on people, sustainability, and industrial resilience.

Previous studies have already identified that about 25% of the investment in blockchain technology is being made in the area of Industry 4.0 [3], and that blockchain is also decentralizing the current Platform models [4]. Consequently, we wonder about the impact of blockchain technology on the future Industry 5.0.

Therefore, the objective of our study is to identify the contributions of blockchain technology to the new Industry 5.0.

METHODOLOGY

As can be seen in Figure 1, we have followed a three-phase methodological approach: Industry 5.0 concept review, Systematic Literature Review (SLR) based on two complementary studies, and results presentation.

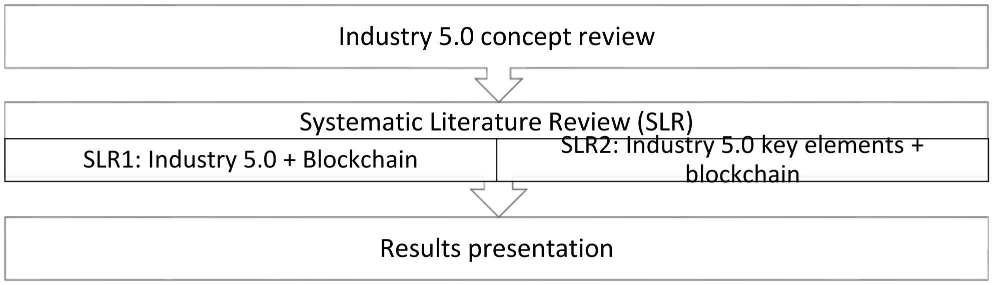

Figure 1. Global methodology workflow.

The first phase of the methodology analyzed Industry 5.0 concept to understand the objectives and challenges. The results are synthesized in the "Introduction to Industry 5.0" section.

After understanding the objectives of Industry 5.0, a second phase of the research was developed based on a Systematic Literature Review (SLR) following Keele's guidelines [4]. Keele’s guidelines for software engineering research were adapted from procedures used in medical and social science researcher, modified to address the specific challenges of this field.

Following Keele’s guidelines we planned the SLR by establishing the need, the research question, and the protocol. Next, we identified sources, main studies, and extraction of data.

In our research, the SLR is based on two complementary SLR studies (Figure 2). The first one (SLR1) tries to answer the following question " What is the applicability of blockchain technology in Industry 5.0?”. To answer this question following the protocol [4], on June 1, 2022, we launched a search in Scopus (source) that identified those documents that included the following keywords: “Industry 5.0” and blockchain. The format of the search was as follows: "KEY ("industry 5.0" blockchain)". The search was limited to Scopus due to its larger number of indexed journals compared to Web of Science (WoS), which is a common practice in SLRs, as noted by Paul and Criado [5]. We included various types of publications, such as congress papers, technical papers, research, and review papers, without any restrictions on language, although all retrieved publications from the search were in English.

Following the methodology, only five results (main studies) were identified in the SLR1 and analyzed, the results of which (descriptive synthesis) are shown below in "Industry 5.0 and Blockchain Related Work" section. According to Paul and Criado [5] and Paul *et al*. [6], a systematic literature review should include at least 40 articles to reveal knowledge clusters and identify research challenges. As our review did not meet these requirements, it does not provide these outcomes.

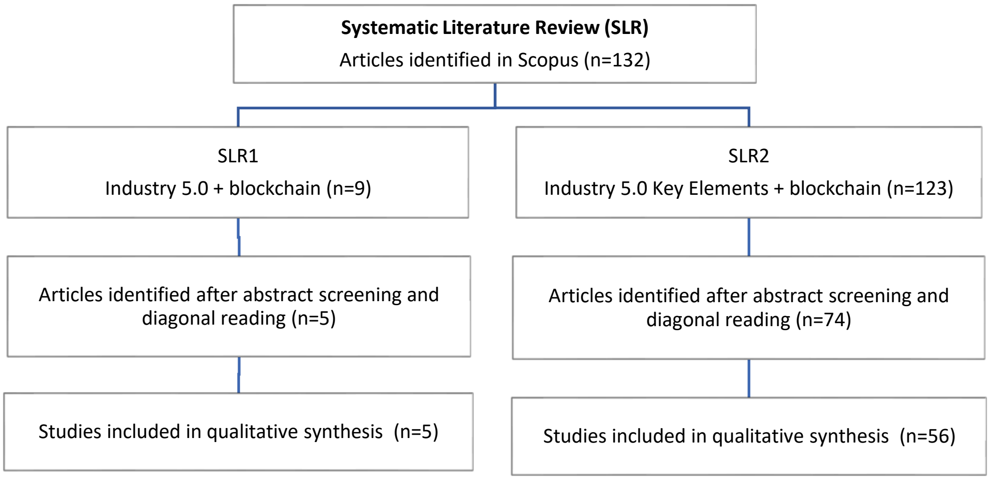

Figure 2. General workflow.

Given the limited literature on the topic from our first SLR, we conducted a second study (SLR2), a theory-based review [6]. The objective of SLR2 was to identify pre-Industry 5.0 studies that advanced the relationship between blockchain and any of the three Industry 5.0 pillars.

The research question in this second study (SLR2) was: "What is the applicability of blockchain technology in the three pillars of Industry 5.0 (sustainability, resilience and human-centricity)?". To answer this question, we conducted a comprehensive search for articles that included keywords related to blockchain and the three primary pillars of Industry 5.0, using the same protocol as SLR1 and searching on the same date. We used article keywords to conduct the search, rather than abstracts, to reduce the number of false positives. Searching abstracts resulted in a high percentage of false positives, which could have distorted the research results.

The resulting search performed on Scopus was: "KEY (((industrial OR industry OR iot) AND sustainability AND blockchain) OR ((industrial OR industry OR iot) AND (resiliency OR resilience) AND blockchain)

OR ((industrial OR industry OR iot) AND ("human centricity" OR "user experience" OR "user centred design" OR "user-centricity") AND blockchain))”.

The complex search returned a total of 123 results. After a first reading of titles, abstracts, 49 of the 123 papers initially identified in the search were discarded. Papers including the words "Industry", "Industrial", or "IoT" but not related to industrial applications were excluded from the SLR, such as those referring to tourism, user mobility, or cybersecurity.

After a full-text reading of the 74 resulting articles, 18 papers were discarded from the study as these papers mentioned blockchain technology but without providing any proposal, value, or use case to be included in the SLR (16), or showed signs of poor quality due to serious misconceptions about the blockchain technology or its platforms (2). Thus, as shown in Figure 3, the analysis was carried out based on the 56 papers that had the expected level of quality and that focused on our case study. In this second SLR we can meet the requirements and guidelines set by the experts [6,7].

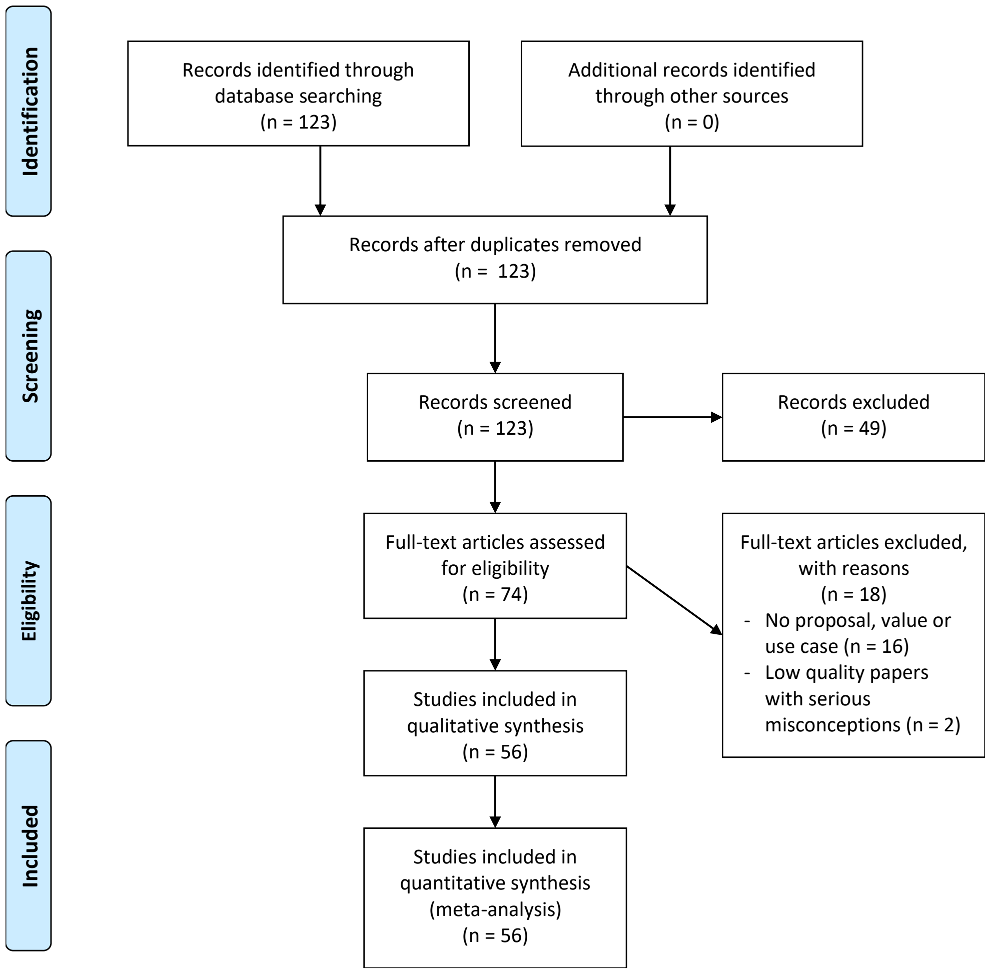

Figure 3. SLR2 PRISMA Flow Diagram.

We analyzed the content of 74 papers by creating an Excel document to record our findings. After reading each document, we identified whether it should be included in the study and recorded reasons for exclusion. Articles were classified by relevance to one of three Industry 5.0 pillars. Each article was analyzed by at least two authors to identify proposed applications, recorded in a spreadsheet with a justification for its functional area. It was noted that several articles covered comparable application domains, leading to the identification of nine distinct areas. Any discrepancies in the classification or definition of the areas were discussed and resolved by all authors in a joint analysis. This approach ensured the reliability and validity of the results.

We chose a descriptive synthesis for our study, following Keele's recommendations for journal or conference paper formats. Our synthesis is included in the "Blockchain's Contribution to Industry 5.0" section.

INTRODUCTION TO INDUSTRY 5.0

The European Commission defines Industry 5.0 in its report [2] as follows: "*Industry 5.0 recognises the power of industry to achieve societal goals beyond jobs and growth to become a resilient provider of prosperity, by making production respect the boundaries of our planet and placing the wellbeing of the industry worker at the centre of the production process*".

Industry must prioritize human-centricity, sustainability, and resilience to achieve genuine prosperity with social, environmental, and societal benefits. This requires a transformation in innovation towards responsible innovation with social impact, maximizing prosperity for all stakeholders. The three key elements (human-centricity, sustainability, and resilience) are interrelated and equally important.

Industry 5.0 prioritizes human-centricity in production processes, emphasizing technology adaptation to workers' needs and diversity. The focus is on worker well-being, safety, and mental welfare, and technology should not violate their privacy, autonomy, or dignity. In contrast, Industry 4.0 placed technology at the center of the industry, expecting workers to adapt to rapidly advancing technologies.

Sustainability is key to guaranteeing the future of the planet, and Industry 5.0 emphasizes the development of circularity processes that allow re-use, re-purpose and recycle natural resources, reducing waste and environmental impact. The use of renewable energies, control of emissions levels, and the optimization of energy consumption will also be key aspects to achieve a more sustainable industry [8, 9].

Geopolitical events and natural crises like Covid-19 have shown the need for a more resilient industry with strategic value chains that can ensure continuity during times of crisis. In addition, the increasing dependence on digital technologies makes the industry vulnerable to cyberattacks, which can cause physical harm and economic damage.

INDUSTRY 5.0 AND BLOCKCHAIN RELATED WORK

In this section we present the results of the first study (SLR1) in which we attempt to identify previous studies researching the applicability and connection of blockchain technology to the emerging Industry 5.0. The first study (SLR1) did not produce conclusive results due to limited literature, which led to a second study (SLR2) whose results are presented in the following section. Five prior articles on the use and impact of blockchain in Industry 5.0 are summarized before the analysis.

Gorodetsky, Larukchin, and Skobelev propose a platform for adaptive management of Industry 5.0 using a digital ecosystem that is self-organizing and blockchain-enabled [10]. Decentralized services can be created, which are not dependent on a service provider, resulting in more resilient and adaptable services.

Doyle-Kent and Kopacek provide a review of post-Industry 4.0 proposals and identify the need for a paradigm shift in the industry [11]. While blockchain is recognized as an enabling technology for Industry 4.0, the authors do not explicitly discuss its role in Industry 5.0. The study emphasizes the need for a user-centered and environmentally sustainable industry, with only general references to new technologies.

Rupa *et al*. suggest using blockchain to manage and distribute medical certificates to workers in Industry 5.0, which can reduce fraud and improve system availability [12].

Lu emphasizes that Industry 5.0 will enable cooperative collaboration between humans and robots, allowing people to rejoin the production process [13]. Personalized customization is identified as the key feature of Industry 5.0, facilitated by the integration of various actors in the value chain and consumers through blockchain and IoT. The author also notes that workers will benefit from a more spacious, friendly, and safe workspace.

Carayannis *et al*. examine the role of artificial intelligence, blockchain, and the Internet of Things (IoT) in the development of Industry 5.0 [14]. The authors identify the decentralized Web3 built on top of blockchain technology as a new web that enables users and companies to regain control of their data.

In summary, the work done up to date is insufficient and apparently disjointed as it does not provide clear answers on the role of blockchain in the new Industry 5.0.

BLOCKCHAIN'S CONTRIBUTION TO INDUSTRY 5.0

Given the insufficient available literature about the potential of blockchain technology in Industry 5.0, we have analyzed the relationship of blockchain technology with the main pillars of Industry 5.0 (SLR2). The study identified 9 blockchain functionalities in Industry 5.0, grouped by 3 pillars. Figure 4 summarizes these findings and will serve as a basis for future analysis. Table A.1 in the appendix lists the selected papers and their connection to each functionality.

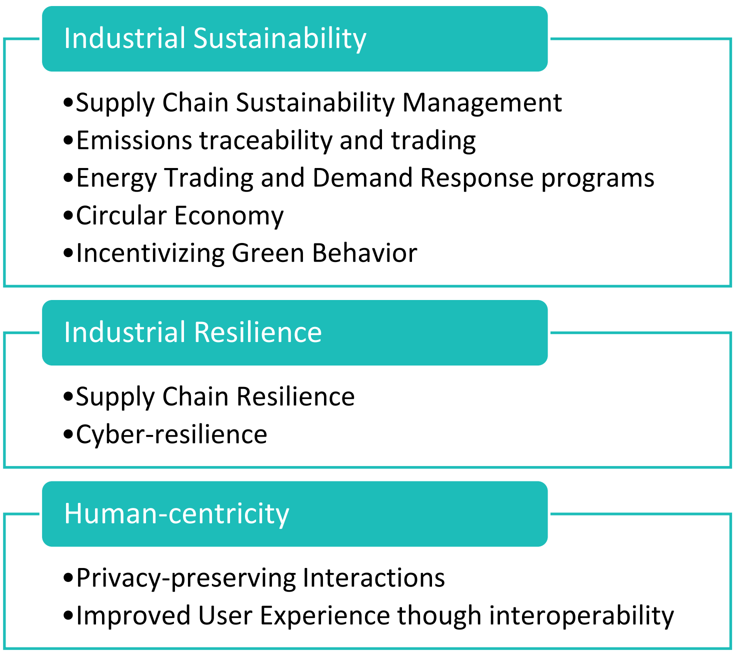

Figure 4. Blockchain applicability in Industry 5.0.

- ***Industrial Sustainability***

The SLR analysis suggests that managing supply chain sustainability, traceability, and emissions trading have significant potential for immediate impact in industrial sustainability. In contrast, incentivizing green behavior through blockchain tokens appears less mature. Five use cases have been identified where blockchain can enhance industrial sustainability, and increased academic activity and ongoing projects demonstrate the feasibility of these initiatives.

Supply Chain Sustainability Management

Authors highlight blockchain's potential in managing sustainable supply chains, although benefits may vary depending on the author's perspective. Leng *et al*. underline the value of blockchain in the entire value chain [15], but they highlight the use of blockchain to create a global manufacturing that allows the interoperability of data avoiding silos created by national laws, and introduce the concept of social manufacturing.

Other research identifies blockchain's ability to make sustainability-related information available to the end user for decision-making as part of its value [16-20], while several studies [21-36] highlights the impact of blockchain technology in supply chains based on the three dimensions of sustainability: environmental, economic, and social. Varriale *et al*. [22,23] also focus their contribution on maximizing the possibilities of blockchain traceability combined with the potential of IoT technology, which according to them would allow to reliably know the vehicle footprint, supply chains waste management, as well as to maximize the conservation of resources such as water in industries such as agri-food. Other authors also highlights a more sustainable food supply chain by tracing the impact of all stakeholders, including even farm-specific emissions measured by these IoT devices and unalterably recorded on the blockchain [25-30].

Ko *et al*. focus on the ability of blockchain to provide real-time traceability of assets in the value chain, resulting in cost savings [37]. Kramer *et al*. specifically discuss the advantages of vertical ecosystem architecture where one of the companies is responsible for coordinating supply chain activities [38].

Finally, Rane and Thakker introduce the concept of green procurement [39]. Blockchain can provide greater trustworthiness in the process of acquiring goods and services. Buyers can identify those options that minimize the use of energy and efficient waste disposal thanks to the blockchain traceability of products.

Emissions Traceability and Trading

Blockchain can be advantageous in the environmental impact assessment of industries and their products, specifically in traceability and trading of emissions. It enables peer-to-peer buying and selling between participants in a decentralized way, ensuring the auditability and immutability of the process, potentially reducing fraud and environmental impact. [15, 22, 38-45]. These blockchain Emission Trading Schemes (ETS) can be useful for fashion apparel manufacturing industry, where traceability is crucial to manage the environmental impact caused by manufacturing process and raw material used.

Another interesting concept introduced by different authors is Life Cycle Assessment (LCA) [46-49], which is currently mainly focused on product traceability with blockchain, but could be used for environmental impact assessment of products, maintaining accurate carbon footprint information and creating an incentive structure based on it. This can offer traceable environmental impact information for purchasing decisions, encouraging users to be more aware of sustainability.

Energy Trading and Demand Response Programs

The exchange and commercialization of energy is an area constantly pointed out by different authors where blockchain could bring great added value to the industry [40, 41, 50, 51]. All of them make special emphasis on the fact that P2P energy markets promote the use and generation of green energies by valorizing the surplus of renewables.

Megha *et al*. also propose the incorporation of other actors in the ecosystem to enable the generation of decentralized demand response programs among various stakeholders in the energy ecosystem [41]. Demand response programs with P2P marketplaces and blockchain can improve grid sustainability by decentralizing management and coordination of stakeholders, flattening demand curves, and avoiding immediate energy generation from highly pollutant sources.

Circular Economy

Blockchain can promote the circular economy by lowering transaction costs, enhancing communication and performance across the supply chain, protecting human rights, and ultimately reducing carbon footprint [22, 47, 52, 53].

Alves *et al*. also add the possibility of incorporating IoT sensors to the circular economy process [54]. IoT devices can automate traceability and reduce costs, enabling economic sustainability in the circular economy, particularly in low-priced sectors like textiles where the environmental impact is high. This is crucial for promoting sustainability in these sectors.

Incentivizing Green Behavior

Esmaeilian *et al*. consider that consumer green behavior is vital for sustainability [21]. Green attitudes include recycling, waste reduction, local consumption, purchase of refurbished or energy-efficient products, energy conservation, reuse, repair, maintenance, and sharing.

Incentivizing sustainable behavior among consumers is difficult without incentives. Token offerings can incentivize sustainability by financing green attitudes. Tokens can be exchanged for products, creating a reward system to promote sustainable behavior among stakeholders in the product life cycle.

- ***Industrial Resilience***

Industry 5.0 must increase its resilience to unforeseen events, such as supply chain ruptures or cyber-attacks. Blockchain can help improve industrial resilience in supply chain and cyber resilience use cases, with supply chain resilience having a greater impact on society and the economy.

Supply Chain Resilience

According to Maryniak *et al*. [55] "a resilient chain is a chain with a high level of visibility of the goods being moved that can adapt elastically to changes in the environment. It is also a chain in which the partners trust each other and care for the security of goods, transactions, and collected data". The authors say that "blockchain technology, with the support of other technologies, could allow for the development of the attributes of resilient chains". Blockchain makes supply chains more transparent and reliable by providing a single, agreed-upon view of information and a non-repudiation mechanism. This generates resilient supply chains and improves the resilience of industries.

Asante *et al*. conducted a review in which they identified that supply chain management must adhere to the three core fundamental security principles to offer resilience to the supply chain: confidentiality, integrity, and availability [56]. Taqui *et al*. present a framework for achieving resilient supply chains by reviewing the literature, presenting the benefits of using blockchain technology for supply chain resilience [57].

Ivanov *et al*. proposed a supply chain risk analytics framework that includes the concept of "digital supply chain twins" for simulating the impact of changes on the supply chain [58,59]. In this framework blockchain plays an important role by performing advanced tracking and tracing of data. Lohmer *et al*. also simulated the enhanced resilience of supply chains that adopt blockchain technology for collaboration, utilizing intelligent agents in their simulation [60].

Cyber-resilience

Other authors focus their studies on cyber-resilience [61-65]. Among them, Balistri *et al*. offer digital resilience by using blockchain as a secure repository of the topology, access rules, and recovery information of the infrastructure itself [61, 62]. Gajek *et al*. highlight the advantages of blockchain technology in the event of an industrial cyber-attack such as Stuxnet [63]. Other authors mention general benefits of blockchain for resilience.

Finally, Babich and Hilary focus their study on the benefits of blockchain technology related to operations management such as visibility, aggregation, validation, automation, and resilience [66]. However, the paper also highlights weaknesses of the technology such as lack of privacy, standardization, or inefficiency, among others.

- ***Human-centricity***

Studying the worker experience with new technologies will become increasingly important in the future, particularly in the context of Industry 5.0. Although research in this area is gaining attention from the scientific community, there have been limited advancements linked to blockchain.

In our SLR we have found two areas of study related to the benefit of blockchain on user experience in an industrial context. Although, the number of studies is limited, it is sufficient to give us a couple of clear trends. Research should focus on developing a blockchain-based user experience to enhance user satisfaction, which is anticipated to be an important area of development in the near future.

Privacy-preserving Interactions

Our analysis indicates that the scientific community has primarily focused on the privacy of user data through the use of blockchain in conjunction with privacy-preserving computation techniques such as homomorphic encryption, secure multi-party computation, or federated learning [67]. Blockchain manages and enforces access and policies of user data, ensuring data privacy for both third parties and users, allowing extraction of aggregate knowledge without compromising individual privacy.

Similarly, Bosri *et al*. propose to create privacy preserving computation architectures using edge computing for the processing of data disassociated from user identities [68]. By storing records of data transactions instead of the data itself, blockchain provides users with control over who can access their data, ensuring data privacy and maintaining data integrity and provenance in relationships with third parties. This type of techniques could help to create a more personalized environment for workers, respecting their privacy. In fact, it fits perfectly with the new Self-Sovereign Identity (SSI) models that could also be directly applied to the user's relationship with the industrial work environment.

Improved User Experience Through Interoperability of Industrial Systems

Other authors present in their research the benefits of blockchain technology for promoting the interoperability of different industrial systems, or IoT systems in general [69,70]. Improved interoperability among systems will create a more intuitive and user-centered experience for users in the future, with integrated data and actions reflected across multiple systems.

In the case of Tang *et al*. they also propose a novel way to achieve such interoperability using the IoT Passport, which is inspired by international passports for people [70]. The IoT Passport will enable devices to establish arbitrary trust relationships and specific collaboration rules. The implementation of this passport could follow the SSI verifiable credentials standard, leading to further increased interoperability.

DISCUSSION

The main contribution of this paper is the discovery of 9 knowledge clusters that answer the main question of the article, which is to identify the contribution of blockchain to the new paradigm of Industry 5.0.

To the best of our knowledge, the authors are not aware of any other SLR that has analyzed the relationship between Industry 5.0 and blockchain. The nine areas that our SLR has identified can also be the basis for future research on the use and application of blockchain technology, thus accelerating the creation of knowledge linked to Industry 5.0 and its adoption by industry.

It should be noted that blockchain still has some limitations, particularly in terms of scalability and energy consumption. These limitations may potentially pose a challenge to the identified use cases for blockchain in different industries. Nonetheless, there are promising developments in these areas, including the integration of alternative consensus mechanisms, which may help to address these challenges [71], but we must wait for these studies to obtain results before the use cases linked to emissions traceability, energy trading, circular economy and incentivization of green behaviors become truly viable.

These 9 application areas identified in our study show that blockchain, through its adoption in Industry 5.0, can make a clear impact on the sustainability and resilience of our economy, environment, and society.

CONCLUSIONS AND FUTURE WORK

A systematic literature review was conducted to explore the role of blockchain technology in the emerging Industry 5.0. While blockchain has been a part of enabling technologies for Industry 4.0, there are no studies explicitly analyzing its application in Industry 5.0 due to the novelty of this industrial paradigm.

Only five studies mentioned blockchain and Industry 5.0, without exploring the possibilities of blockchain in this context, as discussed in the "Industry 5.0 and Blockchain Related Work" section. This new industrial paradigm prioritizes environmental, social, and economic sustainability, with a focus on the human factor. These results are not conclusive, and that is why we have conducted the study from another perspective.

The second orientation analyzes how blockchain contributes to the three main pillars of Industry 5.0. The results of the study provide a clear understanding of how blockchain supports the Industry 5.0 based on existing literature prior to the conceptualization of Industry 5.0. Thanks to this second phase of the study, a more extensive, detailed, and precise results have been obtained. As demonstrated in the first SLR study, there was a gap in the literature that we intend to fill with the present study. To the authors' knowledge, there is no other SLR that analyzes the application and impact of blockchain in Industry 5.0.

Our study identifies 9 areas of knowledge in which blockchain can benefit Industry 5.0, these nine areas described in the section "Blockchain's contribution to Industry 5.0" are the main contribution of the study, and the basis for future studies. Figure 5 shows a summary of the research agenda for each of the areas identified.

Industry 5.0 Pillar	**Research Area**	**Research Challenge**
Sustainability	Supply Chain Sustainability Management	Maximize blockchain's benefits for sustainable supply chains, including global interoperability and resource conservation, while promoting green procurement practices through traceability.
	Emissions traceability and trading	Develop blockchain solutions for emissions traceability/trading and LCA with blockchain for environmental impact assessment, while incentivizing sustainability and addressing implementation barriers
	Energy Trading and Demand Response programs	Develop blockchain solutions for P2P energy markets and decentralized demand response programs, and leverage blockchain for promoting circular economy, reducing carbon footprint, while using IoT sensors to automate traceability and reduce costs in low-priced sectors
	Circular Economy	Incorporate blockchain and IoT devices in the circular economy process, automating traceability and reducing costs, particularly in low-priced sectors like textiles where the environmental impact is high, to promote sustainability in these sectors.
	Incentivizing Green Behavior	Incentivize sustainable behavior among consumers through token offerings that create a reward system to promote green attitudes
Resilience	Supply Chain Resilience	Improve blockchain technology to create transparent and trustworthy supply chains with high visibility, security, and adaptability
	Cyber-resilience	Explore the use of blockchain to enhance cyber-resilience and secure industrial systems against cyber attacks
Human-centricity	Privacy-preserving Interactions	Empower users to control data access in their relationships with third parties, fostering personalized work environments with maintained data integrity and provenance.
	Improved User Experience through interoperability	Develop blockchain-based solutions to enhance interoperability between industrial and IoT systems, enabling a more user-centered experience with integrated data and actions reflected across multiple systems

Figure 5. Future research agenda for each area.

One limitation of our study is the early stage of Industry 5.0 and the immaturity of blockchain technology. While our study includes a substantial number of papers (51), future research is likely to produce more publications in this area. Thus, it may be necessary to conduct a new SLR in the coming years to expand and enhance the current study.

In addition, there may be studies related to the use of blockchain technology in industrial sustainability, resilience, or human centricity that have not been applied to industry and therefore have not been identified even though they could be applicable to the industrial context.

Our work can guide researchers who want to explore how blockchain technology contributes to Industry 5.0. The 9 areas identified in the SLR represent new research topics for the benefits of blockchain adoption in Industry 5.0, which offer a great scientific interest for the community. Therefore, these new lines of research should be explored in greater depth, with special emphasis on those linked to the relationship between blockchain and user-centricity, since it is a very understudied concept in the field of industry, and which is of vital importance for Industry 5.0.

Practitioners can use our study to identify opportunities for creating products and services that meet the needs of Industry 5.0 in the 9 areas identified. This presents a chance for startups to specialize in addressing these challenges.

REFERENCES

1. LIAO, Yongxin, et al. Past, present and future of Industry 4.0-a systematic literature review and research agenda proposal. International journal of production research, 2017, vol. 55, no 12, p. 3609-3629.
2. BREQUE, Maija, et al. Industry 5.0: towards a sustainable, human-centric and resilient European industry. Luxembourg, LU: European Commission, Directorate-General for Research and Innovation, 2021.
3. LAGE, Oscar; SAIZ-SANTOS, María; ZARZUELO, José Manuel. Real business applications and investments in blockchain technology. Electronics, 2022, vol. 11, no 3, p. 438. https://doi.org/10.3390/electronics11030438
4. LAGE, Oscar; SAIZ-SANTOS, María; ZARZUELO, José Manuel. Decentralized platform economy: emerging blockchain-based decentralized platform business models. Electronic Markets, 2022, vol. 32, no 3, p. 1707-1723.
5. KEELE, Staffs. Guidelines for performing systematic literature reviews in software engineering (Vol. 5). Technical report, Ver. 2.3 EBSE Technical Report. EBSE, 2007.
6. PAUL, Justin; CRIADO, Alex Rialp. The art of writing literature review: What do we know and what do we need to know?. *International Business Review*, 2020, vol. 29, no 4, p. 101717.
7. PAUL, Justin, et al. Scientific procedures and rationales for systematic literature reviews (SPAR-4-SLR). *International Journal of Consumer Studies*, 2021, vol. 45, no 4, p. O1-O16.
8. KHAN, Syed Abdul Rehman, et al. A state-of-the-art review and meta-analysis on sustainable supply chain management: Future research directions. Journal of Cleaner Production, 2021, vol. 278, p. 123357.

9. ROMERO-CASTRO, Noelia; LÓPEZ-CABARCOS, M. Ángeles; PINEIRO-CHOUSA, Juan. Uncovering complexity in the economic assessment of derogations from the European industrial emissions directive. Journal of Innovation & Knowledge, 2022, vol. 7, no 1, p. 100159.
10. GORODETSKY, Vladimir; LARUKCHIN, Vladimir; SKOBELEV, Petr. Conceptual model of digital platform for enterprises of industry 5.0. In Intelligent Distributed Computing XIII. Springer International Publishing, 2020. p. 35-40.
11. DOYLE-KENT, Mary; KOPACEK, Peter. Industry 5.0: Is the manufacturing industry on the cusp of a new revolution?. In Proceedings of the International Symposium for Production Research 2019. Springer International Publishing, 2020. p. 432-441.
12. RUPA, Ch, et al. Industry 5.0: Ethereum blockchain technology based DApp smart contract. Math. Biosci. Eng, 2021, vol. 18, no 5, p. 7010-7027.
13. LU, Yang. The current status and developing trends of Industry 4.0: A Review. Information Systems Frontiers, 2021, p. 1-20.
14. CARAYANNIS, Elias G., et al. Known unknowns in an era of technological and viral disruptions—implications for theory, policy, and practice. Journal of the knowledge economy, 2021, p. 1-24.
15. LENG, Jiewu, et al. Blockchain-empowered sustainable manufacturing and product lifecycle management in industry 4.0: A survey. Renewable and sustainable energy reviews, 2020, vol. 132, p. 110112.
16. AHMED, Wafaa AH; MACCARTHY, Bart L. Blockchain-enabled supply chain traceability in the textile and apparel supply chain: a case study of the fiber producer, lenzing. Sustainability, 2021, vol. 13, no 19, p. 10496.
17. NOONAN, Jean; DORAN, Patrick. Blockchain's Impact on Consumer's Perspective in the Luxury Fashion Industry: A Position Paper. In Responsible AI and Analytics for an Ethical and Inclusive Digitized Society: 20th IFIP WG 6.11 Conference on e-Business, e-Services and e-Society, I3E 2021, Galway, Ireland, September 1–3, 2021, Proceedings 20. Springer International Publishing, 2021. p. 596-606.
18. LUZZANI, Gloria, et al. Blockchain technology in wine chain for collecting and addressing sustainable performance: An exploratory study. Sustainability, 2021, vol. 13, no 22, p. 12898.
19. TSOUKAS, Vasileios, et al. Blockchain technology in food supply chain: A state of the art. In *2021 6th South-East Europe Design Automation, Computer Engineering, Computer Networks and Social Media Conference (SEEDA-CECNSM)*. IEEE, 2021. p. 1-8.
20. PAUL, Tripti, et al. The impact of blockchain technology on the tea supply chain and its sustainable performance. Technological Forecasting and Social Change, 2021, vol. 173, p. 121163.
21. ESMAEILIAN, Behzad, et al. Blockchain for the future of sustainable supply chain management in Industry 4.0. Resources, Conservation and Recycling, 2020, vol. 163, p. 105064.
22. VARRIALE, Vincenzo, et al. The unknown potential of blockchain for sustainable supply chains. Sustainability, 2020, vol. 12, no 22, p. 9400.

23. VARRIALE, Vincenzo, et al. Sustainable supply chains with blockchain, IoT and RFID: A simulation on order management. Sustainability, 2021, vol. 13, no 11, p. 6372.
24. KHANFAR, Ahmad AA, et al. Applications of blockchain technology in sustainable manufacturing and supply chain management: A systematic review. Sustainability, 2021, vol. 13, no 14, p. 7870.
25. EASHWAR, S.; CHAWLA, Paras. Evolution of agritech business 4.0–architecture and future research directions. In IOP Conference Series: Earth and Environmental Science. IOP Publishing, 2021. p. 012011.
26. VARAVALLO, Giuseppe, et al. Traceability platform based on green blockchain: an application case study in dairy supply chain. *Sustainability*, 2022, vol. 14, no 6, p. 3321.
27. FENG, Huanhuan, et al. Applying blockchain technology to improve agri-food traceability: A review of development methods, benefits and challenges. Journal of cleaner production, 2020, vol. 260, p. 121031.
28. VENKATESH, V. G., et al. System architecture for blockchain based transparency of supply chain social sustainability. *Robotics and Computer-Integrated Manufacturing*, 2020, vol. 63, p. 101896.
29. NURGAZINA, Jamilya, et al. Distributed ledger technology applications in food supply chains: A review of challenges and future research directions. Sustainability, 2021, vol. 13, no 8, p. 4206.
30. SONG, Luona, et al. Blockchain-based flexible double-chain architecture and performance optimization for better sustainability in agriculture. CMC-Computers Materials & Continua, 2021, vol. 68, no 1, p. 1429-1446.
31. DIETRICH, Fabian, et al. Smart contract-based blockchain solution to reduce supply chain risks. In Advances in Production Management Systems. Towards Smart and Digital Manufacturing: IFIP WG 5.7 International Conference, APMS 2020, Novi Sad, Serbia, August 30–September 3, 2020, Proceedings, Part II. Springer International Publishing, 2020. p. 165-173.
32. SUNMOLA, Funlade T. Context-aware blockchain-based sustainable supply chain visibility management. Procedia Computer Science, 2021, vol. 180, p. 887-892.
33. RADONIC, Nebojsa; KILDETOFT, Mikkel Boding; BECK, Roman. Using blockchain to sustainably manage containers in international shipping. In Proceedings of the International Conference on Information Systems. 2020. p. 1446.
34. SAHOO, Saumyaranjan, et al. Blockchain for sustainable supply chain management: Trends and ways forward. *Electronic Commerce Research*, 2022, p. 1-56.
35. YOON, Jong Han; PISHDAD-BOZORGI, Pardis. State-of-the-art review of blockchain-enabled construction supply chain. Journal of construction engineering and management, 2022, vol. 148, no 2, p. 03121008.
36. ZHANG, Han. Blockchain facilitates a resilient supply chain in steel manufacturing under covid-19. In *22nd European conference on knowledge management, ECKM 2021. Academic Conferences and Publishing International Limited*. 2021. p. 964-972.

37. KO, Taehyun; LEE, Jaeram; RYU, Doojin. Blockchain technology and manufacturing industry: Real-time transparency and cost savings. *Sustainability*, 2018, vol. 10, no 11, p. 4274.
38. KRAMER, Michael Paul; BITSCH, Linda; HANF, Jon. Blockchain and its impacts on agri-food supply chain network management. *Sustainability*, 2021, vol. 13, no 4, p. 2168.
39. RANE, Santosh B.; THAKKER, Shivangi Viral. Green procurement process model based on blockchain–IoT integrated architecture for a sustainable business. *Management of Environmental Quality: An International Journal*, 2020, vol. 31, no 3, p. 741-763.
40. FU, Bailu; SHU, Zhan; LIU, Xiaogang. Blockchain enhanced emission trading framework in fashion apparel manufacturing industry. Sustainability, 2018, vol. 10, no 4, p. 1105.
41. MEGHA, Swati, et al. A survey of blockchain-based solutions for energy industry. In *Web, Artificial Intelligence and Network Applications: Proceedings of the Workshops of the 34th International Conference on Advanced Information Networking and Applications (WAINA-2020)*. Springer International Publishing, 2020. p. 787-797.
42. POPA, Razvan Alexandru, et al. Hybrid platform for assessing air pollutants released from animal husbandry activities for sustainable livestock agriculture. *Sustainability*, 2021, vol. 13, no 17, p. 9633.
43. CARRIÈRES, Vincent, et al. Measuring the Value of Blockchain Traceability in Supporting LCA for Textile Products. Sustainability, 2022, vol. 14, no 4, p. 2109.
44. LI, Qian; WANG, Yingli. Blockchain's role in supporting circular supply chains in the built environment. In 2021 IEEE International Conference on Blockchain (Blockchain). IEEE, 2021. p. 578-583.
45. KEALLEY, Mat, et al. Can blockchain technology show provenance and increase value for Australian sugar?. In 42nd Australian Society of Sugar Cane Technologists Conference 2021, ASSCT 2021, p. 79-86
46. CARRIÈRES, Vincent; LEMIEUX, Andrée-Anne; PELLERIN, Robert. Opportunities of blockchain traceability data for environmental impact assessment in a context of sustainable production. In *Advances in Production Management Systems. Artificial Intelligence for Sustainable and Resilient Production Systems: IFIP WG 5.7 International Conference, APMS 2021, Nantes, France, September 5–9, 2021, Proceedings, Part I*. Springer International Publishing, 2021. p. 124-133.
47. KHAN, Syed Abdul Rehman, et al. Industry 4.0 and circular economy practices: A new era business strategies for environmental sustainability. Business Strategy and the Environment, 2021, vol. 30, no 8, p. 4001-4014.
48. MATTILA, Juri, et al. Blockchain-based deployment of product-centric information systems. *Computers in Industry*, 2021, vol. 125, p. 103342.
49. ZHANG, Abraham, et al. Blockchain-based life cycle assessment: An implementation framework and system architecture. *Resources, Conservation and Recycling*, 2020, vol. 152, p. 104512.

50. WÖRNER, Anselma Meret, et al. Peer-to-peer energy trading in the real world: Market design and evaluation of the user value proposition. *ICIS 2019 Proceedings*, 2019, vol. 2, p. 1221.
51. CHACRA, Suzane Abou; SIRELI, Yesim; CALI, Umit. A review of worldwide blockchain technology initiatives in the energy sector based on go-to-market strategies. *International Journal of Energy Sector Management*, 2021, vol. 15, no 6, p. 1050-1065.
52. TANG, Yuk Ming, et al. Industry 4.0 technology and circular economy practices: business management strategies for environmental sustainability. *Environmental Science and Pollution Research*, 2022, vol. 29, no 33, p. 49752-49769.
53. UPADHYAY, Arvind, et al. Blockchain technology and the circular economy: Implications for sustainability and social responsibility. Journal of Cleaner Production, 2021, vol. 293, p. 126130.
54. ALVES, Luís, et al. Towards circular economy in the textiles and clothing value chain through blockchain technology and IoT: A review. *Waste Management & Research*, 2022, vol. 40, no 1, p. 3-23.
55. MARYNIAK, Anna, et al. Creating Resilient Supply Chains Using Combination of Blockchain Technology and Different 4.0 Technologies. In *Information and Software Technologies: 27th International Conference, ICIST 2021, Kaunas, Lithuania, October 14–16, 2021, Proceedings 27*. Springer International Publishing, 2021. p. 16-31.
56. ASANTE, Mary, et al. Distributed ledger technologies in supply chain security management: A comprehensive survey. *IEEE Transactions on Engineering Management*, 2021.
57. TAQUI, Wissal, et al. Blockchain technology for supply chain resilience. En *2022 14th International Colloquium of Logistics and Supply Chain Management (LOGISTIQUA)*. IEEE, 2022. p. 1-6.
58. IVANOV, Dmitry; DOLGUI, Alexandre; SOKOLOV, Boris. The impact of digital technology and Industry 4.0 on the ripple effect and supply chain risk analytics. *International Journal of Production Research*, 2019, vol. 57, no 3, p. 829-846.
59. IVANOV, Dmitry, et al. Digital supply chain twins: Managing the ripple effect, resilience, and disruption risks by data-driven optimization, simulation, and visibility. *Handbook of ripple effects in the supply chain*, 2019, p. 309-332.
60. LOHMER, Jacob; BUGERT, Niels; LASCH, Rainer. Analysis of resilience strategies and ripple effect in blockchain-coordinated supply chains: An agent-based simulation study. *International journal of production economics*, 2020, vol. 228, p. 107882.
61. BALISTRI, Eugenio, et al. Blockchain for increased cyber-resiliency of industrial edge environments. In *2020 IEEE International Conference on Smart Computing (SMARTCOMP)*. IEEE, 2020. p. 1-8.
62. BALISTRI, Eugenio, et al. Design Guidelines and a Prototype Implementation for Cyber-Resiliency in IT/OT Scenarios Based on Blockchain and Edge Computing. *IEEE Internet of Things Journal*, 2021, vol. 9, no 7, p. 4816-4832.

63. GAJEK, Sebastian; LEES, Michael; JANSEN, Christoph. IIoT and cyber-resilience: Could blockchain have thwarted the Stuxnet attack?. *AI & society*, 2021, vol. 36, p. 725-735.
64. KUMAR, Nallapaneni Manoj, et al. Distributed energy resources and the application of AI, IoT, and blockchain in smart grids. *Energies*, 2020, vol. 13, no 21, p. 5739.
65. AHI, Aman; SINGH, Ajay Vikram. Role of distributed ledger technology (dlt) to enhance resiliency in internet of things (iot) ecosystem. In *2019 Amity International Conference on Artificial Intelligence (AICAI)*. IEEE, 2019. p. 782-786.
66. BABICH, Volodymyr and HILARY, Gilles. Distributed Ledgers and Operations: What Operations Management Researchers Should Know About Blockchain Technology (August 27, 2018). In Forthcoming in Manufacturing & Service Operations Management, Georgetown McDonough School of Business Research Paper No. 3131250, Available at SSRN: https://ssrn.com/abstract=3131250 or http://dx.doi.org/10.2139/ssrn.3131250.
67. JAIN, Saurabh, et al. Blockchain and autonomous vehicles: Recent advances and future directions. *IEEE Access*, 2021, vol. 9, p. 130264-130328.
68. BOSRI, Rabeya, et al. HIDEchain: A user-centric secure edge computing architecture for healthcare IoT devices. In *IEEE INFOCOM 2020-IEEE Conference on Computer Communications Workshops (INFOCOM WKSHPS)*. IEEE, 2020. p. 376-381.
69. ALASBALI, Nada; AZZUHRI, Saaidal Razalli; SALLEH, Rosli. A blockchain-based smart network for IoT-driven smart cities. In *Proceedings of the 2nd International Electronics Communication Conference*. 2020. p. 17-23.
70. TANG, Bo, et al. Iot passport: A blockchain-based trust framework for collaborative internet-of-things. In *Proceedings of the 24th ACM symposium on access control models and technologies*. 2019. p. 83-92.
71. SEDLMEIR, Johannes, et al. The energy consumption of blockchain technology: Beyond myth. *Business & Information Systems Engineering*, 2020, vol. 62, no 6, p. 599-608.

Artículo 2: Blockchain and the decentralization of the cybersecurity industry

Lage, O. y Saiz-Santos, M. (2021). Blockchain and the decentralisation of the cybersecurity industry. *Dyna, 96*(3), artículo 239. https://doi.org/10.6036/10188

Índices de impacto: JCR JIF Q3, JCR JCI Q3, Scopus Q3

BLOCKCHAIN AND THE DECENTRALISATION OF THE CYBERSECURITY INDUSTRY

BLOCKCHAIN Y LA DESCENTRALIZACIÓN DE LA INDUSTRIA DE LA CIBERSEGURIDAD

Oscar Lage 1;2, María Saiz-Santos 2

1 TECNALIA, Basque Research and Technology Alliance (BRTA), Parque Científico y Tecnológico de Bizkaia #700, E-48160 Derio, Spain. Oscar.Lage@tecnalia.com

2 Fac. of Economics and Business Administration, The University of the Basque Country, Av. Lehendakari Aguirre, 83, 48015 Bilbao, Spain

ABSTRACT:	**RESUMEN:**
This paper aims to analyse the potential impact that blockchain technology will have on the cybersecurity industry. We will look at different applications of blockchain technology in the field of cybersecurity, as well as a new trend of decentralisation of cybersecurity services. Blockchain is precisely a cybersecurity architecture that enables the decentralisation of processes and	Este trabajo pretende analizar el impacto potencial que la tecnología blockchain tendrá sobre la industria de ciberseguridad. Veremos diferentes aplicaciones de la tecnología blockchain en el ámbito de la ciberseguridad, así como una nueva tendencia de descentralización de los servicios de ciberseguridad. Blockchain es precisamente una arquitectura de ciberseguridad que permite la

business models, which could have a direct consequence on cybersecurity services, as well as on the industry itself. Cybersecurity companies will have to adapt to a new ecosystem in which the blockchain technology will enable crowdsourcing of cybersecurity services.	descentralización de procesos y modelos de negocio, lo que podría tener una consecuencia directa en los servicios de seguridad, así como en la propia industria. Las empresas de ciberseguridad deberán adaptarse a un nuevo ecosistema en el que el crowdsourcing de servicios de ciberseguridad será habilitado por la tecnología blockchain.
Keywords: Blockchain, Cybersecurity, Disruptive Technology, Technology Innovation, Technology Strategy	Palabras clave: Blockchain, Ciberseguridad, Tecnología Disruptiva, Innovación Tecnológica, Estrategia Tecnológica

1.- INTRODUCTION

More than a decade elapsed since bitcoin [1] was born at the end of 2008. Its goal was to create a fully decentralised and secure cryptocurrency that would serve as a digital value exchange. To achieve this, Nakamoto had to design a fully decentralised cybersecurity architecture that would guarantee the integrity and availability of the system without interruption, and would be resilient to the continuous attacks that this architecture would constantly suffer, as it became one of the greatest digital treasures in the world.

The technology designed to create the Bitcoin network is currently known as blockchain and researchers around the world are applying it to different sectors in which it could provide differential value [2]. One of the main advantages of blockchain technology is its ability to decentralise processes and business models [3], making it possible to create and manage decentralised ecosystems of participants that are coordinated to provide value to each other and manage the exchange of value and compensation thanks to blockchain technology.

In this study, the question we want to answer is whether blockchain, in addition to being a secure architecture that can be used to create new and more secure products and services, can also impact the way in which cybersecurity services are delivered today, and therefore the cybersecurity industry itself.

2.- GLOBAL CYBERSECURITY MARKET

According to the latest Fortune Business Insights report [4] the cybersecurity market size in 2020 was USD 153.16 billion, showing a growth of 7.6% compared to the previous year. A market size of USD 165.78 billion is forecast for 2021, and is projected to grow to USD 366.10 billion by 2028 at a CAGR of 12.0% during the 2021-2028 period.

According to the study, most services today are delivered as cloud or on-premise solutions, mainly to Small and Medium Enterprises (SME's) and Large Enterprises, being the main buying sectors BFSI (Banking, financial services and insurance), IT and Telecommunications, Healthcare, Government and Manufacturing industries.

3.- BLOCKCHAIN APPLICATIONS IN CYBERSECRUITY SERVICES

Blockchain can be a very useful tool for the mature and growing cybersecurity market because, as we have already mentioned, blockchain is a cybersecurity architecture that allows the creation of decentralised ledgers that guarantee the availability, integrity and non-repudiation of all transactions [5].

In fact, the most immediate use of blockchain linked to cybersecurity is precisely to use blockchain as a secure ledger that allows the immutable recording of data. Thanks to this, it will be possible to store immutable evidences of any process [6][7].

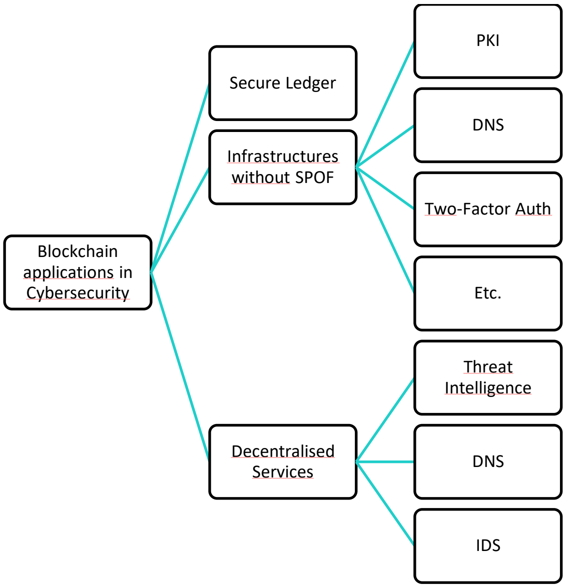

Fig. 1. Blockchain applications in cybersecurity

In his book, Gupta [8] analyses different improvements that blockchain technology can offer to cybersecurity, mainly focusing his analysis on the development of an evolution of PKI architectures, DNS and two-factor authentication using blockchain technology.

In the case of PKI architectures, both Gupta and other authors propose new decentralised models without a Single Point of Failure (SPOF) [9]-[11]. Likewise, there are several proposals in the literature on how to create new decentralised DNS models, thus avoiding the risks of any centralised infrastructure as in the previous case [12]-[14].

Decentralisation is again the benefit that blockchain brings to two-factor authentication architectures and services, as also noted by other authors in the literature [15]-[17].

4.- DECENTRALISATION OF CYBERSECURITY SERVICES

While the previous section analysed how blockchain can offer greater security for critical infrastructure services, we will now look at two specific cases in which blockchain goes a step further and decentralises cybersecurity services currently offered by the cybersecurity industry itself.

The first one is the use of blockchain technology to create a decentralised ecosystem in which network participants can offer a Content Delivery Network (CDN) service [18][19]. CDNs typically aim to maximise the bandwidth available to access a resource on the Internet by replicating that content. The use of CDNs is common so that digital service providers can offer greater resistance to targeted attacks [20].

The second most relevant type of service that could be offered by a community rather than a traditional company is decentralised Threat Intelligence [21]-[24]. The creation of collaborative IDS (Intrusion Detection System) using blockchain technology is even being considered [25].

5.- IMPLICATIONS FOR TEH PROVISION OF CYBERSECURITY SERVICES

Decades ago, we saw how globalisation had a huge impact on the industries of developed countries and their domestic economies [26][27]. Similarly, the Internet transformed many sectors but had a more direct impact on content-related sectors [28], and especially on formats such as encyclopaedias that were replaced by community collaboration around initiatives such as Wikipedia.

A set of experts selected by Nature carried out a comparative analysis between the Encyclopaedia Britannica and Wikipedia in relation to scientific entries [29]. After studying 42 terms, the experts found errors in both encyclopaedias, giving a slight advantage to Encyclopaedia Britannica. However, Wikipedia had a steady growth that allowed it not only to catch up in terms of quality with Encyclopaedia Britannica but also allowed it a wider coverage of concepts and a greater agility in its updates.

In the end, the collaborative and distributed (or decentralised) model was a resounding success, and this is precisely what we believe could happen with all those cybersecurity services that can be decentralised and offered by the community itself.

Crowdsourcing [30] has proven to be rapidly growing, but until now, it has not played a major role in the field of cybersecurity. However, blockchain technology seems to be the driving force behind crowdsourcing in the cybersecurity industry. Starting with Threat Intelligence, CDN or IDS services, among others, cyber intelligence services are being decentralised and industries and professionals will have to adapt to this new model, which will surely have a great impact on a growing but constantly evolving industry.

4.- CONCLUSIONS

Literature and industry evidences support that blockchain technology has great potential in the field of cybersecurity. This technology can be very helpful preventing Single Point of Failure (SPOF) of different critical services.

Just as blockchain is a great cybersecurity technology, it can also become a driver for the transformation of the whole business model of cybersecurity industry. There are already the first advances in creating decentralised services in which the community members can offer these cybersecurity services by their own, creating crowdsourcing initiatives in the field of cybersecurity, just as has happened previously in other sectors.

For all these reasons, we are facing an imminent change in the cybersecurity sector to which professionals and companies will have to adapt and evolve.

One of the open research lines that this work launches is to analyse the potential economic impact that these new decentralised service platforms will have on the cybersecurity market. On the other hand, this new paradigm could also transform cybersecurity employment, in the same way that other jobs such as journalism has already changed by crowdsourcing. Blockchain technology therefore offers a very interesting field of opportunities to develop new business models in cybersecurity and their future challenges.

REFERENCES

[1] Nakamoto, S., & Bitcoin, A. (2008). A peer-to-peer electronic cash system. Bitcoin.–URL: https://bitcoin. org/bitcoin.

[2] Gatteschi, V., Lamberti, F., & Demartini, C. (2020). Blockchain technology use cases. In Advanced Applications of Blockchain Technology (pp. 91-114). Springer, Singapore.

[3] Zheng, Z., Xie, S., Dai, H. N., Chen, X., & Wang, H. (2018). Blockchain challenges and opportunities: A survey. International Journal of Web and Grid Services, 14(4), 352-375.
[4] Insights, F.B. (2021). "Cyber Security Market Size, Share & COVID-19 Impact Analysis, By Component (Solution and Services), By Deployment Type (Cloud and On-Premise), By Enterprise Size (Small & Medium Enterprise and Large Enterprise), By Industry (BFSI, IT and Telecommunications, Retail, Healthcare, Government, Manufacturing, Travel and Transportation, Energy and Utilities and Others) and Regional Forecast, 2021-2028", Report ID:FBI101165.
[5] Golosova, J., & Romanovs, A. (2018, November). The advantages and disadvantages of the blockchain technology. In 2018 IEEE 6th workshop on advances in information, electronic and electrical engineering (AIEEE) (pp. 1-6). IEEE.
[6] White, R., Caiazza, G., Cortesi, A., Im Cho, Y., & Christensen, H. I. (2019). Black block recorder: Immutable black box logging for robots via blockchain. IEEE Robotics and Automation Letters, 4(4), 3812-3819.
[7] Tian, Z., Li, M., Qiu, M., Sun, Y., & Su, S. (2019). Block-DEF: A secure digital evidence framework using blockchain. Information Sciences, 491, 151-165.
[8] Gupta, R. (2018). Hands-On Cybersecurity with Blockchain: Implement DDoS protection, PKI-based identity, 2FA, and DNS security using Blockchain. Packt Publishing Ltd.
[9] Yakubov, A., Shbair, W., Wallbom, A., & Sanda, D. (2018). A blockchain-based pki management framework. In The First IEEE/IFIP International Workshop on Managing and Managed by Blockchain (Man2Block) colocated with IEEE/IFIP NOMS 2018, Tapei, Tawain 23-27 April 2018.
[10] Konoplev, A. S., Busygin, A. G., & Zegzhda, D. P. (2018). A blockchain decentralized public key infrastructure model. Automatic Control and Computer Sciences, 52(8), 1017-1021.
[11] Brunner, C., Knirsch, F., Unterweger, A., & Engel, D. (2020). A Comparison of Blockchain-based PKI Implementations. In ICISSP (pp. 333-340).
[12] Karaarslan, E., & Adiguzel, E. (2018). Blockchain based DNS and PKI solutions. IEEE Communications Standards Magazine, 2(3), 52-57.
[13] Wei-hong, H. U., Meng, A. O., Lin, S. H. I., Jia-gui, X. I. E., & Yang, L. I. U. (2017). Review of blockchain-based DNS alternatives. 网络与信息安全学报, 3(3), 71.
[14] Al-Mashhadi, S., & Manickam, S. (2020). A brief review of blockchain-based DNS systems. International Journal of Internet Technology and Secured Transactions, 10(4), 420-432.
[15] Alharbi, E., & Alghazzawi, D. (2019). Two factor authentication framework using otp-sms based on blockchain. Transactions on Machine Learning and Artificial Intelligence, 7(3), 17-27.
[16] Santosh, S. V. S., Rao, M. K., Sri, P. A., & Hemantha, C. S. (2021). Decentralized Application for Two-Factor Authentication with Smart Contracts. In Inventive Communication and Computational Technologies (pp. 477-486). Springer, Singapore.
[17] Amrutiya, V., Jhamb, S., Priyadarshi, P., & Bhatia, A. (2019, January). Trustless two-factor authentication using smart contracts in blockchains. In 2019 international conference on information networking (ICOIN) (pp. 66-71). IEEE.
[18] Vu, T. X., Chatzinotas, S., & Ottersten, B. (2019, April). Blockchain-based content delivery networks: Content transparency meets user privacy. In 2019 IEEE Wireless Communications and Networking Conference (WCNC) (pp. 1-6). IEEE.
[19] Kim, K., You, Y., Park, M., & Lee, K. (2018, July). DDoS mitigation: Decentralized CDN using private blockchain. In 2018 Tenth International Conference on Ubiquitous and Future Networks (ICUFN) (pp. 693-696). IEEE.
[20] Chadd, A. (2018). DDoS attacks: past, present and future. Network Security, 2018(7), 13-15.
[21] Riesco, R., Larriva-Novo, X., & Villagrá, V. A. (2020). Cybersecurity threat intelligence knowledge exchange based on blockchain. Telecommunication Systems, 73(2), 259-288.

[22] Mendez Mena, D., & Yang, B. (2021). Decentralized Actionable Cyber Threat Intelligence for Networks and the Internet of Things. IoT, 2(1), 1-16.

[23] Menges, F., Putz, B., & Pernul, G. (2020). DEALER: decentralized incentives for threat intelligence reporting and exchange. International Journal of Information Security, 1-21.

[24] Lage, O., de Diego, S., Urkizu, B., Gómez, E., & Gutiérrez, I. (2019). Blockchain Applications in Cybersecurity. In Computer Security Threats. IntechOpen.

[25] Alexopoulos, N., Vasilomanolakis, E., Ivánkó, N. R., & Mühlhäuser, M. (2017, October). Towards blockchain-based collaborative intrusion detection systems. In International Conference on Critical Information Infrastructures Security (pp. 107-118). Springer, Cham.

[26] Caves, R. E., Porter, M. E., Spence, M., & Scott, J. T. (1980). Competition in the open economy: A model applied to Canada (No. 150). Harvard University Press.

[27] Arndt, S. W. (1997). Globalization and the open economy. The North American Journal of Economics and Finance, 8(1), 71-79.

[28] Van der Wurff, R. (2008). The impact of the Internet on media content. The Internet and the mass media, 65-85.

[29] PHO, A. (2005). Internet encyclopaedias go head to head. NATURE, 438, 15.

[30] Howe, J. (2006). The rise of crowdsourcing. Wired magazine, 14(6), 1-4.

Artículo 3: The Value and Applications of Blockchain Technology in Business: A Systematic Review of Real Use Cases

Lage, O., Saiz-Santos, M. y Zarzuelo, J. M. (2021). The value and applications of blockchain technology in business: A systematic review of real use cases. En J. Prieto, A. Partida, P. Leitão y A. Pinto *(eds.), III International Congress on Blockchain and Applications* (pp. 149-160). Springer.

Índices de impacto: Scopus Q4, Springer SPI Q1

The value and applications of blockchain technology in business: a systematic review of real use cases

Oscar Lage[1,2][0000-0003-1168-1932], María Saiz-Santos[2][0000-0002-4969-0044] and José Manuel Zarzuelo[2][0000-0002-3317-5312]

[1] TECNALIA, Basque Research and Technology Alliance (BRTA), Parque Científico y Tecnológico de Bizkaia #700, E-48160 Derio, Spain

[2] Fac. of Economics and Business Administration, The University of the Basque Country, Av. Lehendakari Aguirre, 83, 48015 Bilbao, Spain

Abstract. This work provides an empirical study to identify the specific objective pursued by companies that are currently investing to develop blockchain technologies to improve their processes. Unlike other studies based on the theoretical potential application of blockchain technology in different sectors, the main objective of this paper is to analyse real projects and investment of companies in blockchain technology to identify the main value or use that managers prioritize in their technology development efforts. More than one hundred blockchain projects from different sectors have been examined with the aim of extracting the perceived value of blockchain technology by managers, customers, and partners. Identifying the business value that is most demanded in each sector and company size, as well as the relationship between the values that are jointly demanded. This article assesses the main values attributed to blockchain, highlighting those really appreciated by companies to invest in them and identifying new

applications of blockchain technology in different sectors, and generating organisational change.

[31] **Keywords:** Blockchain, IT Business Value, Technology Innovation, Technology Strategy, Organizational transformation.

1 Introduction

The birth of bitcoin [1] at the end of 2008 was much more than the beginning of the first decentralized cryptocurrency. The technology designed to support bitcoin cryptocurrency would later be called blockchain and give rise to a new family of decentralized technologies. Blockchain is a distributed peer-to-peer architecture that introduces major disruptions to traditional business by decentralising governance through the creation of a secure design that does not require trusted third parties to establish transactional relationships between two parties.

According to 83% of C-suite executives [2], their companies will lose competitive advantage if they do not adopt blockchain. Leaders are increasingly investing in blockchain and digital assets as one of the top five strategic priorities.

There are several overall reviews regarding potential blockchain-based applications [3-6]. However, what is the real value provided to the companies? what specific business needs can be addressed by blockchain?

Beyond theoretical studies about potential applications, this work contributes to the understanding of the business value of blockchain technology for companies, and identifies which features are most required. Everything based on a systematic review of all the blockchain innovation projects that Tecnalia has carried out for private companies and public administration.

The work is organized as follows. Section 2 will review previous work on the state of the art and its contributions. Section 3 presents the methodological approach used to carry out the research. Sections 4, 5 & 6 describe the results and the contribution, explaining the benefits of blockchain for companies and the statistical impact of each one, which is expected to help researchers to identify new projects and applications of this technology. Finally, Section 7, ends with the presentation of the most relevant conclusions, trends, and further research lines.

2 Background and related work

Seebacher et al. [3] conducted one of the first systematic reviews of the literature analysing the common characteristics identified in 32 articles that examined potential uses of the technology. The two main features identified in the work are trust and the decentralized nature of the technology.

Tama et al. [4] identify in their analysis four main areas of potential applicability of blockchain technology, which are financial services, healthcare, business markets, and others, such as digital right management system or reputation system. Hawlitschek et al. [5] evaluate blockchain from the perspective of its possible applicability in the shared economy.

More recently, Casino et al. [6] elaborated a taxonomy of blockchain-based applications after the study of 260 articles and 54 reports of the grey literature. This taxonomy identifies the following potential application domains: financial, integrity verification, governance, Internet of Things, health, education, privacy and security, business/industry and finally data management.

These authors also point out that although the literature attempts to propose blockchain as a panacea it should not be used in every case. In particular, Seebacher et al. [3] remarked that for further research would be interesting to explore the contribution of blockchain in non-theorical projects by performing an empirical analysis of real cases. They suggested that significant deviations are expected between theoretical applications and those finally adopted by industry.

This research is in the same spirit of the research conducted by the previous authors, that is, our aim is to analyse real projects in which companies have invested, to understand and measure the perceived value of blockchain technology in business.

3 Methodology

A mixed research method combining a qualitative and quantitative analysis was carried out to answer our research question: "What is the real business value of blockchain for companies regardless of the sector and application?”. Therefore, a qualitative analysis of actual project documentation was combined with the statistical analysis of the database created from the qualitative analysis.

The starting point was the information associated with blockchain projects carried out by Tecnalia’s cybersecurity and blockchain research group. To endorse the significance of this information it should be noted that Tecnalia is a leading research and technological development centre in Europe. Actually, it is the first private Spanish organisation in contracting, participation, and leadership in the European Horizon 2020 and ranked second in European patent applications.

To obtain the information, 104 blockchain-related contracts in the period from 2017 to 2020 were selected from the corporate ERP (Enterprise Resource Planning) software. The information on these contractual agreements was extracted in a spreadsheet and those contracts belonging to the same project in which several entities were involved were grouped together. There were 55 individual projects and 12 consortium projects with a maximum of seven partners and an average of 4.08 research participants per consortium.

The projects widely reflect the main economic sectors, so we consider it a broad enough sample to obtain significant results. Figure 1 shows the representation and investment by sector in the analysed sample (in percentages).

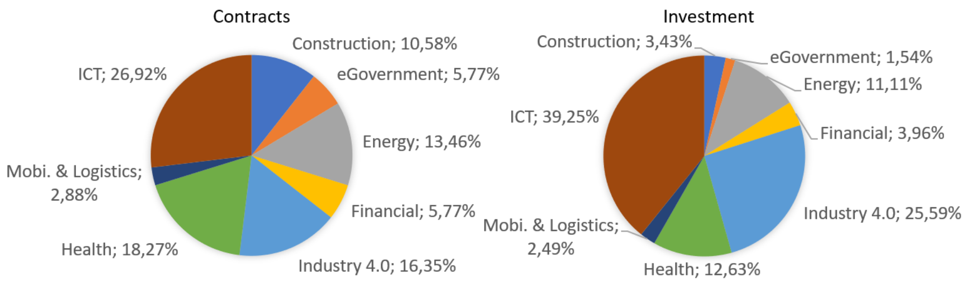

Fig. 1. Blockchain investment distribution by sector.

Regarding the relative impact on the investments, it can be observed how the ICT (Information and Communication Technologies) projects are positioned as the ones with the largest budget, surely because this sector has understood, and demanded, the blockchain technology before others.

Concerning the size of the company, Figure 2 shows the distribution of investments according to company size. As can be seen, medium-sized companies are the ones that prevail both in terms of the number of contracts and their investment.

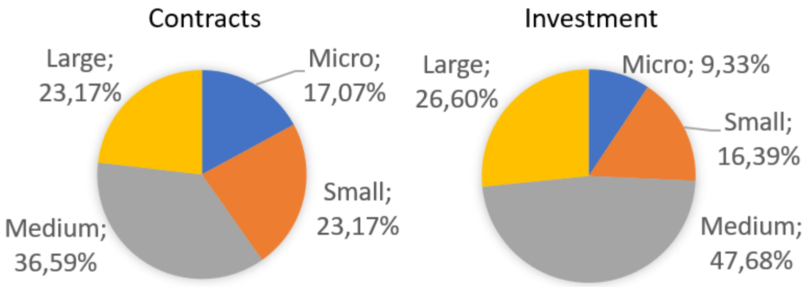

Fig. 2. Blockchain investment distribution by company size.

The next step after the creation of the database was to compile the documentation of contracts, project reports and consortium agreements. In all the documents there was a section that expresses, under different titles and denominations, the needs of the customer or consortium, the opportunity, and the challenge faced by the project using blockchain in combination with different technologies. A qualitative content analysis of the documentation was carried out to identify the keywords that define the needs that motivated the investment.

Thus, to obtain the list of benefits of the technology, a thorough reading of the project documentation was carried out and all the keywords were noted down in the project documentation. Once the keywords expressing the needs covered by blockchain technology had been isolated, they were standardised and grouped together, resulting in 12 business values for which companies are investing in blockchain, which we analyse in the following section. Finally, we performed an analysis of the relationships between the 12 benefits using hierarchical clustering, the results of which are presented in section 6.

4 Business value of blockchain technology

The different benefits identified in the research are discussed below, starting with a definition of each value, and continuing in the following sections with an analysis of the relationships between them.

Decentralization of processes: one of the most obvious benefits of blockchain technology because of its distributed architecture and its ability to create reliable peer-to-peer relationships without the need for a trusted third party to intermediate between the parties [7]. Blockchain enables the management of business-to-business processes in a decentralised way, allowing all parties to directly participate in the management of business processes. Blockchain makes it possible to audit each process, as well as its compliance with the business rules established by the community in the blockchain network [8].

Decentralization of Business Models: the academic literature is now starting to reflect this value [9]-[11]. The research has found how companies want to disrupt current business models, especially platform business models [12]. Internet has enabled the creation of new business models based on digital platforms, like Airbnb and Uber, that allows them to create ecosystems in which some participants offer products/services. Precisely the business model that companies are trying to adopt in the last years, is the one that companies in the study try to destroy. An open and free blockchain application can offer to the suppliers and demanders of products/services a very similar service than the current digital platforms.

Traceability & Provenance of assets: blockchain technology provides an unalterable record of the asset's history, in which both its origin and components can be analysed, as well as all changes, updates, maintenance, and operations throughout its history. Every change made to the resource that is relevant for the ecosystem can be recorded on the blockchain, guaranteeing both the integrity of the data and the date on which it occurred.

The provenance issue arises precisely in several projects of traceability of both tangible and intangible goods [13]. Several projects focused on the origin of the materials used in the industrial or construction process were also analysed, all of them linked to the circular economy [14].

Traceability/Certification of processes and regulatory compliance: this is closely linked to the previous section, however, in this case the traceability is done over a process instead of an asset. In general, it refers to those internal or external processes to organizations that must be monitored, and in some cases certified because in some domains this is necessary for regulatory compliance. Processes linked to different domains have been identified in the literature [15] - [18].

Transparency of processes: closely linked to traceability because transparency is based on giving visibility on the traceability of a process. In addition, blockchain based records give more confidence to the transparency process because there is no doubt that the records have not been modified at a later point in time.

Shared asset/process management: Adams et al. [19] in 2003 analysed the problem of shared asset management, and blockchain can solve the challenges identified in the study by providing all stakeholders with a single synchronised view of the shared resources and their states. This perfect synchronisation can reduce frictions between the different actors, enabling complex ecosystems.

Trustworthiness and integrity: the decentralization of governance, as well as the integrity and immutability of blockchain transactions, make blockchain networks a "source of truth" [20]. Additionally, each participant must digitally sign every transaction they make on the blockchain, which is important for potential claims.

Automation of processes: currently companies do not rely on automating certain decisions based on information that may be published by a third party on a web service because the third party may modify such information, which could result in the company making incorrect decisions, and also not having evidence that the third party has acted in bad faith [21]. Thanks to blockchain, companies can automate decisions based on third party information, which can substantially increase the business value of the companies.

Smart Contracts: in 1994 Szabo [22] devised the term Smart Contract and sometime later, specified the concept of Smart Contracts in more detail [23], but Smart Contracts could not be implemented until blockchain technology had been conceived. When in this study we refer to the term Smart Contract we refer to Szabo's original concept in which there is a custody of value (tokens) in the intermediation between two or more parties.

Digital identity: many ecosystems and users demand a new model of interoperable digital identity, focused and managed by the user himself, and ensuring privacy (Privacy by Design). Allen [24] defined the basis of about a new decentralised identity model called "Self-Sovereign Identity” (SSI). SSI ensures that users maintains control of their identity and do not have to rely on any central entity. Thus, users will be able to present the attributes of their identity (age, nationality, academic qualifications, etc.) to third parties minimizing the presented information using zero knowledge proofs [25] to maximize their privacy.

Sovereignty of data and data-driven services: it is a growing need in business [26]. Today, most business data are not being exploited, nor is artificial intelligence being able to play a greater role, precisely because of the desire to have control over the data. Companies are afraid of sharing data with third parties because once they do it they no longer have control over it, data can be replicated and distributed without their consent, losing its economic value [27].

Machine-to-Machine (M2M) transactions and Machine Economy: this is a new paradigm that emerges by transferring the sharing economy to the IoT [28]. Thanks to the capability of decentralization and tokenization of assets and services of blockchain, the Machine Economy allows the creation of a new sharing economy among the machines themselves; putting in value their data/services in this ecosystem, and operating in an autonomous way with tokens [29]. The token economy [30] in the IoT field is still very novel but in the set of analysed projects it can be discovered tokenized transactions between machines in Industrial Internet of Things (IIoT) (manufacturing and energy) as well as other proofs of concept in the fields of autonomous vehicles.

5 Blockchain business value impact analysis

The demand for each business value has been studied according to different impact criteria. This will help to understand the needs of the companies, as well as to identify patterns. The first analysis determines the investment in each of these values by company size.

Tamaño	Decentraliz. procesos	Dec. mod. negocio	Trazabilidad Activos	Trazabilidad procesos	Transparen. Procesos	Gest. activos compartidos	Confianza e integridad	Automatiz. procesos	Contratos inteligentes	Ident. digital	Soberanía dato	Machine Economy
Micro	14,96	9,16	4,60	9,92	2,12	4,28	16,96	-	5,81	12,11	9,50	10,58
Peq.	8,11	2,44	8,03	13,00	4,11	8,04	21,53	-	5,34	13,11	8,11	8,17
Med.	8,50	1,49	6,36	15,33	3,23	12,04	17,32	5,91	5,53	9,61	6,42	8,25
Gran	15,14	2,45	6,45	7,23	1,89	5,22	21,51	11,03	1,13	14,32	4,20	9,42

shows how trustworthiness & integrity is the most demanded need, it represents between 16,96% and 21,51% of the investment, depending on the size of the company. On the other hand, automation of processes is the only aspect in which some of the company sizes do not invest, specifically in the case of micro and small enterprises. Probably because large and medium-sized companies have more complex processes where blockchain can provide greater value and justify the return on investment.

Table 1. Business value by company size (percentages)

Size	Decentralis. of processes	Decentralis. of Busines. Mod.	Traceab. .& Prov. Assets	Traceab./Cert. Processes	Transp. Processes	Shared asset Management	Trust & Integrity	Automation of Processes	Smart Contracts	Digital Identity	Sovereignty of Data.	Machine Economy
Micro	14,96	9,16	4,60	9,92	2,12	4,28	16,96	-	5,81	12,11	9,50	10,58
Small	8,11	2,44	8,03	13,00	4,11	8,04	21,53	-	5,34	13,11	8,11	8,17
Med.	8,50	1,49	6,36	15,33	3,23	12,04	17,32	5,91	5,53	9,61	6,42	8,25
Large	15,14	2,45	6,45	7,23	1,89	5,22	21,51	11,03	1,13	14,32	4,20	9,42

Micro enterprises are most active investing in the decentralisation of business processes and Machine Economy, although with less difference compared to other company sizes. Micro and large companies are investing in the decentralisation of processes, in contrast to small and medium-sized companies that mainly invest in traceability of processes. We can observe how medium-sized companies are the most active investors in shared asset management; and large companies stand out for their investment in process automation and limited investment in Smart Contracts.

Table 2 presents the percentage of investment made by sector in each of the identified business values. The construction sector is mainly investing in process traceability, shared asset management, and trustworthiness. No investments have been identified in more decentralised characteristics such as process decentralisation, business models, smart contracts, or Machine Economy.

Table 2. Business value by sector (percentages)

Sector	Decentralis. of processes	Decentralis. of Busines. Mod.	Traceab. .& Prov. Assets	Traceab./Cert. Processes	Transp. Processes	Shared asset Management	Trust & Integrity	Automation of Processes	Smart Contracts	Digital Identity	Sovereignty of Data.	Machine Economy
Cons.	-	-	10,78	22,21	10,78	22,21	22,21	6,51	-	5,31	-	-
eGov	9,93	-	-	24,34	5,26	24,34	13,98	1,75	-	16,04	4,35	-
Energ.	3,74	4,23	15,42	15,38	1,68	13,77	15,79	10,77	3,82	-	-	15,42
Finan.	0,69	1,38	0,69	22,14	8,46	22,83	10,49	22,14	11,18	-	-	-
Ind4.0	4,08	0,90	4,31	4,66	0,79	10,79	20,90	10,57	1,83	6,44	15,84	18,89
Health	13,53	5,89	5,90	12,39	-	17,88	17,88	5,19	-	12,69	8,64	-
Mobil.	11,20	6,81	7,99	7,99	3,60	14,80	14,80	14,80	-	11,20	-	6,81
ICT	9,03	1,94	2,25	7,35	0,33	4,34	17,64	10,29	3,48	19,23	11,75	12,36

Governments are mainly investing in process traceability and shared asset management, followed by digital identity for their citizens and decentralisation of processes. Furthermore, is one of the few sectors that is not investing in asset traceability.

Energy sector is heavily investing in process and asset traceability, as well as process automation to improve its current processes. In addition, due to the decentralisation of power generation and emerging prosumers [31], the energy sector is investing in trust and integrity, shared asset management, and Machine Economy.

Financial industry is focused on improving its current processes, with most of its investment focused on shared asset management, process automation, and traceability. Precisely because the disintermediation of financial relations could jeopardise its medium/long-term business viability, there is no investment in the decentralisation of processes.

The fourth industrial revolution is reflected in the industrial investments that have trust and integrity of relationships at their core, as well as industrial data sovereignty and Machine Economy. In a second tier, shared asset management and process automation could be highlighted.

Health sector invests mainly in shared resource management, digital identity, and trust, with traceability and decentralisation of processes in a secondary plane. All this fits with a more patient-centric vision in which health services aim to interoperate and empower the user over their health data.

In the case of mobility, we should note that they mainly invest in shared asset management, digital identity, and trust, but in this case their commitment is linked to process automation rather than process decentralisation.

ICT sector stands out for its clear commitment to digital identity and trust, which aims to change the identity model towards a Self-Sovereign Identity (SSI), followed by data sovereignty and Machine Economy linked to the data economy and IoT ecosystem.

Finally, Figure 3 shows the investment made in each of the business values identified in the study. Evaluated projects indicate a higher investment in trustworthiness of data and relationships between different stakeholders. This characteristic represents the 18% of global investment.

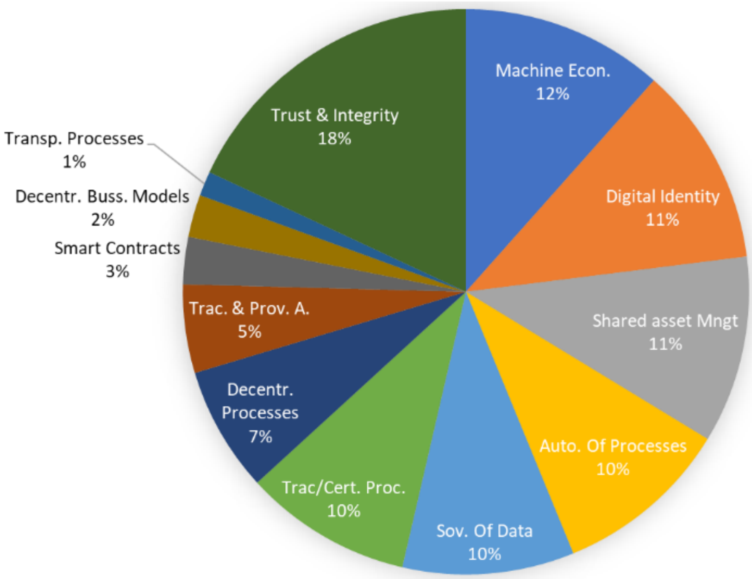

Fig. 3. Blockchain investment distribution by business value.

Machine Economy is the next value with the highest investment. This distinctive IoT trend, both for consumer and industrial applications, represents 12% of global investment; probably driven by the high investment in ICT and Industry 4.0 projects, as shown in Figure 1. These four business values together account for 56% of the overall analysed investment.

Surprisingly, the three business benefits that have received the least investment are process transparency, decentralisation of business models and smart contracts. Together, they represent only 6% of the analysed investment, followed by asset traceability which represents just 5% of the investment. These features are some of the most frequently mentioned in the studies reviewed in section 2, but they are not the ones in which companies are making their main investments.

6 Relational model of blockchain provided value

After discussing the business value and impact that blockchain technology offers to companies, the next step was to analyse if there is any relationship in the demand of these values. For this purpose, a clustering analysis using a hierarchical cluster was carried out [32]. To perform the analysis, we have associated with each busines benefit a 104-tuple vector, corresponding to the 104 projects examined in this paper. Each component has been assigned the worth 1 if the business value was present in the purposes of the project, and 0 otherwise. Then we used the squared Euclidean distance as a measure of the relationship between the business values. In this way we have obtained a dendrogram (Fig. 4) where we can appreciate the relationship between the different business benefits of the blockchain technology in the analysed projects [33].

The dendrogram shows clear relationships between the decentralization of business models and smart contracts. The result is natural since one of the most common ways of creating decentralized businesses is through a Decentralized Autonomous Organization (DAO) which is based on a smart contract that governs the organization [34]. In the case of M2M transactions and Machine Economy, it is clearly related to the above as it is a decentralization of the current IoT business models through smart contracts. The fourth value in the first cluster is process decentralization, which is also found when business models are decentralized.

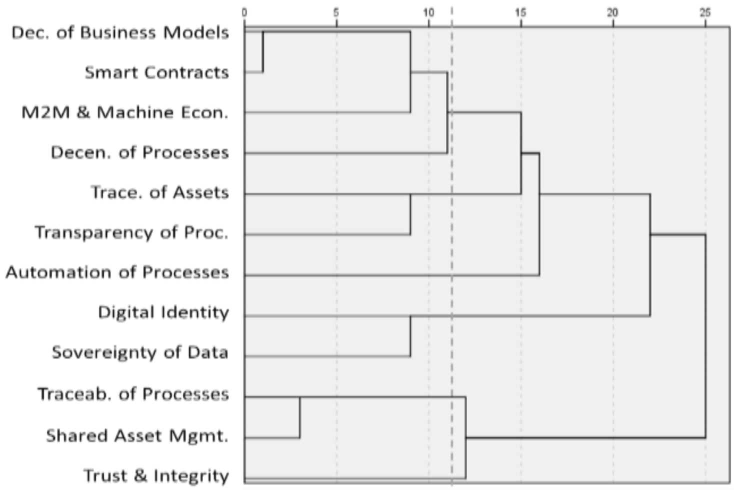

Fig. 4. Hierarchical Clustering Dendrogram using an average linkage between groups (rescaled distance).

Traceability and provenance of assets is a highly demanded value in transparency projects, that is why these two variables are closely related in many of the analysed projects.

Something similar occurs with the traceability of processes and the management of shared assets, which are closely related and form a cluster, as many shared asset management projects also require traceability of the processes carried out on shared assets.

Digital identity and data sovereignty are also closely linked, since in order to create data sovereignty systems it is common to use a decentralized identity on the basis of which to implement policies related to data consumption.

Finally, it should be noted that there are two factors that are not so closely related with others and, therefore, each one forms a cluster on its own. These characteristics are Trustworthiness & Integrity, and Process Automation.

7 Conclusions and future work

More than one hundred real blockchain contracts were analysed to answer the research question of what blockchain business values companies are investing in, regardless of the sector and application. The research has been done based on a systematic analysis of actual company investments rather than theoretical benefits and applications of the technology. The real needs of the companies regarding blockchain were identified, classified, and correlated.

Our findings allow us to obtain the business value of blockchain for companies in real projects, since until then the literature only had specific use cases or reviews of potential blockchain applications, but in no case a review and analysis based on a set of real projects in which companies have invested. The study will allow to identify new applications of the blockchain technology in scenarios that have not yet been identified, increasing the adoption of blockchain technology.

On the other hand, the study shows that although two of the most promising values of blockchain technology are the ability to decentralise processes and business models, companies are mainly demanding trustworthiness of their information, digital identity, and shared asset management. This might indicate that companies are making pragmatic decisions and are in a process of learning.

Despite the above, the work has identified that although decentralisation of business models currently only represents 2% of investment, all sectors, except construction and governments, are beginning to invest in it; which can represent a great risk to current models, such as the aforementioned platform business model.

Therefore, one of the lines opened by this research is to explore how blockchain technology will decentralize and disrupt current business models, and what kind of new decentralized business models will emerge.

Acknowledgments J. M. Zarzuelo acknowledges support from the Spanish Ministry of Science and Innovation (PID2019- 105291GB-I00), and by UPV/EHU (GIU20/019).

References

1. Nakamoto S. Bitcoin: A peer-to-peer electronic cash system. (2008)
2. Deloitte's 2020 Goblal Blockchain Survey (online) https://www2.deloitte.com/content/dam/insights/us/articles/6608_2020-global-blockchain-survey/DI_CIR%202020%20global%20blockchain%20survey.pdf, accessed at 2021/05/07
3. Seebacher, S., et al.: Blockchain technology as an enabler of service systems: A structured literature review. International Conference on Exploring Services Science, 12-23, (2017).
4. Tama, B. A., et al.: A critical review of blockchain and its current applications. In 2017 International Conference on Electrical Engineering and Computer Science (ICECOS) pp. 109-113, (2017).
5. Hawlitschek, F., et al.: The limits of trust-free systems: A literature review on blockchain technology and trust in the sharing economy. Electronic commerce research and applications, 29, 50-63 (2018).
6. Casino, F., et al.: A systematic literature review of blockchain-based applications: current status, classification and open issues. Telematics and informatics, 36, 55-81 (2019).
7. Zheng, Z., et al.: An overview of blockchain technology: Architecture, consensus, and future trends. In 2017 IEEE international congress on big data, pp. 557-564 (2017).
8. Mendling, J., et al.: Blockchains for business process management-challenges and opportunities. ACM Transactions on Management Information Systems, 9(1), 1-16 (2018).

9. Nowiński, W., et al.: How can blockchain technology disrupt the existing business models?. Entrepreneurial Business and Economics Review, 5(3), 173-188 (2017).
10. Lage, O. et al.: Blockchain and the decentralisation of the cybersecurity Industry. DYNA, 96(3). 239. DOI: https://doi.org/10.6036/10188, (2021).
11. Morkunas, V. J., et al.: How blockchain technologies impact your business model. Business Horizons, 62(3), 295-306 (2019).
12. Täuscher, K., et al.: Understanding platform business models: A mixed methods study of marketplaces. European Management Journal, 36(3), 319-329 (2018).
13. Montecchi, et al.: It's real, trust me! Establishing supply chain provenance using blockchain. Business Horizons, 62(3), 283-293 (2019).
14. Kouhizadeh, et al.: At the nexus of blockchain technology, the circular economy, and product deletion. Applied Sciences, 9(8), 1712 (2019).
15. Shih, C. S., et al.: Design and implementation of distributed traceability system for smart factories based on blockchain technology. In Proceedings of the Conference on Research in Adaptive and Convergent Systems, pp. 181-188 (2019).
16. Caro, M. P., et al.: Blockchain-based traceability in Agri-Food supply chain management: A practical implementation. In 2018 IoT Vertical and Topical Summit on Agriculture-Tuscany (IOT Tuscany) (pp. 1-4). IEEE (2018).
17. Compert, C., et al.: Blockchain and GDPR: How blockchain could address five areas associated with GDPR compliance. IBM Security White Paper (2018).
18. Ølnes, S., et al.: Blockchain in government: Benefits and implications of distributed ledger technology for information sharing. Government Information Quarterly, 34, 355-364 (2017).
19. Adams, W. M., et al.: Managing tragedies: understanding conflict over common pool resources. Science, 302(5652), 1915-1916 (2003).
20. Böhme, R., et al.: Bitcoin: Economics, technology, and governance. Journal of economic Perspectives, 29(2), 213-38 (2015).
21. Ter Hofstede, A. H. et al. (ed.). Modern Business Process Automation: YAWL and its support environment. Springer Science & Business Media, 2009. p.492
22. Szabo, N. Smart contracts. Unpublished manuscript, 1994.

23. Szabo, N. Smart contracts: building blocks for digital markets. EXTROPY: The Journal of Transhumanist Thought,(16), 18(2) (1996).
24. Allen, C. The path to self-sovereign identity. Life with Alacrity, (2016).
25. Goldreich, O., et al.: Definitions and properties of zero-knowledge proof systems. Journal of Cryptology, 7(1), 1-32 (1994).
26. Jarke, M., Data Sovereignty and Data Space Ecosystems. Business and Information Systems Engineering, (2019).
27. Harris, D., et al.: Standards for secure data sharing across organizations. Computer Standards & Interfaces, 29(1), 86-96 (2007).
28. Lage, O.: Blockchain: From Industry 4.0 to the Machine Economy. In Computer Security Threats. IntechOpen (2019).
29. Chen, Y.: Blockchain tokens and the potential democratization of entrepreneurship and innovation. Business Horizons, 61(4), 567-575 (2018).
30. Lee, J. Y.: A decentralized token economy: How blockchain and cryptocurrency can revolutionize business. Business Horizons, 62(6), 773-784 (2019).
31. Morstyn, T. et al.: Using peer-to-peer energy-trading platforms to incentivize prosumers to form federated power plants. Nature Energy, 3(2), 94-101 (2018).
32. Žiberna, A., et al.: A comparison of different approaches to hierarchical clustering of ordinal data. Metodoloski zvezki, 1(1), 57 (2004).
33. Forina, M., et al.: Clustering with dendrograms on interpretation variables. Analytica Chimica Acta, 454(1), 13-19 (2002).
34. Norta, A.: Designing a smart-contract application layer for transacting decentralized autonomous organizations. In International Conference on Advances in Computing and Data Sciences, pp. 595-604 (2016).

Artículo 4: Real business applications and investments in blockchain technology

Lage, O., Saiz-Santos, M. y Zarzuelo, J. M. (2022). Real business applications and investments in blockchain technology. *Electronics*, *11*(3), artículo 438. https://doi.org/10.3390/electronics11030438

Índices de impacto: JCR JCI Q2, JCR JIF Q3, Scopus Q2

Real Business Applications and Investments in Blockchain Technology

Oscar Lage [1,2,*], María Saiz-Santos [2] and José Manuel Zarzuelo [2]

[1] TECNALIA, Basque Research and Technology Alliance (BRTA), Parque Científico y Tecnológico de Bizkaia #700, 48160 Derio, Spain

[2] Faculty of Economics and Business Administration, The University of the Basque Country, Av. Lehendakari Aguirre, 83, 48015 Bilbao, Spain; maria.saiz@ehu.eus (M.S.-S.); josemanuel.zarzuelo@ehu.eus (J.M.Z.)

* Correspondence: Oscar.Lage@tecnalia.com

Abstract: This paper provides an empirical study to identify the objective of companies that are currently investing in adopting blockchain technologies to improve their processes and services. Unlike other studies based on the theoretical potential application of blockchain technology in different sectors, the main objective of this paper is to analyze real projects and investment of companies in blockchain technology. More than 100 blockchain projects from different sectors were examined with the aim of extracting the perceived applicability and business value of blockchain technology by managers, customers, and partners. We identified the most demanded business value and functional properties in each sector and company size, as well as the relationship between the properties that are demanded together. This article assesses the main functional values attributed to blockchain, highlighting those really appreciated by companies that invest in them and identifying new applications of blockchain technology in different sectors, and generating organizational change. The article reveals that, as expected, significant deviations are already occurring

between theoretical applications identified in the literature and those finally adopted by the industry.

Keywords: blockchain; IT business value; technology innovation; technology strategy; organizational transformation

1. Introduction

The birth of bitcoin [1] at the end of 2008 was much more than the beginning of the first decentralized cryptocurrency. The technology designed to support bitcoin cryptocurrency would later be called blockchain and give rise to a new family of decentralized technologies. Blockchain is a distributed peer-to-peer architecture that introduces major disruptions to traditional business by decentralizing governance through the creation of a secure design that does not require trusted third parties to establish transactional relationships between two parties.

However, it was not until 2014–2016 when researchers began to identify the benefits of blockchain technology for different industries. Financial services [73,74], healthcare [75,76], energy [77,78], and public administrations [79] were some of the first industries to analyze the theorical applications of blockchain technology, and in general of Distributed Ledger Technologies (DLTs).

According to 83% of C-suite executives [2], their companies will lose competitive advantage if they do not adopt blockchain. Leaders are increasingly investing in blockchain and digital assets as one of the top five strategic priorities, with 66% forecasting investment of USD 1 million or more in the next months, nearly 40% of them have blockchain in production.

There are several overall reviews regarding potential or theorical blockchain-based applications (Table 1). However, what is the real functional value provided to the companies? What specific business needs can be addressed by blockchain?

Table 1. Applications investment by company size (percentages).

Source	Research Objective(s)
Seebacher et al. [10]	Systematic literature review of blockchain applicability.
Tama et al. [11]	Identification of the main areas of potential applicability of blockchain technology.
Hawlitschek et al. [12]	Evaluation of blockchain from the perspective of its potential application in the shared economy.
Casino et al. [13]	Systematic literature review of blockchain applicability. Elaborate on a taxonomy of blockchain-based applications in several sectors.
Laroiya et al. [85]	Overview of the different uses and applications of blockchain technology.
Perera et al. [86]	Identification of potential applications, characteristics, and adoption drivers of blockchain in the construction industry.
Ko et al. [87]	Identification of potential blockchain applications in the manufacturing industry.

Seebacher et al. [3] conducted one of the first systematic reviews of the literature analyzing the common characteristics identified in 32 articles that examined potential uses of the technology. The two main features identified in the work are trust and the decentralized nature of the technology. Concerning trust, three pillars were identified: (i) transparency that favors interaction and reduces friction between parties, (ii) data integrity through the verification of transactions by peers and the use of cryptography, and finally (iii) the immutability of agreed transactions. In terms of the decentralized nature, three other characteristics were highlighted: (i) the privacy and pseudo-anonymity of the participants, (i) their reliability through data redundancy and their consequent potential for automation, and (iii) its versatility. These characteristics allow the understanding of the two fundamental pillars of any blockchain use case. Therefore, trust and decentralization, to a higher or lower degree, depending on the network typology, will be present in the following reviews.

Tama et al. [4] identify in their analysis four main areas of potential applicability of blockchain technology. The first area is financial services, analyzing the impact of cryptocurrencies on the financial market and the decentralization of their services. The second is the healthcare sector, which highlights the potential of blockchain technology to facilitate the interoperability of electronic health records, as well as patient self-governance over their data. Regarding the third category, "*Business and industry*", diverse applications were found: (i) the use of Distributed Autonomous Corporation (DAC) as an entity to offer services between IoT devices, (ii) the traceability related to the supply chains in the food sector, or (iii) the use of blockchain tokens to generate an edge computing market. Finally, under the name "*Other Implementations*", other hypothetical uses of blockchain technology were identified, such as the digital right management system, reputation system, digital content distribution system, WIFI authentication, and IoT security.

Hawlitschek et al. [5] evaluate blockchain from the perspective of its possible applicability in the shared economy, and identify that the conceptualization of trust, one of the two main basic characteristics of the sharing economy according to the authors, differs between the blockchain contexts and the collaborative economy literature. However, according to the authors blockchain can play a key role in the future of the shared economy.

Casino et al. [6] elaborated on a taxonomy of blockchain-based applications after the study of 260 articles and 54 reports of the grey literature. This taxonomy identifies the following potential application domains: financial applications, integrity verification, governance, Internet of Things and distributed device management [88], health, education, privacy and security, business and industry, and data management.

Laroiya et al. [85] analyze the application of blockchain in various use cases: financial services, banking, insurance, healthcare, voting, real estate, supply chain, music industry, and identity management. After their study, the authors determined that industries are adopting blockchain for its transparency, security, inexpensiveness, security, as well as for creating a better contribution economy, preventing payment scams and its ability to perform financial transactions in minutes.

Perera et al. [86] focus their study on the applicability of blockchain technology in the construction industry. The authors identify 12 characteristics of blockchain that potentially bring value to this specific sector, and six drivers for its adoption. However, the authors point out that data privacy, data storage and querying, scaling difficulties, and the need for high computational power are barriers that may hinder the adoption of the technology in this sector.

Ko et al. [87] identify that real-time transparency and the reduced costs achieved by blockchain technology can help a manufacturing firm to compete in the market by increasing its profits. The authors conclude that blockchain enables the manufacturing industry to reduce surveillance and networking costs, but that it will require an investment for deployment. The authors show that this deployment investment would pay for itself in a very short time.

These authors also point out that although the literature attempts to propose blockchain as a panacea it should not be used in every case. In particular, Seebacher et al. [3] remarked that for further research it would be interesting to explore the contribution of blockchain in non-theorical projects by performing an empirical analysis of real cases. They suggested that significant deviations are expected between theoretical applications and those finally adopted by industry.

This research is in the same spirit of the research conducted by the previous authors, that is, our aim is to analyze real projects in which companies have invested, to understand and measure the perceived value of blockchain technology in business. Everything is based on a systematic review of all the blockchain innovation projects that Tecnalia has carried out for private companies and public administration.

The work is organized as follows. Section 2 presents the methodological approach used to carry out the research. Sections 3 describe the results and the contribution, explaining the benefits of blockchain for companies and the statistical impact of each one, which is expected to help researchers to identify new projects and applications of this technology. Finally, Section 4 ends with the presentation of the most relevant conclusions, trends, and further research lines.

2. Materials and Methods

A mixed research method combining a qualitative and quantitative analysis was carried out to answer our research question: "What is the real business value and functional properties of blockchain for companies regardless of the sector and application?". Therefore, a qualitative analysis of actual project documentation was combined with the statistical analysis of the database created from the qualitative analysis.

The starting point was the information associated with blockchain projects carried out by Tecnalia's cybersecurity and blockchain research group. To endorse the significance of this information it should be noted that Tecnalia is a leading research and technological development center in Europe. It is the first private Spanish organization in contracting, participation, and leadership in the European Horizon 2020 and ranked second in European patent applications.

To obtain the information, 104 blockchain-related contracts in the period from 2017 to 2020 were selected from the corporate ERP (Enterprise Resource Planning) software. The information on these contractual agreements was extracted in a spreadsheet and those contracts belonging to the same project in which several entities were involved were grouped together. There were 55 individual projects and 12 consortium projects with a maximum of seven partners and an average of 4.08 research participants per consortium.

The projects widely reflect the main economic sectors, so we consider it a broad enough sample to obtain significant results. Figure 1 shows the representation and investment by sector in the analyzed sample (in percentages).

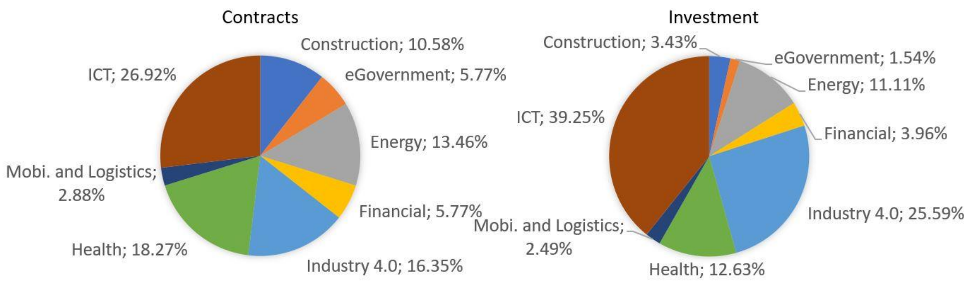

Figure 1. Blockchain investment distribution by sector.

Regarding the relative impact on the investments, it can be observed how the ICT (Information and Communication Technologies) projects are positioned as the ones with the largest budget, surely because this sector has understood, and demanded, the blockchain technology before others.

Concerning the size of the company, Figure 2 shows the distribution of investments according to company size. As can be seen, medium-sized companies are the ones that prevail both in terms of the number of contracts and their investment.

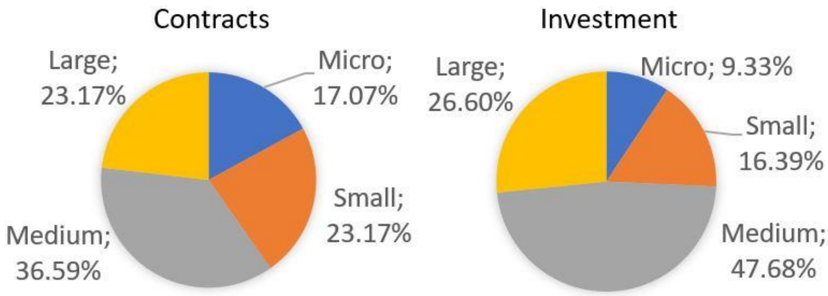

Figure 2. Blockchain investment distribution by company size.

The next step after the creation of the database was to compile the documentation of contracts, project reports, and consortium agreements. In all the documents there was a section that expresses, under different titles and denominations, the needs of the customer or consortium, the opportunity, and the challenge faced by the project using blockchain in combination with different technologies. A qualitative content analysis of the documentation was carried out to identify the keywords that define the needs that motivated the investment.

Thus, to obtain the list of benefits of the technology, a thorough reading of the project documentation was carried out and all the keywords were noted down in the project documentation. Once the keywords expressing the needs covered by blockchain technology had been isolated, they were standardized and grouped together, resulting in 12 values or applications for which companies are investing in blockchain, which we analyze in the following section. Finally, we performed an analysis of the relationships between the 12 benefits using hierarchical clustering, the results of which are presented in Section 3.3.

3. Results

The different benefits identified in the research are discussed below, starting with a definition of each perceived value, continuing in the following sections with an understanding of the impact of each of them in the different sectors or company sizes, and finally with an analysis of the relationships between them.

3.1. Perceived Value of Blockchain Technology

3.1.1. Decentralization of Processes

Decentralization of processes is one of the most obvious benefits of blockchain technology because of its distributed architecture and its ability to create reliable peer-to-peer relationships without the need for a trusted third party to intermediate between the parties [7].

Blockchain enables the management of business-to-business processes in a decentralized way, allowing all parties to directly participate in the management of business processes. Blockchain makes it possible to audit each process, as well as its compliance with the business rules established by the community in the blockchain network [8].

In several of the evaluated projects, there was a group of participants who wanted to establish a common management of processes, however, for political or economic reasons, they had decided not to implement it [91]. These participants considered that creating a third-party organization, or relying on an existing one, was more costly than the benefit of joint transactions. They also did not consider that all of the processes could be managed by one of the community participants, as this would give that participant huge power by managing the information and processes of the rest of the partners. With blockchain technology, these types of communities have been able to create an application so that they can interact with each other in a decentralized way.

In other cases, the centralization of the decision making was a risk and a single point of failure/attack that could cause a great impact on the ecosystem, so they have found blockchain to be a solution. Furthermore, in other projects, geopolitical interests and the need for decision-making not to be “implemented” in a single territory, or continent, were combined to give confidence to the parties in adopting the system [92]. For others, the purpose was to create a digital ecosystem between devices that interact with each other in a decentralized manner, closely related with M2M and Machine Economy.

Finally, this decentralization of governance was the way to reach the decentralization of business models as will be seen in the following section.

3.1.2. Decentralization of Business Models

The academic literature is now starting to reflect the decentralization of business models in studies such as [9–11]. The research has determined how companies want to disrupt current business models, especially platform business models [12].

The Internet has enabled the creation of new business models based on digital platforms, such as Airbnb and Uber, that allows them to create ecosystems in which some participants offer products/services, while others require such products/services, so they use the platform to establish contact. Currently, countless companies are trying to be the Uber for X or Y of their ecosystem, to create the digital platforms that respond to a specific need and charge for the intermediation between parties.

Precisely the business model that companies have been trying to adopt in recent years, the platform business model, is the one that companies in the study try to destroy. An open and free blockchain application can offer to the suppliers and demanders of products/services a very similar service to the current digital platforms. In addition to the analyzed projects, it is possible to find initiatives such as OpenBazaar that aim to disrupt and be a decentralized and free alternative of companies such as eBay or AliExpress that follow the platform business model [97].

3.1.3. Traceability and Provenance of Assets

Blockchain technology provides an unalterable record of the asset's history, in which both its origin and components can be evaluated, as well as all changes, updates, maintenance, and operations throughout its history. Every change made to the resource that is relevant for the ecosystem can be recorded on the blockchain, guaranteeing both the integrity of the data, and the date on which it occurred.

This traceability of assets, and the components that compose them, can also be carried out throughout the entire supply/value chain, making it possible to analyze the impact of any change in the design/composition of a product at operational level. This anticipates changes in consumption trends, avoids manually entering details of products received by suppliers, automates claims and guarantees without requiring paperwork, and, lastly, provides greater assurance in relation to certificates of origin of materials/products compared to current paper-based certificates [98].

The main industrial actors had already tried to create traceability systems before using traditional systems controlled by themselves. However, they had not been accepted by the rest of the ecosystem because nobody wanted to admit that the giant of the supply chain was also the custodian of the information of the whole chain, giving them an even more privileged position than they already had before. Therefore, blockchain offers an alternative in which all participants in the supply/value chain can create a community in which there is no privileged central entity.

In some of the evaluated projects these assets were intangible, for example, energy, where precisely the traceability of their provenance is crucial to demonstrate to customers the origin and type of energy consumed, especially in those cases where the consumer is paying for renewable energy [99].

The need to trace another typology of intangible resources such as intellectual property rights linked to digital assets of various types has also been identified [100]. In all cases, the requirements were very common, it was necessary to prove that at a certain date the asset had already been created by someone. In addition, in some cases it was necessary to trace the rights to its use/consumption [101].

The provenance issue arises precisely in several projects of traceability of both tangible and intangible goods [13]. Several projects focused on the origin of the materials used in the industrial or construction process were also studied, all of them linked to the circular economy [33,34].

3.1.4. Traceability/Certification of Processes and Regulatory Compliance

Process traceability is closely linked to the previous section, as it benefits from the blockchain's ability to create an unalterable tracking that is not controlled by a single key player. However, in this case the traceability is completed over a process instead of an asset. There are cases in which there is no obvious differentiation between them, since examples can be found such as the processes of industrial transformation of an asset in which a company presents both needs. In these cases, the project must provide value in both aspects by carrying out the traceability of the item and its state, in addition to the traceability of industrial transformation process applied to the resource.

However, in general, when process traceability is mentioned, it refers to those internal or external processes to organizations that must be monitored, and in some cases certified because in some domains this is necessary for regulatory compliance. Processes linked to different domains have been identified in the literature:

Construction and industrial transformation processes linked to quality standards or circular economy certifications [15].

Food safety processes in a supply chain [16], sometimes also linked to the process of obtaining labels of quality, bio, and ecological.

Compliance with personal data protection regulations such as GDPR, monitoring the access and exploitation of sensitive data [17].

Traceability of financial operations for regulatory compliance [108].

Tenders or registration of power of attorney in the public sector [18].

3.1.5. Transparency of Processes

Transparency is usually closely linked to traceability because if transparency is desired for suppliers, customers, or stakeholders in general, it is only necessary to give them visibility of the traceability of that process. In addition, when this traceability has been reflected in blockchain gives it more confidence to the transparency process because blockchain guarantees that the records have not been modified later to adjust them to another reality.

However, transparency is independent of the traceability of blockchain processes, as there is the possibility to offer transparency on processes that are not traced in blockchain, reflecting only the result of the process in the blockchain. Therefore, such transparency can be completed based on a blockchain process traceability or based on any other set of data on specific processes that want to be exposed, once or even periodically.

Among the evaluated projects, transparency projects in the field of e-government and healthcare have been mainly identified. Governments have always required transparency and this is precisely one of the values that blockchain brings to it [110], while in the health domain there are projects where transparency is required in clinical trials and related processes [111].

Traceability of construction processes, circular economy, or even the origin of energy, are the other applications where the need for transparency with other actors in the ecosystem was present.

3.1.6. Shared Asset/Process Management

Adams et al. [19] in 2003 analyzed the problem of shared asset management and defined it as: "…the management of common pool resources can be viewed as a problem of collective action and analyzed in terms of the costs and benefits of cooperation, institutional development, and monitoring, according to variables such as group size, composition, relationship with external powers, and resource characteristics…".

Blockchain can solve the challenges identified in the study by providing all stakeholders with a single synchronized view of the shared resources and their states. This perfect synchronization and holistic vision can facilitate the shared management of resources, allowing to reduce frictions between the different actors, enabling complex ecosystems.

This is especially relevant in use cases where some of the parties depend on the resource status of other community participants to make decisions. In these cases, it is important to have the certainty that the information available to each actor is up to date when deciding on or performing an action, as well as having the consensus of the rest of the stakeholders so that at any given time two participants cannot execute a change in the process, or asset, that is incompatible between them; and in that case, the blockchain ensures that only one of the two simultaneous changes can take place. This happens, for example, when two participants launch a simultaneous reservation order on a shared asset. One of the two orders should be accepted, and the other should be rejected when processed by the community. Something so easy to implement in a single organization is complex in a shared resource environment, especially when a single participant is not to be trusted as a central decision-maker and coordinator of all shared resources.

Sometimes shared asset management refers to a set of actors having exactly the same visibility over the state of an item, or its history, without the possibility of being discordant.

This need has been found in the evaluated projects linked to a set of actors who need to know the status of a financial asset, a commercial/logistic transaction, authorizations to third parties to access certain information, administrative consents, shared whitelist/blacklist in threat intelligence environments, or even the status of items listed in marketplaces.

3.1.7. Trustworthiness and Integrity

The decentralization of governance, as well as the integrity and immutability of blockchain transactions, make blockchain networks a “source of truth” [20]. Additionally, each participant must digitally sign every transaction they make on the blockchain, so that, in addition to agreeing with “the truth”, it is recorded who is responsible for any change or evolution of that truth. This is important for possible claims among participants in case the information recorded by any of them was not entirely accurate. Therefore, blockchain is the right technology to create reliable repositories to make, and automate, decisions in companies.

There are different reasons for which a group of participants requires a common reliable source of information. The study shows cybersecurity projects that need to know with certainty attack signatures, commands, or even verify the integrity of a software/firmware or configuration to be installed [21]. Projects required a reliable source from which to automate indemnifications, technical evidence records for subsequent forensic analysis, or claims between parties [115]. Other projects required the registration of intellectual property, verifiable credentials linked to a self-sovereign identity [116], or even clinical trial results and consent from informants for further evaluation. In general, any type of information that could be used a posteriori, or even information that third parties must trust in order to automate their own processes as discussed below.

3.1.8. Automation of Processes

Many projects required a unique synchronized vision of the state of shared assets or resources of common interest, as well as the integrity and reliability of the information registered about those assets/processes to fully automate the decision-making processes.

It is feasible to avoid manual monitoring to automate and make decisions with the certainty that up-to-date information about a process/asset is available, and reliable, besides the fact that a third party cannot modify it for its own benefit.

Currently, companies do not rely on automating certain decisions based on information that may be published by a third party on a web service because the third party may modify such information, which could result in the company making incorrect decisions, and also not having evidence that the third party has acted in bad faith [21]. Thanks to blockchain, companies can automate decisions based on third party information, which can substantially increase the business value of the companies.

The studied projects presented cases of automation and enforcement of IT processes such as the deletion of user data in an automated way based on the user’s right to be forgotten, the triggering of contingency actions for cyber security such as the isolation of an infrastructure from the Internet, or the automated closure of network ports based on threat intelligence information [118]. In the industrial area, automated actions are carried out in the operations infrastructure based on information from trusted third parties registered in the blockchain without these orders having to be supervised by humans, interaction between robotic swarm systems [119], or robotic process automation in an office environment [120].

3.1.9. Smart Contracts

In 1994, Szabo [121] devised the term Smart Contract and defined it as: "a computerized transaction protocol that executes the terms of a contract. The general objectives of smart contract design are to satisfy common contractual conditions (such as payment terms, liens, confidentiality, and even enforcement), minimize exceptions both malicious and accidental, and minimize the need for trusted intermediaries". Sometime later, the concept of Smart Contracts was specified in more detail [23], but Smart Contracts could not be implemented until blockchain technology had been conceived. Precisely, the first programs that were designed in blockchain were the Smart Contracts. That is why today we call Smart Contracts any native blockchain program, even though this program in many cases may be executing or automating processes that are not a "contract" between two agents. When in this study we refer to the term Smart Contract we refer to Szabo's original concept in which there is a custody of value (tokens) in the intermediation between two or more parties.

Not surprisingly, in the analysis the need to satisfy contractual conditions between two or more agents has been found, which is one of the main and differential values of blockchain technology. Thus, among the evaluated projects we found several marketplaces of different typology (Energy, Manufacturing Industry, etc.) [123], bilateral contracts specially focused on energy [124], parametric insurance that automatically indemnifies through assets tokenized in a blockchain [125], several examples of sharing economy and prosumers [126], and automated distribution of digital intellectual property rights [101].

3.1.10. Digital Identity

Many ecosystems and users demand a new model of interoperable digital identity, focused and managed by the user himself, and ensuring privacy (Privacy by Design).

In 2016, Allen [24] defined the basis of a new decentralized identity model called "Self-Sovereign Identity" (SSI). This new identity concept aims to respond to the demand for a new identity based on 10 principles designed to ensure that users maintain control of their identity and do not have to rely on any central entity. Thus, users will be able to present the attributes of their identity (age, nationality, academic qualifications, etc.) to third parties minimizing the presented information using zero knowledge proofs [25] to maximize their privacy. This allows users to prove, for example, their legal age without disclosing their specific age.

In the sample of analyzed projects, typical cases have been found such as the identity of users of public services as well as other digital services (e.g., financial or health services). These are the most common in the academic literature, but we have also discovered cases of a more industrial nature in which industrial devices, or even the manufactured products themselves acquire that "I" character. They obtain an identity that enriches with parameters about their certifications regarding design, manufacturing processes, or homologations. Moreover, these identity attributes can be used in operation so that a system of systems admits the execution of a certain component, depending on the provided credentials.

3.1.11. Sovereignty of Data and Data-Driven Services

Governance and sovereignty of data and data-driven services is a growing need in business [26]. Today, most business data are not being exploited, nor is artificial intelligence being able to play a greater role, precisely because of the desire to have control over the data.

Companies are afraid of sharing data with third parties because once they do it they no longer have control over it, and data can be replicated and distributed without their consent, losing its economic value [27].

Unblocking this situation and valuing data is something in which blockchain, in combination with different privacy-preserving technologies such as homomorphic encryption [28], differential privacy [132], Federated Learning [133], or Secure Multi-Party Computing [134], can be decisive. In some cases, these techniques have recently been used to design a privacy-preserving contact tracing framework [135].

Precisely in this line of secure data exploitation are the analyzed projects, whose objective is to allow training of machine/deep learning models with third party data without making a disclosure of such data, third parties offering services on business data without having direct access to the information (or at least not in plain text), or simply secure data sharing managed by a digital trusted third party, that is blockchain.

3.1.12. Machine-to-Machine (M2M) Transactions and Machine Economy

The Machine-to-Machine (M2M) transactions and particularly the Machine Economy, or M2M Economy, is a new paradigm that emerges by transferring the sharing economy to the IoT [136]. Thanks to the capability of decentralization and tokenization of assets and services of blockchain, the Machine Economy allows the creation of a new sharing economy among the machines themselves; putting in as value their data/services in this ecosystem, and operating in an autonomous way with tokens [29]. Attaran et al. [138] discuss in the chapter "new business applications for the blockchain" several cases linked to M2M transactions.

The token economy [30] in the IoT field is still very novel. However, in the set of analyzed projects tokenized transactions between machines in Industrial Internet of Things (IIoT) (manufacturing and energy) can be discovered as well as other proofs of concept in the fields of autonomous vehicles.

3.2. Blockchain Applications Impact Analysis

The demand for each use case was studied according to different impact criteria. This will help to understand the needs of the companies, as well as to identify patterns.

The first analysis determines the investment in each of these functionalities by company size. Table 2 shows how trustworthiness and integrity is the most demanded need, it represents between 16.96% and 21.51% of the investment, depending on the size of the company. On the other hand, automation of processes is the only aspect in which some of the company sizes do not invest, specifically in the case of micro and small enterprises. This is probably because large and medium-sized companies have more complex processes where blockchain can provide greater value and justify the return on investment.

Table 2. Applications investment by company size (percentages).

Size	Dec. of Processes	Dec. of Buss. Models	Trac. of Assets	Trac. of Processes	Trans. of Processes	Shared Asset Mgmt.	Trust and Integrity	Autom. of Processes	Smart Contracts	Digital Identity	Sovereignty Data	Machine Economy
Micro	14.96	9.16	4.60	9.92	2.12	4.28	16.96	-	5.81	12.11	9.50	10.58

Small	8.11	2.44	8.03	13.00	4.11	8.04	21.53	-	5.34	13.11	8.11	8.17
Med.	8.50	1.49	6.36	15.33	3.23	12.04	17.32	5.91	5.53	9.61	6.42	8.25
Large	15.14	2.45	6.45	7.23	1.89	5.22	21.51	11.03	1.13	14.32	4.20	9.42

Micro enterprises are most active investing in the decentralization of business processes and Machine Economy, although with less difference compared to other company sizes. Micro and large companies are investing in the decentralization of processes, in contrast to small and medium-sized companies that mainly invest in traceability of processes. We can observe how medium-sized companies are the most active investors in shared asset management; and large companies stand out for their investment in process automation and limited investment in Smart Contracts.

Table 3 presents the percentage of investment made by sector in each of the identified applications. The construction sector is mainly investing in process traceability, shared asset management, and trustworthiness. No investments have been identified in more decentralized characteristics such as process decentralization, business models, smart contracts, or Machine Economy.

Table 3. Applications investment by sector (percentages).

Sector	Dec. of Processes	Dec. of Buss. Models	Trac. of Assets	Trac. of Processes	Trans. of Processes	Shared Asset Mgmt.	Trust and Integrity	Autom. of Processes	Smart Contracts	Digital Identity	Sovereignty Data	Machine Economy
Cons.	-	-	10.78	22.21	10.78	22.21	22.21	6.51	-	5.31	-	-
eGov	9.93	-	-	24.34	5.26	24.34	13.98	1.75	-	16.04	4.35	-
Energ.	3.74	4.23	15.42	15.38	1.68	13.77	15.79	10.77	3.82	-	-	15.42
Finan.	0.69	1.38	0.69	22.14	8.46	22.83	10.49	22.14	11.18	-	-	-
Ind4.0	4.08	0.90	4.31	4.66	0.79	10.79	20.90	10.57	1.83	6.44	15.84	18.89
Health	13.53	5.89	5.90	12.39	-	17.88	17.88	5.19	-	12.69	8.64	-
Mobil.	11.20	6.81	7.99	7.99	3.60	14.80	14.80	14.80	-	11.20	-	6.81
ICT	9.03	1.94	2.25	7.35	0.33	4.34	17.64	10.29	3.48	19.23	11.75	12.36

Governments are mainly investing in process traceability and shared asset management, followed by digital identity for their citizens and decentralization of processes. Furthermore, it is one of the few sectors that is not investing in asset traceability.

The energy sector is heavily investing in process and asset traceability, as well as process automation to improve its current processes. In addition, due to the decentralization of power generation and emerging prosumers [31], the energy sector is investing in trust and integrity, shared asset management, and Machine Economy.

The financial industry is focused on improving its current processes, with most of its investment focused on shared asset management, process automation, and traceability. Precisely, because the disintermediation of financial relations could jeopardize its medium/long-term business viability, there is no investment in the decentralization of processes.

The fourth industrial revolution is reflected in the industrial investments that have trust and integrity of relationships at their core, as well as industrial data sovereignty and Machine Economy. In a second tier, shared asset management and process automation could be highlighted.

The health sector invests mainly in shared resource management, digital identity, and trust, with traceability and decentralization of processes in a secondary plane. All this fits with a more patient-centric vision in which health services aim to interoperate and empower the user over their health data.

In the case of mobility, we should note that they mainly invest in shared asset management, digital identity, and trust, but in this case their commitment is linked to process automation rather than process decentralization.

The ICT sector stands out for its clear commitment to digital identity and trust, which aims to change the identity model towards a Self-Sovereign Identity (SSI), followed by data sovereignty and Machine Economy linked to the data economy and IoT ecosystem.

Finally, Figure 3 shows the investment made in each of the applications identified in the study. Evaluated projects indicate a higher investment in trustworthiness of data and relationships between different stakeholders. This characteristic represents 18% of global investment.

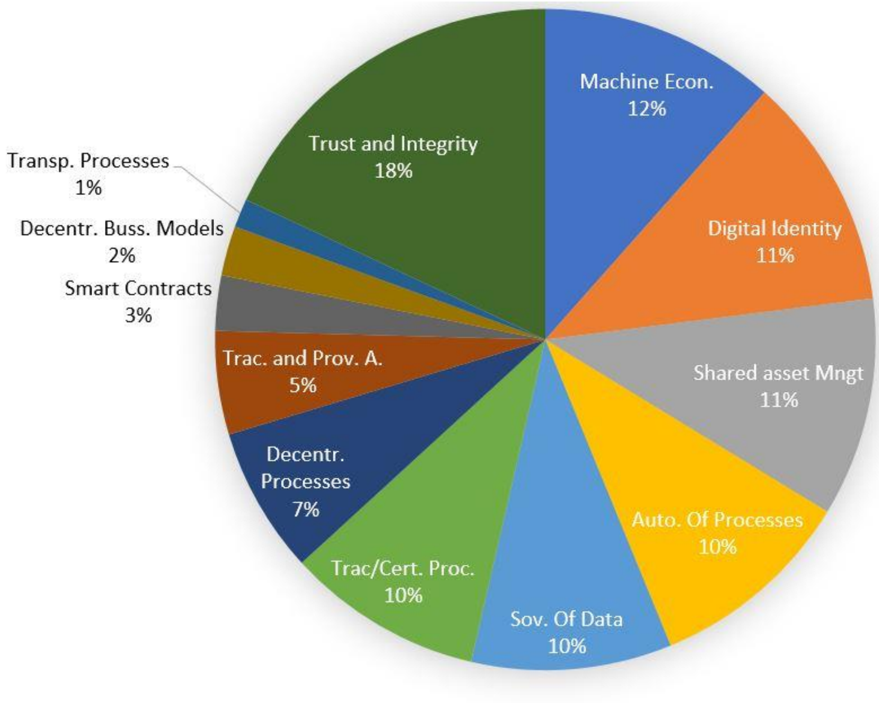

Figure 3. Blockchain investment distribution by business value.

Machine Economy is the next value with the highest investment. This distinctive IoT trend, both for consumer and industrial applications, represents 12% of global investment; probably driven by the high investment in ICT and Industry 4.0 projects, as shown in Figure 1. The next most heavily invested business values are Digital Identity and Shared Asset Management, each representing 11% of global blockchain investment. These four business applications together account for 56% of the overall analyzed investment.

Surprisingly, the three functionalities that have received the least investment are process transparency, decentralization of business models, and smart contracts. Together, they represent only 6% of the analyzed investment, followed by asset traceability which represents just 5% of the investment. These features are some of the most frequently mentioned in the studies reviewed in the introduction, but they are not the ones in which companies are making their main investments. We will analyze this fact in the conclusions.

3.3. Relational Model of Blockchain Provided Value

After discussing the business value and impact that blockchain technology offers to companies, the next step was to analyze if there is any relationship between the demands of these functionalities. That is, the relationship between the investment in these functional values by companies in their projects, to infer if there is a relationship between them.

For this purpose, a clustering analysis using a hierarchical cluster was carried out [32]. To perform the analysis, we associated with each busines application a 104-tuple vector, corresponding to the 104 projects examined in this paper. Each component was assigned the worth 1 if the functionality was present in the purposes of the project, and 0 otherwise. Then, we used the squared Euclidean distance as a measure of the relationship between the applications. In this way, we obtained a dendrogram (Figure 4) where we can appreciate the relationship between the different functional values of the blockchain technology in the analyzed projects [33]. Different cluster sizes were explored and it was decided to establish a cluster of six since it is the one with more coherence.

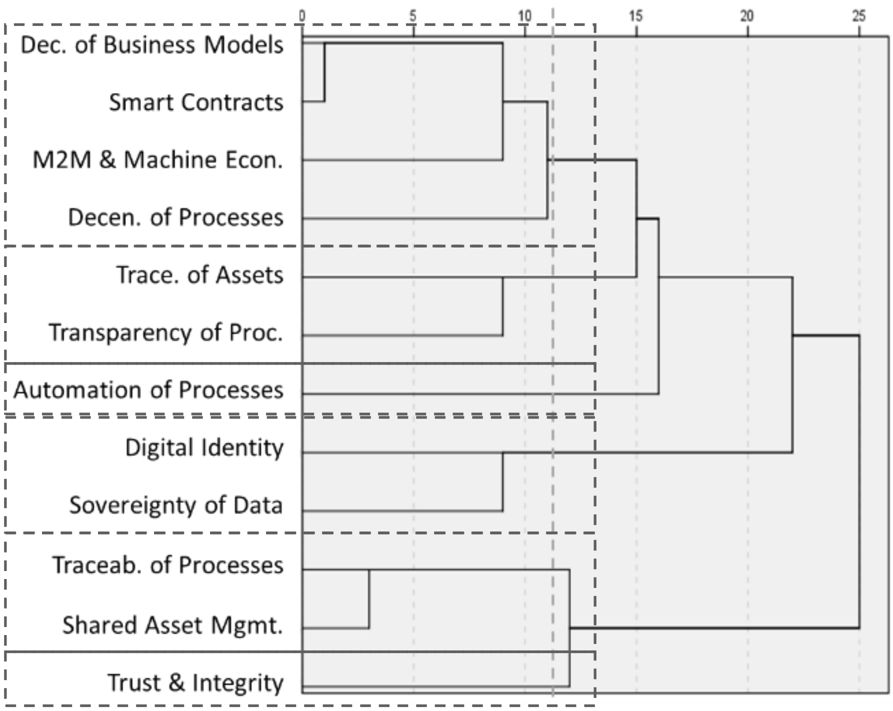

Figure 4. Hierarchical clustering dendrogram using an average linkage between groups (rescaled distance).

The dendrogram shows clear relationships between the decentralization of business models and smart contracts. The result is natural since one of the most common ways of creating decentralized businesses is through a Decentralized Autonomous Organization (DAO) which is based on a smart contract that governs the organization [34]. In the case of M2M transactions and Machine Economy, it is clearly related to the above as it is a decentralization of the current IoT business models through smart contracts. The fourth value in the first cluster is process decentralization, which is also found when business models are decentralized.

Traceability and provenance of assets is a highly demanded value in transparency projects, that is why these two variables are closely related in many of the analyzed projects. These two characteristics represent the second cluster.

Something similar occurs with the traceability of processes and the management of shared assets, which are closely related and form a cluster. The reason for this is that many of the shared asset management projects we analyzed also required traceability of the processes performed on those shared assets.

Digital identity and data sovereignty are also closely linked and form a cluster, since in order to create data sovereignty systems it is common to use a decentralized identity on the basis of which to implement policies related to data consumption.

Finally, it should be noted that there are two factors that are not so closely related with others and, therefore, each one forms a cluster on its own. These characteristics are Trustworthiness and Integrity and Automation of Processes.

4. Conclusions

More than 100 real blockchain contracts were analyzed to answer the research question of what blockchain functional values companies are investing in, regardless of the sector and use case. The research was completed based on a systematic analysis of actual company investments rather than theoretical benefits of the technology. Based on the documentation of analyzed projects, the real needs of the companies regarding blockchain were identified, classified, and correlated.

Our findings allow us to obtain the real value of blockchain for companies, since until then the literature only had specific use cases or reviews of potential blockchain applications, but in no case a review and analysis based on a set of real projects in which companies have invested. In addition, the article shows the relationship between these identified values, allowing a clustering of six elements since many of the values are demanded jointly. The study will allow to identify new applications of the blockchain technology in scenarios that have not yet been identified, increasing the adoption of blockchain technology.

On the other hand, the study shows that three of the most promising values of blockchain technology are the ability to decentralize processes, business models, and the creation of smart contracts. However, we found that combined they only represent 6% of the actual investment in blockchain. We discovered that companies are mainly demanding trustworthiness of their information, Machine Economy, digital identity, and shared asset management which together account for more than half of the economic investment of companies in blockchain technology. This might indicate that companies are making pragmatic decisions and are in a process of learning. This may be representative of the fact that we are still in the early stages of blockchain technology adoption, and that companies need to learn about the technology before undertaking investments of greater uncertainty or risk.

4.1. Limitations

Although the results of the study are very promising and show that companies are starting to invest in blockchain technology, the reader should be aware that blockchain technology still presents different challenges at the technological level [74–76].

On the other hand, our own study also has limitations. The authors consider that the sample of 104 contracts in the most relevant industries is sufficiently representative; actually, a larger sample could only slightly vary the results. Likewise, the sample may also present some geographic bias since the investments are mostly from European companies.

We are at a very early stage in the adoption and deployment of blockchain technology. In the coming years, researchers may identify new uses of the technology that we do not know of today. These new uses may also represent part of the investment of companies in the coming years.

4.2. Future Research

Because this analysis of investment in blockchain technology was carried out independently of its specific uses, this study can help to identify new applications of this technology that have not been yet considered in the literature. Thus, expert researchers in different domains will be able to use the present manuscript as a basis for their reflection and identify new applications of blockchain technology in their field of expertise.

On the other hand, the work identified that although decentralization of business models currently only represents 2% of investment, all sectors, except construction and governments, are beginning to invest in it; this can represent a great risk to current models, such as the aforementioned platform business model.

Therefore, another research line opened by this research is to explore how blockchain technology will decentralize and disrupt current business models, and what kind of new decentralized business models will emerge.

Author Contributions: Conceptualization, O.L., M.S.-S. and J.M.Z.; methodology, O.L., M.S.-S. and J.M.Z.; formal analysis, O.L. and J.M.Z.; investigation, O.L. and M.S.-S.; resources, O.L. and M.S.-S.; data curation, O.L.; writing—original draft preparation, O.L.; writing—review and editing, O.L., M.S.-S., and J.M.Z.; supervision, M.S.-S. and J.M.Z.; funding acquisition, J.M.Z. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by Spanish Ministry of Science and Innovation, grant number PID2019- 105291GB-I00; and by The Basque Country University, grant number GIU20/019.

Institutional Review Board Statement: Not applicable

Informed Consent Statement: Not applicable

Conflicts of Interest: The authors declare no conflict of interest.

References

72. Nakamoto, S. *Bitcoin: A Peer-to-Peer Electronic Cash System*; Bitcoin–URL: https://bitcoin.org/bitcoin.pdf , 2008.
73. Fanning, K.; Centers, D.P. Blockchain and Its Coming Impact on Financial Services. *J. Corp. Account. Financ.* **2016**, *27*, 53–57.
74. Collomb, A.; Sok, K. Blockchain/distributed ledger technology (DLT): What impact on the financial sector? *Digiworld Econ. J.* **2016**, 103, pp. 93-111.
75. Mettler, M. Blockchain technology in healthcare: The revolution starts here. In Proceedings of the 2016 IEEE 18th International Conference on e-Health Networking, Applications and Services (Healthcom), Munich, Germany, 14–16 September 2016; IEEE: New York, NY, USA, 2016; pp. 1–3.
76. Ekblaw, A.; Azaria, A.; Halamka, J.D.; Lippman, A. A Case Study for Blockchain in Healthcare: "MedRec" prototype for electronic health records and medical research data. In Proceedings of the IEEE Open & Big Data Conference, Los Alamitos, CA, USA, 15–18 December 2021; p. 13.
77. Wang, L.; Xie, Y.; Zhang, D.; Liu, J.; Jiang, S.; Zhang, Y.; Li, M. Credible Peer-to-Peer Trading with Double-Layer Energy Blockchain Network in Distributed Electricity Markets. *Electronics* **2021**, *10*, 1815.
78. Huang, Z.; Li, Z.; Lai, C.S.; Zhao, Z., Wu, X.; Li, X. , Tong, N., Lai, L.L. A novel power market mechanism based on blockchain for electric vehicle charging stations. *Electronics* **2021**, *10*, 307.
79. Ølnes, S. Beyond bitcoin-Public sector innovation using the bitcoin blockchain technology. In Proceedings of the Norsk Konferanse for Organisasjoners Bruk at IT, Oslo, Norway, November 2015.
80. Deloitte's 2020 Goblal Blockchain Survey. Available online: https://www2.deloitte.com/content/dam/insights/us/articles/6608_2020-global-blockchain-survey/DI_CIR%202020%20global%20blockchain%20survey.pdf (accessed on 7 December 2021).
81. Seebacher, S.; Schüritz, R. Blockchain technology as an enabler of service systems: A structured literature review. *Int. Conf. Explor. Serv. Sci.* **2017**, pp. 12–23.
82. Tama, B.A.; Kweka, B.J.; Park, Y.; Rhee, K.H. A critical review of blockchain and its current applications. In Proceedings of the 2017 International Conference on Electrical Engineering and Computer Science (ICECOS), Sriwijaya, Indonesia, 2017; pp. 109–113.
83. Hawlitschek, F.; Notheisen, B.; Teubner, T. The limits of trust-free systems: A literature review on blockchain technology and trust in the sharing economy. *Electron. Commer. Res. Appl.* **2018**, *29*, 50–63.

84. Casino, F.; Dasaklis, T.K.; Patsakis, C. A systematic literature review of blockchain-based applications: Current status, classification and open issues. *Telemat. Inform.* **2019**, *36*, 55–81.
85. Laroiya, C.; Saxena, D.; Komalavalli, C. Applications of blockchain technology. In *Handbook of Research on Blockchain Technology*; Academic Press, United States, 2020; pp. 213–243.
86. Perera, S.; Nanayakkara, S.; Rodrigo, M.N.N.; Senaratne, S.; Weinand, R. Blockchain technology: Is it hype or real in the construction industry? *J. Ind. Inf. Integr.* **2020**, *17*, 100125.
87. Ko, T.; Lee, J.; Ryu, D. Blockchain technology and manufacturing industry: Real-time transparency and cost savings. *Sustainability* **2018**, *10*, 4274.
88. Casado-Vara, R.; Chamoso, P.; De la Prieta, F.; Prieto, J.; Corchado, J.M. Non-linear adaptive closed-loop control system for improved efficiency in IoT-blockchain management. *Inf. Fusion* **2019**, *49*, 227–239.
89. Zheng, Z.; Xie, S.; Dai, H.; Wang, H. An overview of blockchain technology: Architecture, consensus, and future trends. In 2017 IEEE International Congress on Big Data, Honolulu, HI, USA, 25–30 June 2017; pp. 557–564.
90. Mendling, J.; Weber, I.; Aalst, W.V.D.; Brocke, J.V., Cabanillas, C.; Daniel, F., Debois, S.; Di Chiccio, C.; Dumas, M.; Dustar, S.; et al. Blockchains for business process management-challenges and opportunities. *ACM Trans. Manag. Inf. Syst.* **2018**, *9*, 1–16.
91. Harmon, P. *Business Process Change: A Business Process Management Guide for Managers and Process Professionals*; Morgan Kaufmann: Burlington, United States 2019.
92. Caldara, D.; Iacoviello, M. Measuring geopolitical risk. *FRB Int. Financ. Discuss. Pap.* **2018**, *2018*, 1222.
93. Nowiński, W.; Kozma, M. How can blockchain technology disrupt the existing business models? *Entrep. Bus. Econ. Rev.* **2017**, *5*, 173–188.
94. Lage, O.; Saiz-Santos, M. Blockchain and the decentralisation of the cybersecurity Industry. *DYNA* **2021**, *96*, 239. https://doi.org/10.6036/10188.
95. Morkunas, V.J.; Paschen, J.; Boon, E. How blockchain technologies impact your business model. *Bus. Horiz.* **2019**, *62*, 295–306.
96. Täuscher, K.; Laudien, S.M. Understanding platform business models: A mixed methods study of marketplaces. *Eur. Manag. J.* **2018**, *36*, 319–329.
97. Stoletov, N. Uberisation Business Model Based on Blockchain for Implementation Decentralized Application for Lease/Rent Lodging. In Proceedings of the Information Systems and Technologies to Support Learning: Proceedings of EMENA-ISTL, Fez, Morocco, 25-27 October 2018; Volume 111, p. 225.

98. Mezquita, Y.; Casado-Vara, R.; González Briones, A.; Prieto, J.; Corchado, J.M. Blockchain-based architecture for the control of logistics activities: Pharmaceutical utilities case study. *Log. J. IGPL* **2021**, *29*, 974–985.
99. Andoni, M.; Robu, V.; Flynn, D., Abram, S., Geach, D.; Jenkins, D., McCAllum, P.; Peacock, A. Blockchain technology in the energy sector: A systematic review of challenges and opportunities. *Renew. Sustain. Energy Rev.* **2019**, *100*, 143–174.
100. Ito, K.; O'dair, M. A Critical Examination of the Application of Blockchain Technology to Intellectual Property Management. In *Business Transformation through Blockchain*; Palgrave Macmillan: Cham, Switzerland, 2019; pp. 317–335.
101. Finck, M.; Moscon, V. Copyright Law on Blockchains: Between New Forms of Rights Administration and Digital Rights Management 2.0. *IIC-Int. Rev. Intellect. Prop. Compet. Law* **2019**, *50*, 77–108.
102. Montecchi, M.; Plangger, K.; Etter, M. It's real, trust me! Establishing supply chain provenance using blockchain. *Bus. Horiz.* **2019**, *62*, 283–293.
103. Kouhizadeh, M.; Sarkis, J.; Zhu, Q. At the nexus of blockchain technology, the circular economy, and product deletion. *Appl. Sci.* **2019**, *9*, 1712.
104. Hatzivasilis, G.; Ioannidis, S.; Fysarakis, K.; Spanoudakis, G.; Papadakis, N. The green blockchains of circular economy. *Electronics* **2021**, *10*, 2008.
105. Shih, C.S.; Yang, K.W. Design and implementation of distributed traceability system for smart factories based on blockchain technology. In Proceedings of the Conference on Research in Adaptive and Convergent Systems, 2019; pp. 181–188.
106. Caro, M.P.; Ali, M.S.; Vecchio, M.; Giaffreda, R. Blockchain-based traceability in Agri-Food supply chain management: A practical implementation. In *2018 IoT Vertical and Topical Summit on Agriculture-Tuscany (IOT Tuscany)*; IEEE: Tuscany, Italy, 8-9 May 2018; pp. 1–4.
107. Compert, C.; Luineti, M.; Portier, B. Blockchain and GDPR: How blockchain could address five areas associated with GDPR compliance. *IBM Secur. White Pap.* **2018**.
108. YOO, S. Blockchain based financial case analysis and its implications. *Asia Pac. J. Innov. Entrep.* **2017**, *11*, 312–321.
109. Ølnes, S.; Ubacht, J.; Janssen, M. Blockchain in government: Benefits and implications of distributed ledger technology for information sharing. *Gov. Inf. Q.* **2017**, *34*, 355–364.
110. Batubara, F.R.; Ubacht, J.; Janssen, M. Challenges of blockchain technology adoption for e-government: A systematic literature review. In Proceedings of the 19th Annual International Conference on Digital Government Research: Governance in the Data Age, 2018; pp. 1–9.

111. Nugent, T.; Upton, D.; Cimpoesu, M. Improving data transparency in clinical trials using blockchain smart contracts. *F1000Research* **2016**, *5*, 2541.
112. Adams, W.M.; Brockington, D.; Dyson, J.; Vira, B. Managing tragedies: Understanding conflict over common pool resources. *Science* **2003**, *302*, 1915–1916.
113. Böhme, R.; Christin, N.; Edelman, B.; Moore, T. Bitcoin: Economics, technology, and governance. *J. Econ. Perspect.* **2015**, *29*, 213–238.
114. Serrano, O.L.; de Diego, S. D. D.; Seco, I.; Larrucea, X. Semi-real-time Hash Comparison for Detecting Intrusions Using Blockchain. In International Conference on Model and Data Engineering, Touluse, France, 28-31 October; Springer: Cham, Switzerland, 2019; pp. 165–179.
115. Ryu, J.H.; Sharma, P.K.; Jo, J.H.; Park, J.H. A blockchain-based decentralized efficient investigation framework for IoT digital forensics. *J. Supercomput.* **2019**, *75*, 4372–4387.
116. Ferdous, M.S.; Chowdhury, F.; Alassafi, M.O. In search of self-sovereign identity leveraging blockchain technology. *IEEE Access* **2019**, *7*, 103059–103079.
117. Ter Hofstede, A.H.; Van der Aalst, W.M.; Adams, M.; Russell, N. (Eds.) *Modern Business Process Automation: YAWL and Its Support Environment*; Springer Science & Business Media: Berlin, Germany, 2009; p. 492.
118. De Diego, S.; Gonçalves, C.; Lage, O., Manshell, J., Kontoulis, M., Moustakidis, S.; Guerra, B.; Liapis, A. Blockchain-Based Threat Registry Platform. In 2019 IEEE 10th Annual Information Technology, Electronics and Mobile Communication Conference (IEMCON); IEEE: 2019; p. 892–898.
119. Ferrer, E.C. The blockchain: A new framework for robotic swarm systems. In Proceedings of the Future Technologies Conference, Vancouver, Canada, 15-16 November: Springer: Cham, Switzerland, 2018; pp. 1037–1058.
120. Van der Aalst, W.M.; Bichler, M.; Heinzl, A. Robotic process automation. *Bus. Inf. Syst. Eng.* **2018**, *60*, 269–272.
121. Szabo, N. *Smart Contracts*; Unpublished manuscript; 1994.
122. Szabo, N. Smart contracts: Building blocks for digital markets. *EXTROPY J. Transhumanist Thought*, Extropy Institute, California, United States, **1996**, 16, pp. 18-20.
123. Subramanian, H. Decentralized blockchain-based electronic marketplaces. *Commun. ACM* **2017**, *61*, 78–84.

124. Van Leeuwen, G.; AlSkaif, T.; Gibescu, M.; van Sark, W. An integrated blockchain-based energy management platform with bilateral trading for microgrid communities. *Appl. Energy* **2020**, *263*, 114613.
125. Gatteschi, V.; Lamberti, F.; Demartini, C.; Pranteda, C.; Santamaría, V. Blockchain and smart contracts for insurance: Is the technology mature enough? *Future Interne*t **2018**, *10*, 20.
126. Pazaitis, A.; De Filippi, P.; Kostakis, V. Blockchain and value systems in the sharing economy: The illustrative case of Backfeed. *Technol. Forecast. Soc. Change* **2017**, *125*, 105–115.
127. Allen, C. The path to self-sovereign identity. *Life Alacrity* **2016**.
128. Goldreich, O.; Oren, Y. Definitions and properties of zero-knowledge proof systems. *J. Cryptol.* **1994**, *7*, 1–32.
129. Jarke, M. Data Sovereignty and Data Space Ecosystems. *Bus. Inf. Syst. Eng.* **2019**, *61*, 549–550.
130. Harris, D.; Khan, L.; Paul, R.; Thuraisingham, B. Standards for secure data sharing across organizations. *Comput. Stand. Interfaces* **2007**, *29*, 86–96.
131. Naehrig, M.; Lauter, K.; Vaikuntanathan, V. Can homomorphic encryption be practical? In Proceedings of the 3rd ACM Workshop on Cloud Computing Security Workshop, Chicago, Illinois, USA, October 2011; pp. 113–124.
132. Park, Y.H.; Kim, Y.; Shim, J. Blockchain-Based Privacy-Preserving System for Genomic Data Management Using Local Differential Privacy. *Electronics* **2021**, *10*, 3019.
133. Peng, Z.; Xu, J.; Chu, X.; Gao, S.; Yao, Y.; Gu, R.; Tang, Y. Vfchain: Enabling verifiable and auditable federated learning via blockchain systems. *IEEE Trans. Netw. Sci. Engineering*. **2021**.
134. Du, W.; Atallah, M.J. Secure multi-party computation problems and their applications: A review and open problems. In Proceedings of the 2001, Workshop on New Security Paradigms, 2001; pp. 13–22. https://doi.org/10.1145/508171.508174
135. Peng, Z.; Xu, C.; Wang, H.; Huang, J.; Xu, J.; Chu, X. P2B-Trace: Privacy-Preserving Blockchain-based Contact Tracing to Combat Pandemics. In Proceedings of the 2021 International Conference on Management of Data, Xi’an, Shaanxi, China, 20-25 Jun 2021; pp. 2389–2393.
136. Lage, O. Blockchain: From Industry 4.0 to the Machine Economy. In *Computer Security Threats*; IntechOpen: London, UK, 2019.
137. Chen, Y. Blockchain tokens and the potential democratization of entrepreneurship and innovation. *Bus. Horiz.* **2018**, *61*, 567–575.

138. Attaran, M.; Gunasekaran, A. *Applications of Blockchain Technology in Business: Challenges and Opportunities*; Springer Nature: Berlin, Germany, 2019.
139. Lee, J.Y. A decentralized token economy: How blockchain and cryptocurrency can revolutionize business. *Bus. Horiz.* **2019**, *62*, 773–784.
140. Morstyn, T.; Farrell, N.; Darby, S.J.; McCulloch, M.D. Using peer-to-peer energy-trading platforms to incentivize prosumers to form federated power plants. *Nat. Energy 2018*, *3*, 94–101.
141. Žiberna, A.; Kejzar, N.; Golob, P. A comparison of different approaches to hierarchical clustering of ordinal data. *Metodoloski Zv.* **2004**, *1*, 57.
142. Forina, M.; Armanino, C.; Raggio, V. Clustering with dendrograms on interpretation variables. *Anal. Chim. Acta* **2002**, *454*, 13–19.
143. Norta, A. Designing a smart-contract application layer for transacting decentralized autonomous organizations. In Proceedings of the International Conference on Advances in Computing and Data Sciences, Ghaziabad, 11-12 November 2016; pp. 595–604.
144. Hughes, L.; Dwivedi, Y.K.; Misra, S.K.; Rana, N.P.; Raghavan, V.; Akella, V. Blockchain research, practice and policy: Applications, benefits, limitations, emerging research themes and research agenda. *Int. J. Inf. Manag.* **2019**, *49*, 114–129.
145. Wu, H.; Peng, Z.; Guo, S.; Yang, Y.; Xiao, B. VQL: Efficient and Verifiable Cloud Query Services for Blockchain Systems. *IEEE Trans. Parallel Distrib. Syst.* **2021**, *33*, 1393–1406.
146. Frizzo-Barker, J.; Chow-White, P.A.; Adams, P.R.; Mentanko, J.; Ha, D.; Green, S. Blockchain as a disruptive technology for business: A systematic review. *Int. J. Inf. Manag.* **2020**, *51*, 102029.

Artículo 5: Decentralized platform economy: emerging blockchain-based decentralized platform business models

Lage, O., Saiz-Santos, M. y Zarzuelo, J. M. (2022). Decentralized platform economy: Emerging blockchain-based decentralized platform business models. *Electronic Markets, 32*(3), 1707-1723. https://doi.org/10.1007/s12525-022-00586-4

Índices de impacto: JCR JCI Q1, JCR JIF Q2, Scopus Q1

Decentralized Platform Economy: Emerging Blockchain-Based Decentralized Platform Business Models

Oscar Lage [1,2,*], María Saiz-Santos [2] and José Manuel Zarzuelo [2]

[1] TECNALIA, Basque Research and Technology Alliance (BRTA), Parque Científico y Tecnológico de Bizkaia #700, 48160 Derio, Spain

[2] Faculty of Economics and Business Administration, The University of the Basque Country, Av. Lehendakari Aguirre, 83, 48015 Bilbao, Spain; maria.saiz@ehu.eus (M.S.-S.); josemanuel.zarzuelo@ehu.eus (J.M.Z.)

* Correspondence: Oscar.Lage@tecnalia.com

Abstract:

Emerging decentralized multisided platforms aim to create more open collaborations between participants and question currently centralized networked business models, such as Google, Amazon, Uber, or Airbnb. In this paper, a systematic analysis of the emerging decentralized platform economy is presented based on blockchain technology.

The research aims to fill a gap in the literature, as there is currently no specific analyses on these emerging multisided decentralized electronic markets. Eighty-two decentralized platforms were studied. The study contributes to the literature on decentralized platform taxonomy to structure the emerging research domain of decentralized platform business models. Applying a cluster analysis, three emerging archetypes of decentralized platforms were found, referred to as hosted, federated, and shared platform models. The research contributes to a better understanding of emerging decentralized business platforms. According to the findings, two-thirds of the analyzed platforms, namely, federated and shared archetypes, do not follow traditional models. Rather, their aim is to create new business and community relationships. Furthermore, the archetype of shared platforms is the most disruptive, showing a higher level of decentralization and business model change.

Keywords: Blockchain, Business models, Decentralized platforms, Decentralized business, Disruptive technology, Web3

1 Introduction

During the dot-com boom, countless start-ups successfully launched initial public offerings (IPOs) without meeting traditional success metrics (Ljungqvist et al., 2003). These start-ups were not even close to a profit; however, they were found very attractive by investors and could raise capital without much effort.

While many of these companies went bankrupt, a few such as Amazon and eBay managed to survive the bubble burst, creating large economic empires. The question is, what was the secret of their success?

Parker and Alstyne (2005) were pioneers in the study of companies that survived and were successful. They defined a formal model that explained how "the two-sided network" was able to benefit from new information technologies in creating platform models whose main added value was to bring together and intermediate between two (or more) sides of a market. Shortly afterward, together with Eisenmann, they defined the strategy of these companies and the dynamics of these market ecosystems (Eisenmann et al., 2006). These businesses are now known as platforms, and their business models are the most successful in the economy (Mancha and Gordon, 2021). In the latest study (Hunter et al., 2020) carried out by PricewaterhouseCoopers, eight of the top ten companies in the world are platforms; only Saudi Arabian Oil and Berkshire Hathaway are based on traditional pipeline business models, and the latter has dropped two places in the last two years from seventh to ninth place. Therefore, entrepreneurs today are proposing platform business models, as it seems to be a key pattern for the success of a highly scalable business.

However, the platform economy can be transformed in the coming years with the arrival of the blockchain and its ability to decentralize business models. Blockchain could be a disruptive technology that changes the business ecosystem, as the Internet did a few decades ago (Crosby et al., 2016). The arrival of the Internet in the business environment in the 1990s made it possible to digitalize traditional pipeline models and make them more efficient. A few years later, change came with the arrival of platforms that replaced countless traditional pipeline models. This change was very fast in the services segment, but has yet to become equally important in sectors such as manufacturing (Van Dyck et al., 2020).

De Reuver et al. (2018) specified a well-known research agenda for digital platform models, in which they advance the distributed nature of new information systems (ISs), which will mark, in the coming years, the research challenges for these electronic markets. The authors point out that new challenges emerging for digital markets due to the new emerging technical architectures. Among the research questions proposed in their agenda, the following aspects should be highlighted. (i) Are digital platforms here to stay? Will we see more or fewer platforms in the future and how will future decentralization affect these electronic markets? (ii) How should platforms be designed? With the incorporation of new technologies, such as IoT, cloud computing, or blockchain, the technical and relational architecture of platforms will evolve in the coming years. (iii) How do digital platforms transform industries? The emerging platform economy requires research into the disruptive impact that these new platforms on organizations and their business models. The authors conclude that the power structures and relationships between participants in a decentralized ecosystem will change. They also point to the urgency of doing much more research on several emerging phenomena, such as decentralized technologies that enable innovation in digital platforms.

Alt (2020) remarks that blockchain technologies can serve as infrastructure for electronic markets. This is because blockchain, as a technology, acts as an intermediary between two parties in an agile way without requiring trusted third parties to ensure the security of the transaction. Alt points out that "…this leads to the question of whether platform providers are still necessary and paves the road toward completely decentralized blockchain-based electronic marketplaces…". Wigang (2020) indicates that this decentralization contributes to bypassing intermediaries and reducing the costs for mediating between buyers and sellers.

The research topic includes an analysis of how the decentralization of platforms through the incorporation of decentralized technologies, such as blockchain, will transform electronic markets. This research topic is new and requires, as the authors note, research on the impact of the emerging phenomenon of platform decentralization. As seen in the following section, there is research on the phenomenon of initial coin offering (ICO) and its tokens, and on the architecture of startups that provide services based on blockchain, among others. However, there is a gap in the literature on the specific analysis of these new decentralized platform business models and how a new decentralized platform economy is emerging. Thus, the aim is to answer the following research question (RQ):

RQ: What are the emerging archetypes of decentralized platforms and their main characteristics?

The research contributes to the understanding of these new platform models emerging due to the incorporation of blockchain to decentralize platform models. The work analyses 82 platforms, and as a result, provides the literature with a taxonomy of the main characteristics of these emerging platforms, as well as the main archetypes that are currently emerging, namely, hosted, federated, and shared platforms.

There is no similar work that investigates the new decentralized networked business, regardless of their source of funding or legal form, including totally open and decentralized projects that could be a radical change in the current electronic markets, such as Wikipedia's introduction of the encyclopedias segment. This research reviews all the latest advances in this regard, which in many cases are focused on a specific area, for example ICOs, or at a more general level creating archetypes of companies using blockchain technology. While authors identify the decentralized platforms, they do not make a specific analysis of them.

The research applies to the broad set of electronic marketplaces, and investigates the characteristics of decentralized models of interaction, as well as between the different parts of a marketplace. This represents a new trend that is still in its infancy and is slowly developing, but constitutes a new market model applicable to any sector in which platforms are currently operating. In addition, the research is conducted from a multidisciplinary perspective, including technological aspects among the characteristics to be analyzed, which provides greater precision to the study.

The paper is intended to be useful for all those researchers who are studying the impact of decentralized technologies on platform business models, as well as for those practitioners who want to create new decentralized platforms or decentralize existing ones.

The manuscript is organized as follows. The background section reviews previous work on the subject and its contributions, which will help to understand the platform ecosystem. The methodology section presents the methodological approach used to carry out the research. The following two sections describe the results and the contributions and explain the new emerging platform models and their characteristics, which will help entrepreneurs and researchers to understand these models and help practitioners evolve to one of these new platform models, if that fits into their strategy. Finally, the Discussion and Conclusions sections present the most relevant conclusions, trends, and topics for further research.

2 Background and Related Work

Parker et al. (2016) summarize how the "power of the platform" can radically transform a segment in a matter of months, something that has happened to many industries in the last few years due to the irruption of platforms, such as Airbnb, Uber, or Facebook, in their respective traditional pipeline ecosystems. Parker et al. (2016) define platforms as follows:

"*A platform is a business based on enabling value-creating interactions between external producers and consumers. The platform provides an open participative infrastructure for these interactions and sets governance conditions for them. The platform's overarching purpose: to consummate matches among users and facilitate the exchange of goods, services, or social currency, thereby enabling value creation for all participants*".

Unlike pipelines, where each actor is part of a well-defined position in the value generation chain, platform users can participate in different roles, allowing the same party to act both as a consumer of a platform and as a producer of it (e.g., reading and writing articles; buying and selling of goods). These users who act on both sides of the market are known as prosumers.

As a result, the platforms have unlocked new sources of value, allowing not only these users to participate in them as value creators, but also allowing value to be delinked from the assets (Şimşek et al., 2022). In the shared economy generated by platforms, it is common to see how private users can register their valuable assets (flats, cars, etc.) and offer them to strangers thanks to the trustworthiness that the platforms have gained. This model has also promoted new user behavior, since some years ago, it was unimaginable to share car trips with a third party or to rent your house to a stranger for a couple of days (Lang et al., 2021).

Platforms, unlike traditional pipelines, scale exponentially, as they do not need to invest in the assets that are offered to their users. The main asset of the platforms is data; the platforms exploit it to know the preferences of their users, and based on their feedback, they generate better recommendations. Moreover, this feedback serves them to automatically discriminate against low-value content (community-driven curation). However, traditional models require a control mechanism, such as editors and quality supervisors, which again are costly and slow down the growth of companies based on traditional pipelines.

According to Chakravarty et al. (2014), the main benefit for each side of the market is access to the other side. This is the so-called network effect, which goes beyond just access to the other side of the market (McIntyre et al., 2021). The network effect refers to the impact that the number of users of a platform has on the value created for a particular user. This effect can be positive if the number of platform users creates a significant value for the user or negative because if it grows in an unmanaged way, it reduces the value provided to each user (Panico and Cennamo, 2022).

The growth of platforms must be balanced, as uncontrolled growth can create a negative effect and cause a loss of value for users (Schmidt et al., 2021; Li et al., 2021; Stallkamp and Schotter, 2021; Garud et al., 2022). For example, the growth of passengers and drivers in Uber must be proportional, because if there are not enough drivers to meet the demand, it would leave passengers dissatisfied; or if there are too many drivers and the passengers do not demand enough of the drivers' time and services, causing drivers to look for other jobs.

3 Blockchain-based Decentralized Platforms

The ability of blockchain technology to create new models of decentralized platforms is the most significant effect of the introduction of blockchain to platform business models. This decentralization puts at risk monopolistic markets in which one company manages a whole segment of the market, something that has happened mainly due to the networking effect. Subramanian (2017) is one of the first to identify this risk and highlights that decentralization alters the ecosystem by offering safe, reliable, private alternatives with lower costs per transaction, while also mentioning that blockchain-based platforms improve matching and transaction facilitation.

The arrival of new decentralized platforms generates alternative platforms driven by technological progress that can operate without traditional intermediaries (Alt and Zimmermann, 2019), threatening traditional platforms with a centralized coordination topology (Yue et al., 2021). Disintermediation is precisely one of the main traditional problems to be solved in the platform economy (Ladd, 2021), and decentralized platforms can worsen it since it is not necessary for buyers and sellers to look for alternative mechanisms to bypass the platform and its commissions (Zutshi et al., 2021).

Other authors have analyzed the incorporation of blockchain technology in the platform business model from different perspectives. Using the Business Model Canvas (Osterwalder et al., 2010), Morkunas et al. (2019) analyze how each of the nine essential elements of Model Canvas could be affected by blockchain. Schulze et al. (2020) reviewed the literature and defined a small taxonomy of ten elements relating to general blockchain platforms, without focusing on a specific application of blockchain. The results are similar to those identified by Zutshi et al. (2021), who conduct an extensive literature review and identify the development of decentralized and open governance models as one of the main attractions of these platforms, which allows the incorporation of democratic principles of voting, collaborative work, and self-organizing manager-less organizations. Schlecht et al. (2021) foresee a great increase in value due to the incorporation of blockchain technology that will enable new forms of collaboration and business model opportunities. Rajnak and Puschmann (2021) analyze the impact of blockchain technology on banking business models challenging the status quo, but also warn that the technology is still in its early stages of development. Marikyan et al. (2021) analyze the risks and benefits in business models caused by the different technical alternatives of blockchain networks, as well as how blockchain technology contributes to innovation in business models. Recently, Lage et al. (2022) also analyzed more than a hundred blockchain projects to identify the business values most demanded by companies and their level of investment according to the sector and company size. The authors identify that although decentralized business models represent only 2% of the investment in blockchain projects, many sectors are already taking the first steps.

Many authors point to a change in governance and the democratization of these platforms thanks to their decentralization. Chen et al. (2021) examine different alternative platform governance structures promoted by the advantages and benefits of blockchain technology. The authors point out that the decentralization of platform governance is a real trend. Lumineau et al. (2021) point out that blockchain technology promotes a new way of dealing with cooperation and coordination and gives guidelines on when blockchain technology can be more or less effective in managing collaborations. Hein et al. (2020) conduct a thorough analysis of digital platforms and identify different archetypes according to platform ownership: platforms with a central owner, a consortium of partners, or a decentralized peer-to-peer network. These authors indicate that these decentralized platforms can be governed by the users of these decentralized communities, who can have voting rights and participate in the design of new platform functionalities. The application of the principles and values of the cooperative movement could be very similar to the features that blockchain technology offers to these decentralized platforms according to Kollmann et al. (2020). They analyze the case of the D. Tube platform to demonstrate their theory and suggest further study of these platforms to analyze how blockchain is integrated and foster new models of relationships among platform participants. Furthermore, members of decentralized platforms, not only create value for themselves through the exchange of high-value goods and products, but also share the value inherent in the aggregated data, which are cocontrolled and coexploited by the members of the platform (Kolade et al., 2022).

ICOs are also an interesting field of study, and some authors have developed their research around ICOs. The first thing to highlight is the ability of ICOs and their utility tokens to help in the early stages to solve the "chicken and egg" problem on multisided platforms (Drasch et al., 2020). This problem is one of the main challenges of any new platform (Veisdal, 2020). However, the authors also discover how tokens can have contradictory incentives for participants and might even inhibit platform usage since the financial incentive (ICO) initially boosts platform expansion. Additionally, Bachmann et al. (2021) analyze a set of 131 ICOs with the objective of identifying the design parameters of these ICOs as a novel financing strategy and identify five ICO design archetypes.

Furthermore, we should highlight two interesting papers similar to this research. The first is the analysis of 99 blockchain ventures performed by Weking et al. (2020) to explore the impact of blockchain technology on business models. As a result, they identify five archetypal patterns of different blockchain-based services: blockchain for business integration, blockchain as a multisided platform, blockchain for security, blockchain technology as an offering, and blockchain for monetary value transfer. The second pattern, blockchain as a multisided platform, is the one associated with this research. The authors identify the characteristics of invested companies that use blockchain to create platform ecosystems. The studied platforms use external blockchain networks (Ethereum mostly), charge per transaction to their customers on their own token, and use a traditional web to address their customers. On the other hand, Tönnissen et al. (2020) point out the lack of understanding of the different business models of startups born from an ICO. They conduct a study of 195 ICOs of which they identify three archetypes of token-based ecosystem business models. The authors point out that these three archetypes can be related to Moore's (1996) commonly used framework for organizational stages. The first, Pioneering (vision) model, represents cases where the ICO token is used primarily as an Exchange for benefits, with no specific activities to increase its value. They are mainly startups that do not generate platforms (one-sided markets) and with a very low level of collaboration. Second, the expansion model has the active participation of stakeholders, and therefore, increases the value of the tokens for all involved parties. The authors recommend this model for startups that want to finance themselves through an ICO and implement a business model with partners with a common currency. Last, the authority model shows a lower level of control, as neither the price nor the terms of the contract are subject to supplier specifications, and the direct network effect plays an important role. This model allows building innovative and value-oriented business models with trading partners using a proprietary blockchain network and enabling network effects to succeed in the B2C segment. These last two ICO archetypes would be the closest to this research, since the first type of ICO would be excluded, as it does not constitute an electronic market.

4 Characteristics of Decentralized Platforms

There are no studies that offer a specific characterization for decentralized multisided markets, which is why one of the main contributions of the present work has been to elaborate a taxonomy following the guidelines specified for the second phase of the research "Research phase 2: decentralized platform taxonomy" of the “Methodology” section. In that section, the process followed to identify and select those characteristics that best represent decentralized platform business models is explained and the taxonomy is represented.

In Table 1, the features with their origin are presented. Each feature comes from the literature related to platform models, from the blockchain technology, or a traditional feature powered by the technology. In the last case, although the feature was previously present in traditional blockchain platforms, it provides new possibilities; for example, the participation of users and developers can become much more relevant, allowing them to be part of the governance of the platform. In the section "Key properties of Blockchain-based Decentralized Platform Models", these characteristics (taxonomy) are explained in detail, and in the section “Identifying Decentralized Platform Models”, their values in the different archetypes are identified in the study.

Table 3. Origin of the characteristics selected in the taxonomy. Source: own elaboration

Interaction components	**Origin of the characteristic**
Nº of roles	Traditional
Exchange of info primary object.	Traditional
Filter	Traditional
Direct interaction between users	Traditional
Internal exchange of goods	Traditional
Currency exchanged	Traditional
Member curation	Traditional
Direct network effect	Traditional
Openness	
Manager participation	Traditional
Open source	Traditional
Shared governance	Blockchain Enhanced
Developer participation	Blockchain Enhanced
User participation	Blockchain Enhanced
Tokenomics	
Token usage	Blockchain Technology
Token Type	Blockchain Technology
Market Properties	
B2B Market	Traditional
B2C Market	Traditional
Price Control	Traditional

Contractual Terms controlled	Traditional
Monetization	Blockchain Enhanced
Who Pays?	Blockchain Enhanced
Marketing strategy	
Launch strategy	Traditional
Viral growth	Traditional

It should be noted that decentralized platforms maintain the same characteristics in relation to the interaction and marketing strategy components, while adopting new features specific to blockchain technology regarding the use of blockchain tokens in different areas. In turn, concerning the openness of the platform and the properties of the market, there are some properties that acquire new properties:

- “Shared governance”, “developer participation”, and “user participation”: unlike centralized platforms in which users can participate in some limited functionalities/roles, in decentralized platforms, the governance and developers can be the community itself. Moreover, in some cases, new functionalities will always be proposed and voted upon by the platform users themselves.
- “Monetization” and “Who Pays”: in decentralized platforms, as will be observed in the following sections, there may not be a monetization model of the platform, and nobody may pay directly or indirectly for its services, since a platform can be completely open and communal due to decentralized technologies.

5 Filling the Research Gap

Schulze et al. (2020) conclude their study by referring to the need to carry out an extensive study and find the relationships between the different characteristics of existing platforms to identify archetypes of blockchain platforms, that is, new models that could guide practitioners when designing new blockchain-based platforms. However, none of the previous authors have systematically analyzed existing platforms by characterizing new decentralized business platforms. Many of the previous studies focus exclusively on the analysis and characterization of ICOs and their utility tokens, characterizing different archetypes and characteristics in a general way, but not focused on multisided platform models. Other studies analyze companies that use blockchain to provide decentralized services, identifying platform business models as one of the typologies, but without going into specific detail, as this is not their focus. Finally, other studies analyze the usefulness of blockchain technology in different sectors or cases, in general.

The contribution of this work is to develop a taxonomy of decentralized business platform models and determine the different archetypes and their properties. This study fills an existing gap in the literature by focusing on analyzing and characterizing specifically decentralized multisided markets, not including any other type of project that does not attempt to create a decentralized networked business. In addition, none of the analyzed papers incorporates networked open-source platforms, which is a new feature offered by blockchain technology that allows the community itself to create and operate such platforms without requiring a company or trusted third party to manage them. This is radically new and has great potential to generate new relationship models in electronic markets, so it is necessary to incorporate this type of platform into the study.

6 Methodology

To carry out the research, a multimethod research approach was followed consisting of three stages, as shown in Figure 1. First, a wide range of decentralized platforms was identified and the necessary database created to carry out the research (step 1). Second, a taxonomy was developed to structure the emerging research domain of decentralized platform models and to establish the basis for further research activities (step 2). Finally, a cluster analysis was performed to identify the decentralized platform archetypes and their properties (step 3).

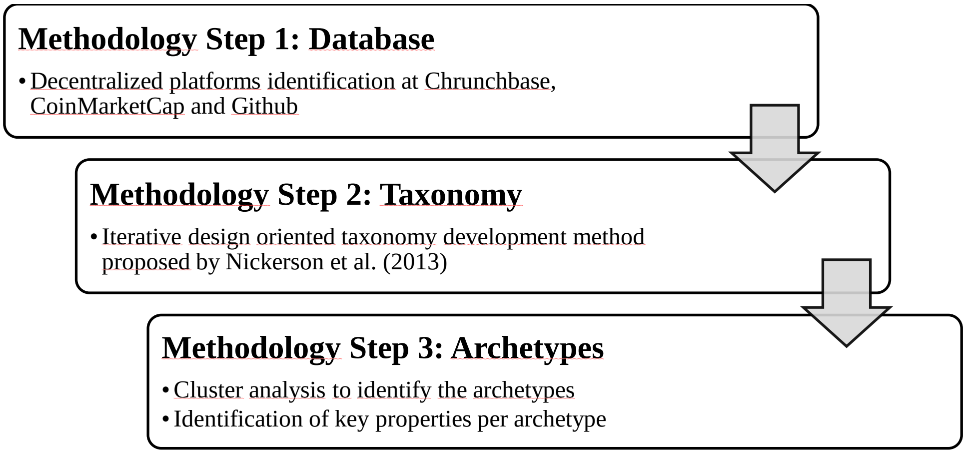

Figure 5. Methodology steps.

Several of the state-of-the-art articles conducting similar studies follow a similar methodology, since taxonomies create the basis for future research and improve the understanding of a new phenomenon (Glass and Vessey 1995). In addition, through the application of clustering techniques, new archetypes of platforms that are emerging can be identified, enhancing the understanding of this new concept of decentralized electronic markets.

The following three subsections detail each of the three steps that conform to the methodology.

6.1 Methodology Step 1: Database

The starting point of this methodology was the selection of a sample of decentralized business platforms during September 2020. To identify decentralized platforms, three data sources were used: Crunchbase (crunchbase.com), CoinMarketCap (coinmarketcap.com) and Github (github.com). These data sources are commonly used to carry out different research and studies.

Crunchbase is the largest database for new ventures (Marra et al. 2015) and guarantees high-quality results with respect to invested companies. Crunchbase is commonly used by high-quality publications to perform similar searches (Żbikowski et al., 2021; Weking et al., 2020; Kézai et al. 2020; Ferrati et al., 2020).

An analysis in Crunchbase was conducted by running a complex search for companies in the blockchain industry. The first search parameter used in the search was the type of industry, focusing on those companies that have been classified by Crunchbase's specialized team in the blockchain industry: (Industries > include any > Blockchain). In addition, a second filtering parameter related to the current status of the company was introduced: (Operating Status > does not equal > Closed) from initial companies classified as blockchain, only those that are not rated as closed by the Crunchbase team were obtained.

The results of this search were organized according to the Crunchbase Rank (CB Rank), a proprietary algorithm that, according to Stephan (2018), combines different factors from each company, such as media appearances, engagement with the community, acquisitions, investments, etc., to identify companies with the highest potential and impact. The first 100 items of the results were analyzed, and after a first analysis of the public information of these startups, the criterion of discarding all those initiatives whose main value proposition was not the creation of a decentralized platform was applied. Following this criterion, 59 organizations that were aligned with the study were selected. We discarded 41 companies that mostly offered services based on blockchain technology, including consulting specialized in the technology, but did not create electronic marketplaces, so they were not useful for the study.

As expected, during the search process, the absence of some important organizations in the sector was noticed, such as FileCoin or Augur. We have therefore chosen CoinMarketCap as a second source to complement the results obtained in Crunchbase. CoinMarketCap is the world's most popular price-tracking website for cryptoassets. The majority of studies related to cryptocurrencies and ICOs use this service for their asset search (Roosenboom et al., 2020; Alt, 2020; Felix et al., 2019), and a recent study has confirmed the reliability and quality of its index (Vidal-Tomás, 2022). This is because the CoinMarketCap team rigorously checks the projects that apply for admission to its platform before listing them. For a cryptocurrency to be considered by CoinMarketCap, it must be listed on an exchange with a certain trading volume of that asset. In addition, CoinMarketCap regularly monitors a set of qualitative and quantitative factors to maximize the quality of its indices, which are publicly accessible on its website.

Using CoinMarketCap, the different blockchain tokens were sorted according to their Market Cap, which is calculated by multiplying the amount of tokens in circulation and the current market value of each token. The first 100 tokens of the search results were analyzed. Following an analysis of the public information related to these 100 token initiatives, 11 tokens were selected that were used as an exchange of value in a decentralized market. Most of the discarded projects were cryptocurrencies (e.g., bitcoin). With this selection of 11 new decentralized platforms, researchers made sure to include in the study companies that have not followed the investment parameters identified by Crunchbase or, due to their novel characteristics, their index has not prioritized, despite being relevant for the community valuing their tokens positively, economically, to be in the top 100.

Finally, to locate fully open projects that could be created by the community, even without financial support, a search was launched on Github for projects tagged with blockchain labels. GitHub is the largest and most advanced development platform in the world, and more than 73 million developers use GitHub for the collaborative development of millions of open-source projects. Therefore, researchers use their data to research the open-source community (Wachs, 2022). After analyzing the first 100 results tagged with blockchain labels and discarding cryptocurrencies or core technology projects (Hyperledger projects, Ethereum, etc.), another 12 open projects were identified. These projects are platforms created voluntarily and collaboratively by the community.

The three data sources used to conduct the search represent the fundamental resources for identifying invested startups (Crunchbase), the most valued tokens (CoinMarketCap), and the main open projects that the community is creating (GitHub). As indicated, researchers from all fields regularly use these three sources in their studies. The results of the three searches were filtered to select those that represented decentralized platforms, that is, emerging decentralized versions of traditional multisided markets that use blockchain technology to create such decentralization.

Publicly available information was used from those projects to perform the filtering process.

Any researcher could access the three sources and replicate the searches indicated in the paper to obtain the results, as well as identify those that represent blockchain-based platform models and that do not depend on a central server to manage them, in other words, decentralized platforms.

As a result, a total of 82 platforms based on blockchain technology were identified in the database. The complete list of platforms that compose the database can be found in Figure 3 of the appendix. The 82 projects reflect the main markets in which new platform businesses are emerging, so the sample is considered sufficiently representative of the new decentralized platform economy to conduct the study. Table 2 shows the markets and their representation in the analyzed sample.

Table 4. Market distribution of analyzed sample. Source: own elaboration

Market	Number Projects	% of appearance
Decentralized Computation	14	17.07%
Content Distribution	4	4.88%
Cybersecurity	3	3.66%
File Storage	5	6.10%
Gambling	3	3.66%
Governance	4	4.88%
Identity	6	7.32%
Marketplaces	13	15.85%
Messaging	6	7.32%
Music	2	2.44%
Social Networks	13	15.85%
Video & Streaming	6	7.32%
Web Search	3	3.66%

The next step was to compile the information relating to the 82 selected platforms. To do so, we the websites of all of them were consulted, the associated white papers downloaded, information published on their respective social networks (mainly Twitter and Medium) and interviews and articles from the main specialized media (Cointelegraph, CoinDesk and CriptoNoticias) were compiled.

6.2 Methodology Step 2: Taxonomy

According to Nickerson et al. (2010), a taxonomy is an instrument, the result of a design science research approach, based on dimensions that contain properties that are mutually exclusive and collectively exhaustive. A taxonomy aims to provide a basis for further research by systematically classifying the properties of the objects of interest, promoting understanding of a phenomenon (Glass and Vessey, 1995).

To address this phase, the iterative design-oriented taxonomy development method proposed by Nickerson et al. (2013) integrates conceptual and empirical perspectives. The methodology requires empirical to conceptual and conceptual to empirical iterations. These iterations should end when the final conditions are met; in this case, we have kept the Nickerson et al. (2013) proposal of eight objective and five subjective conditions, as they were perfectly adapted to this case study.

In the empirical to conceptual iterations, we analyzed in detail a subset of the 82 selected platforms to identify properties and group them into dimensions, where possible, through the creation of labels for sets of related features (Baley, 1984).

To address conceptual to empirical iterations, we draw on the literature to identify characteristics. Decentralized platforms inherit the general properties of multiside platforms and specific aspects of blockchain technology. Different general properties proposed by (Parker et al., 2005, 2016; Eisenmann et al., 2006; Van Dyck et al., 2020; Chakravarty et al., 2014; Evans et al., 2003), as well as different properties of blockchain technology (Crosby et al., 2016; Subramanian, 2017; Morkunas et al., 2019; Schulze et al., 2020; Kollmann et al., 2020; Weking et al., 2020), have been analyzed. At the end of each of the iterations, we evaluate whether the current taxonomy meets the final conditions.

During later iterations, the applicability of these characteristics with the platforms in our database is tested. Many properties that did not provide value and did not offer relevant information to differentiate between one platform and another were discarded, and they had the same value for all the projects.

Finally, based on the selected characteristics (Table 2), a taxonomy that is based on 23 dimensions that truly characterize a decentralized platform was obtained. The dimensions and properties of the taxonomy are detailed in the key properties of the blockchain-based decentralized platform section.

6.3 Methodology Step 3: Archetypes

A cluster analysis was performed to identify the different models of decentralized platforms, which will allows the identification of different archetypes. Cluster analysis is a statistical technique that allows the researcher to group platforms by minimizing within-group variance, while maximizing the between-group variance (Blashfield and Aldenderfer, 1988).

The first step of the clustering methodology was the selection of the grouping variables. The taxonomy, which was carried out in the previous phase, grouped variables following a deductive approach. Until this point, the database created in the first step only had a list of 82 startups, so it was completed with the 23 dimensions of each of the 82 platforms. For this purpose, all the public information available for each of the projects under study was accessed (websites, white papers, information published in social networks, and interviews/articles from the main and specialized media).

We then analyzed a different weight of these variables; more precisely, we assigned a weight of 40% divided equally among the following four aspects that considered key in the characterization of the possible platform models: Member Curation, Shared Governance, Manager participation, and Monetization Strategy. The remaining 60% of the weight was equally shared by the remaining 19 dimensions. In other words, these four dimensions were estimated to be approximately three times as relevant as each of the rest, when considering potential new platform models.

After the selection of the variables, an appropriate clustering algorithm was selected, in particular hierarchical clustering using Ward's method as an agglomeration technique in the analysis, and Euclidean distance over the weighted values as a measure of the relationship between the values (Žiberna et al., 2004).

To validate the results obtained following this clustering algorithm, nonhierarchical clustering algorithms were tested, such as k-means or k-modes (Huand, 1998). The results of all of them have been similar to those obtained when applying hierarchical clustering using Ward's method on the Euclidean distance.

7 Key Properties of Blockchain-Based Decentralized Platform Models

Following the second phase of the methodology, the main characteristics of a decentralized platform business model and defined a taxonomy of 23 dimensions were selected. Taxonomy is one of the main results of this study, so in this section, each dimension and characteristics of the taxonomy are presented, specifying the results obtained during the study. The results are grouped into 5 thematic areas to facilitate the understanding of the taxonomy.

7.1 Interaction Components

Parker et al. (2016) define the core interaction as involving three key components: the participants, the unit of value, and the filter. All three must be clearly identified, and the relationships between them must be carefully designed to make the interaction as simple, attractive, and valuable as possible for users.

The minimum **number of participants** (roles) will be 2 (two-sided market), but there can be many more in a multisided market. In fact, it is common for a platform to start with its key interaction (two-sided) and evolve by incorporating other interactions that provide added value (multisided). In addition, the platform should facilitate role changes for users. In the analysis, an average of 3.56 roles in the analyzed platforms was obtained.

The basic **unit value** is information. For every interaction, information must be shared. On some occasions, the interaction of information will only be the first phase. In the second phase, the exchange of goods or services about which information was obtained will take place. On other occasions, the information itself will be the unit of value exchanged, with no other existing unit or no other additional information; 43.9% in the analyzed decentralized platforms. For this reason, the unit of value will be used as a parameter, with the information being the primary or a secondary objective of the interaction.

In general, most platforms will offer a **filter** based on a software tool to permit the exchange of the appropriate value between users. A well-designed filter ensures that users receive only the value units relevant to them. Even so, several platforms use a minimum number of filters or only the filters that are internal to the platform (47.56% in our analysis), not exposing them to the user because instead of providing a tool (a search form), the purpose is to provide a unified user experience and offer a service, regardless of who is providing it. This is why, for example, the users do not know which other members of the decentralized FileCoin platform are offering them the storage service. The only thing they need to know is that the information is always available, and it will be the platform itself that manages which other members store this information and its redundancy. Therefore, there are platforms that offer a filter to the user and there are other platforms that do not, even though they implement it internally to provide the customer a better service.

On the other hand, the **interaction between users may be direct or indirect**. Direct interaction (36.59%) usually occurs on analyzed social networks, while indirect interaction occurs in cases where the platform filters and directly offers the service, without direct contact between the two sides of the market.

The **exchange of goods or services may be internal** to the platform (such as decentralized social networks), 91.46% among the analyzed platforms, or may take place **externally** (such as Airbnb). Platforms are more interested in internal exchanges, and the platforms’ main objective is to ensure that the supplier and the consumer always use the platform to exchange value. This is because, in many cases, once both parties are in contact with each other outside the platform, they could leave the platform if that would save them some cost.

The **type of value exchanged** is also a parameter that must be considered when defining the interaction. On some platforms (7.32%), the value exchanged will be a currency (like eBay), while on others, it may be another form of value, such as attention or likes on social networks, even tokens on decentralized platforms (Oliveira et al., 2018).

Member curation is a way of maintaining the quality of the platform by eliminating fake items, members who bully other members, etc. This is a feature, that in a decentralized platform, is complex to manage by the community and, in many cases, requires community consensus over very well-defined rules. It is precisely this difficulty and the open nature of the decentralized platforms, because this characteristic is not very common among decentralized platforms (18.29%).

In addition, some platforms benefit from the value of the **direct network effect** with the incorporation of new participants in the network (98.78%), regardless of the new member's role or the market side they adopt.

7.2 Openness

The openness of the platform is a key characteristic in decentralized platforms. The key aspect to be analyzed is the level of **relationship and participation of the manager and sponsor**. The analysis revealed four classic models in the analyzed platforms (Eisenmann et al., 2008, 2009):

- *Proprietary Model:* The whole chain from the generation of the platform to its exploitation is proprietary and closed (20.73%).
- *Licensing:* An organization produces a platform that is exploited by third parties (13.41%).
- *Joint Venture Model:* An organization and volunteers develop the platform that they jointly exploit as a single unit (20.73%).
- *Shared Model:* A group of users and organizations develop the platform, and any of them or third parties can exploit a version of the platform (45.12%).

Many of the analyzed platforms offer great transparency to their ecosystem by publishing their code as **open source**. This is not common in traditional platforms, but 78.05% of the decentralized platforms analyzed in this study have this property.

Shared governance is also not common. However, in the case of decentralized platforms, 54.88% were openly governed by or with the community. In addition, the level of governance by the community can be total in a decentralized platform, something unthinkable in a traditional platform governed by a company. Thus, in the case of decentralized platforms, it is not only about letting third parties participate in the governance, but also about the community being sovereign enough to self-manage and govern the platform without the need for any central entity.

Developer participation (85.37%) can create secondary functionalities, identify needs that the platform had not previously identified, etc. Thanks to the participation of external developers, the platform increases its functionality. If an external application coexists with the platform and acquires part of the interaction, it is always possible to incorporate or replicate it within the platform. It should be noted that in the study we have found decentralized platforms where this feature rises to the point where the community of developers are the ones developing the platform in its totality, as opposed to the traditional centralized platforms where this feature was limited to a company owning the electronic marketplace, letting external developers participate only in certain functions.

The **users' participation** in the creation of the platform is also possible (31.71%). An example of such participation in a well-known traditional platform is the use of the hashtag on Twitter. A user began marking the themes of his tweets to identify and search for them. When the initiators of the platform found that it was a good practice for users, it was incorporated into Twitter as a core functionality. In the case of some decentralized platforms, the user community is the one that proposes the new functionalities to be developed in the platform, since decentralized platforms are totally self-managed by the user community.

7.3 Tokenomics

Tokenomics is the study of the economy (demand and supply) generated by tokens in a blockchain ecosystem (Lo & Medda, 2020; Mougayar, 2020). Two variables were identified in this field during the study.

The first is whether the platform uses a specific **token**, based on which it creates its token economy. This is something new and exclusive to this type of platform. Most of the analyzed platforms (85.37%) interacted with some tokens. On the other hand, the **token type** is also very relevant to the study. The analysis used one of the latest and simplest classifications proposed by the community (MakerDAO, 2020):

- *Platform Token:* Supports dapps execution on the blockchain (30.49%).
- *Security Token:* Represents legal ownership of a physical or digital asset (no presence in our study)
- *Transactional Token:* Units of value for the exchange of goods and services (8.54%).
- *Utility Token:* Integrated into the protocol of the platform and used to access the platform services (60.98%).
- *Governance Token:* Voting tokens for shared governance (39.02%).

In the analysis, some platforms were found to have more than one type of token, either because they had a specific token of each type or because the same token could be used for more than one purpose.

7.4 Market Properties

The platform can address **business-to-business (B2B)** or **business-to-customer (B2C)** transactions, or both. Some analyzed platforms impose control over their members' relationships (1.22%). One way is to establish **price control**, which, in many cases, means defining the price of items. In other cases, platforms establish **control over the contractual terms** between the parties. This type of practice is not very common among traditional platforms and is even less frequent on decentralized platforms.

The **monetization** of platforms is very complex, as there are markets where their services are considered to be free. This is why the platform must, in many cases, look for indirect ways to monetize and offer the primary interactions for free or almost free. In any case, analyzed platforms use one of the following strategies to monetize:

- *Transaction fee* (56.1%).
- *Access to the platform*, can be hourly, monthly, etc. (6.1%).
- *Enhanced Access* to allow premium functionalities at a price (4.88%).
- *Enhanced Curation*, offering more accurate, suitable, and higher quality results (23.17%).
- *Free & Open* (6.09%).

It should be noted that there are totally free and open platforms in this new emerging model of decentralized platforms. These community-created platforms have no economic objective.

Who pays for the services of the platform is also an important characteristic. In some analyzed platforms, no member pays, as mentioned above (21.05%), in others all members pay (7.32%), or even some members (one side) pay and cover the service for the rest of the users who access it for free or at very reduced prices (82.93%). Free decentralized ecosystems where nobody pays may even be promoted by users of traditional electronic markets to save the costs of traditional intermediaries. Again, the possibility that the community itself can create decentralized platforms as a substitute for the current traditional platforms has a clear economic purpose, as already advanced by Alt and Zimmermann (2019).

7.5 Marketing Strategy

One of the most critical points for any platform is its **launch strategy** (Parker et al., 2016). Platforms need a minimum set of users to generate the network effect and bring value to users. In addition, all sides of the platform must be proportionally represented (for someone to sell a product, there must be buyers and vice versa). The following types of launch strategies have been detected in the analyzed platforms:

- *Follow the Rabbit:* In these cases, the platform is launched with a controlled set of users that generate value and attract other users. For this purpose, some platforms are designed to attract a specific set of users (either producers or consumers) who attract the other side. (58.67%)

- *Piggyback:* Creating complementary value for an existing set of users from another platform, as PayPal did for eBay users. (8.00%)
- *Seeding:* In those cases where the strategy is that the platform itself creates units of very high value or hires specialists who create it to attract the rest of the users. (16.00%)
- *Producer Evangelism:* Platforms that attract producers who move their natural clients to the platform. (16.00%)
- *Big-bang Adoption:* Using the traditional strategy of push marketing to attract a large volume of interested parties (from both sides) to your platform (no presence in our study).
- *Micromarket:* Starting with a small specific market to improve to match and then grow into other markets. (1.33%)

In traditional platforms, it is also common to find the single-side strategy, which is based on the creation of a platform specialized in a single product or service. Once the platform has "captured" that market, it is extended to other services and products. However, none of the decentralized platforms analyzed in this study have used this strategy.

To complement their previous strategies, some of the studied platforms followed a **viral growth** pattern (15.85%). This process of traction stimulates users to spread the platform to generate exponential growth. To do this, it is necessary to identify which users wish to share their units of value or information with other users of their social networks or other platforms to generate in these third parties the impulse to access the platform to consume this unit of value.

These platforms design and facilitate the sharing of these units of value in other platforms. In many cases, they even integrate with these third-party platforms, in which users exchange value to facilitate exchange.

8 Identifying Decentralized Platform Models

The next step in the study was to analyze the possible existence of different archetypes of decentralized platform business models. For this purpose, following the third phase of our methodology, a clustering analysis using a hierarchical cluster was carried out based on the 23 dimensions of the taxonomy, identifying, as a result, the different archetypes present in our database.

Different cluster sizes were explored, and a cluster of three was decided upon because this was an option with more coherence. Dendrogram visualization (Forina et al., 2002) shows how there can be three large blocks of projects with a close relationship among them (Figure 2).

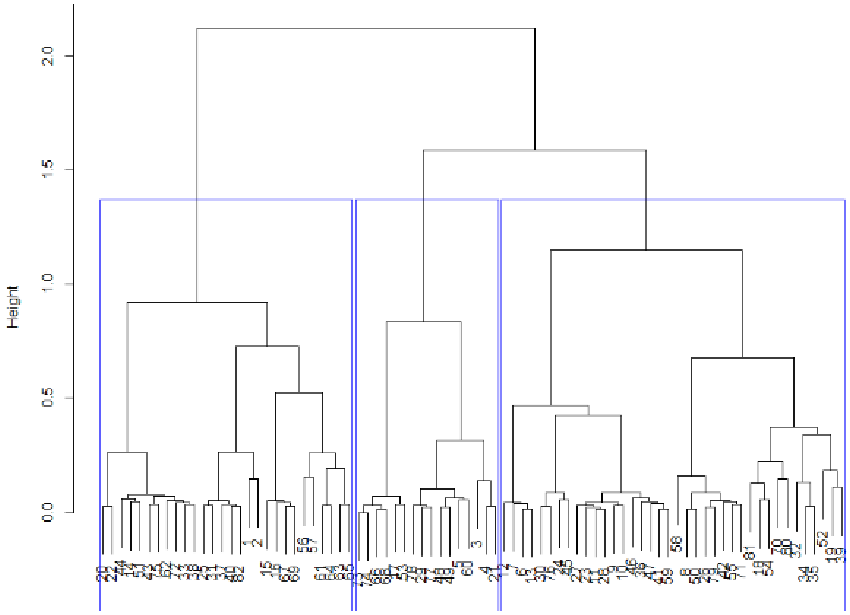

Figure 6. Hierarchical clustering dendrogram showing a 3-element cluster. Source: own elaboration

In fact, two of these groups in the dendrogram visualization (the two on the right) have a closer relationship with each other than with the first one. Actually, this closeness is totally consistent, as shall be seen.

After analyzing the dimensions and characteristics associated with the platforms of each cluster, they were named them as follows (from left to right): hosted, federated, and shared. These three archetypes represent the three new models of decentralized business platforms that are emerging.

Below, the unique characteristics and differences of these three emerging models (hosted, federated, and shared) are analyzed.

The archetype of the hosted platform bears the closest similarity to the current platforms. It is the model with the highest percentage of curated members and it is a proprietary or licensing model regarding its openness, e.g., Althea, Appics, FunFair Technologies, Mesg, Edge Network, FOAM, Civic, OpenSea, Storj, Voice, or Yours, among others.

The federated and shared models are more open, the first one is characterized by the fact that all its platforms follow the joint venture model in their management, they have a high degree of shared governance, developer involvement and user participation. It is a collaborative platform model in which the community collaborates with companies and foundations in search of a unique platform that provides value to all, e.g., Datum, Streamr, Sense, Minds, Theta, or SingularDTV.

The shared model is the most liberal among the models and the one that differs most from traditional platform business models. Shared platforms are free ecosystems of shared management and governance in which, in many cases (21.05%), they have no economic incentive. The community creates those platforms so that everyone can use them freely and deploy one or more networks of that platform for different ecosystems or even create subsystems within the main network governed by the open community, e.g., Aragon, Augur, IPFS, FileCoin, Uport, OpenBazaar, MutualDAO, or 0x, among others.

Table 3 shows how the hosted platforms are characterized by greater control over their members (member curation). Some platforms, such as Althea, do the curation only to open new community networks, while others, such as Mesg or FOAM, do it on a token stake. More social cases, such as Voice and Appics, look for real users. Even in the case of Appics, the objective is to attract influencers and celebrities. Hosted ecosystems also have greater interaction between users and more intensive use of filters.

Table 5. Interaction Components by Platform Model. Source: own elaboration

Interaction components	Hosted	Federated	Shared	Average

Nº of roles	3.50	3.75	3.53	3.56
Exchange of info primary object.	42.86%	75.00%	31.58%	43.90%
Filter	60.71%	56.25%	34.21%	47.56%
Direct interaction between users	39.29%	31.25%	36.84%	36.59%
Internal exchange of goods	85.71%	100.00%	92.11%	91.46%
Currency exchanged	7.14%	0.00%	10.53%	7.32%
Member curation	21.43%	18.75%	15.79%	18.29%
Direct network effect	96.43%	100.00%	100.00%	98.78%

The federated platforms stand out mainly for having as their main objective the exchange of information, because most of them are from the sectors of social networks, content distribution, and video streaming. On the other hand, the most remarkable fact regarding the interaction components of shared platforms is the reduced use of content filters and member curation.

Regarding the openness of the platforms, the main differences between the three platform models can be seen in Table 4. Hosted platforms implement a manager participation scheme of a proprietary and licensing type only. These two models are the most traditional because of the more closed character of these platforms. The federated models use a joint venture model that allows the community to participate in the governance, even though the network is unique and was originally created by a private organization, which is usually a nonprofit foundation, such as the LikeCoin Foundation, Secret Foundation, Datum Foundation, Akasha Foundation, and snglsDAO Foundation (SingularDTV). Finally, shared platforms use a shared model in which both the governance and the deployment of networks are free and open.

Table 6. Openness Properties by Platform Model. Source: own elaboration

Openness	**Hosted**	**Federated**	**Shared**	**Average**
Manager participation				
- Proprietary	60.71%	0.00%	0.00%	20.73%

-	Licensing	39.29%	0.00%	0.00%	13.41%
-	Joint venture	0.00%	100.00%	2.63%	20.73%
-	Shared	0.00%	0.00%	97.37%	45.12%
Open source		39.29%	100.00%	97.37%	78.05%
Shared governance		0.00%	87.50%	81.58%	54.88%
Developer participation		64.29%	93.75%	97.37%	85.37%
User participation		28.57%	43.75%	28.95%	31.71%

In line with the above, the Federated and Shared model platforms have the highest level of shared governance and developer involvement. However, the level of user participation in the federated platforms is surprising. This is probably related to the type of platforms analyzed, namely, social networks, content distribution, etc.

As Table 5 shows, the vast majority of decentralized platforms use some form of token. In fact, 100% of the analyzed federated platforms use it. In the case of the shared platform, it must be considered that some are totally free and open developments that allow users to establish relationships between them without any specific token (e.g., IPFS) or even use cryptocurrencies or any other external payment method, such as Raiden Network or OpenBazaar.

Table 7. Token economy properties by Platform Model. Source: own elaboration

Tokenomics		Hosted	Federated	Shared	Average
Token usage		82.14%	100.00%	81.58%	85.37%
Token Type					
-	Platform token	21.43%	25.00%	39.47%	30.49%
-	Security token	0.00%	0.00%	0.00%	0.00%
- token	Transactional	7.14%	6.25%	10.53%	8.54%
-	Utility token	71.43%	81.25%	44.74%	60.98%
-	Governance token	0.00%	75.00%	52.63%	39.02%

Regarding the type of token used in the decentralized platforms, more than one type of token in the same ecosystem can be found because tokens with several uses, or platforms with several tokens, exist in the same ecosystem. In any case, it is interesting to note that shared platforms use a higher number of platform tokens than the rest. None of the platforms analyzed in this study use security tokens, and a minority use transactional tokens (often as a payment method in a marketplace using traditional cryptocurrencies, such as bitcoin). Finally, it is worth mentioning the greater use of utility tokens by the hosted and federated platforms, as well as the exclusive use of governance tokens by the federated and shared platforms. This is directly related to the more open and pluralistic type of governance of these two ecosystem models.

It can be noted from Table 6 that most platforms merge the B2B and B2C models in their ecosystems and that only a minority of hosted platforms control the prices and contractual terms of the relationships between their members.

Table 8. Market properties by Platform Model. Source: own elaboration

Market Properties		Hosted	Federated	Shared	Average
B2B Market		89.29%	100.00%	97.37%	95.12%
B2C Market		85.71%	81.25%	89.47%	86.59%
Price Control		3.57%	0.00%	0.00%	1.22%
Contractual Terms controlled		3.57%	0.00%	0.00%	1.22%
Monetization					
-	Transaction fee	60.71%	56.25%	52.63%	56.10%
-	Access	7.14%	0.00%	7.89%	6.10%
-	Enhanced access	3.57%	0.00%	7.89%	4.88%
-	Enhanced curation	28.57%	43.75%	10.53%	23.17%
-	Free&Open	0.00%	0.00%	21.05%	9.76%
Who Pays?					
-	All users	14.29%	12.50%	0.00%	7.32%

-	One side	85.71%	87.50%	78.95%	82.93%
-	Nobody	0.00%	0.00%	21.05%	9.76%

Monetization through the transaction fee model is the most used, followed by enhanced curation, which is mainly used in the federated ecosystem model. It should be noted that the Free&Open model is exclusively used in shared ecosystems.

Finally, it should be highlighted that most decentralized ecosystems opt for one side subsidizing the other, followed by the model in which nobody pays because of the influence of shared platforms and the Free & Open monetization model mentioned above.

Regarding Table 7, it is noticeable that to follow the rabbit strategy is more used than any other in the three models. Piggyback and seeding are traditional strategies and are, therefore, more commonly used on hosted platforms. Shared platforms are the only ones that use the micromarket model.

Table 9. Marketing strategy properties by Platform Model. Source: own elaboration

Marketing strategy		**Hosted**	**Federated**	**Shared**	**Average**
Launch strategy					
-	Follow the rabbit	42.86%	50.00%	63.16%	58.67%
-	Piggyback	10.71%	6.25%	5.26%	8.00%
-	Seeding	17.86%	12.50%	13.16%	16.00%
-	Producer evangelism	10.71%	31.25%	10.53%	16.00%
-	Micromarket	0.00%	0.00%	2.63%	1.33%
Viral growth		25.00%	31.25%	2.63%	15.85%

Finally, it is important to highlight how federated platforms stand out for the use of viral growth and producer evangelism strategies. The foundations that create many of these platforms create the ecosystem due to their close collaboration with the community.

9 Discussion

9.1 Reflection on literature

The decentralization of platforms is a research line with growing interest. Subramanian (2017) highlighted that decentralization disrupts the ecosystem. The generation of new decentralized platforms may constitute alternative platforms to traditional ones (Alt and Zimmermann, 2019), aggravating the problem of traditional disintermediation (Ladd, 2021).

Different authors have studied the incorporation of blockchain technology into platform models (Morkunas et al., 2019; Schulze et al., 2020; Zutshi et al., 2021; Lage et al., 2022), providing different views and general characteristics about the benefits of the technology. Most of them identify the decentralization of platforms as a major risk. In addition, they highlight the need to carry out an extensive study and find the relationships between the different characteristics of existing platforms to identify archetypes of blockchain platforms, that is, new models that could guide practitioners when designing new blockchain-based platforms.

Other authors focus their research on the positive effects of cooperation in these decentralized communities (Kollmann et al., 2020; Kolade et al., 2022; Ricciardi et al., 2021), while other works focus on analyzing the initial attraction effect generated by ICOs (Drach et al., 2020).

To our knowledge, the only authors that have performed a systematic analysis to characterize blockchain startups and initiatives that are linked to electronic markets are Weiking et al. (2020) and Tönnissen et al. (2020). In the first one, they explore 99 blockchain ventures extracted from Crunchbase and identify multisided platforms as one of the five archetypes of startups and initiatives that are emerging. Their study does not specifically study this archetype; they focus on identifying the set of all five archetypes. In turn, Tönnissen et al. (2020) analyze blockchain initiatives financed by ICOs and identify three types of archetypes of these initiatives. The first archetype is precisely identified with projects that, in no case, create a market, while in the other two archetypes this is only a possibility, but not necessarily those projects must generate a multisided platform.

None of the previous authors have made a systematic analysis of existing platforms by characterizing new decentralized business platforms, which is currently a gap in the literature.

9.2 Contributions

The main objective of this study is to identify the emerging archetypes of decentralized platform business models and their main characteristics, answer the research question and contribute to the literature to fill this gap in the literature. To this end, a taxonomy of decentralized platform business models has been developed that will serve as a basis for future research for both researchers and practitioners. In this case, this taxonomy serves as a basis for the analysis of 82 decentralized multisided platforms, and using clustering techniques, identified the archetypes of decentralized platforms and their main characteristics, a significant contributed of the study.

To the best of our knowledge, these contributions are unique, as there are no other studies that focus specifically on studying and characterizing decentralized multisided markets. In addition, community-created open-source platforms have been incorporated, which is a new feature offered by blockchain that allows the community to create decentralized platforms operated entirely by the community itself.

9.3 Limitations and future research directions

We are in a very incipient phase of decentralized business platforms, which is why, just as two decades ago, the electronic markets that emerged with the dot-com boom were two-sided networks and later evolved into more complex business models (multisided networks). The archetypes identified could evolve within a few years when decentralized platforms have become established in the economy. Decentralized technologies themselves are also expected to evolve in the coming years, opening up new possibilities. Therefore, this study is an initial starting point that can be used by researchers and practitioners as a basis for future and more specialized research on any of the identified platform types.

In fact, the main research lines opened by this work are the detailed analysis of the shared model and its emerging business models and the study of how this decentralized platform business model can impact current platform models, as it aims to offer the same services but in a totally open way, and even, in some cases, without any kind of fees or intermediaries. These will be the research lines addressed in the future.

10 Conclusions

Eighty-two decentralized platform ecosystems were analyzed to identify the emerging platform business models due to the decentralization power of blockchain technology. For this study, public information on these ecosystems has been compiled (white papers, web, blogs, etc.) and a taxonomy of 23 dimensions characterizing these emerging decentralized platforms was generated.

A cluster analysis applied to the 82 selected platforms led to the identification of 3 archetypes that represent the new emerging decentralized platform models, which are referred to as hosted, federated, and shared, according to their characteristics.

The hosted model mainly presents platform ecosystems that benefit from blockchain technology to be more efficient in their processes, but maintain the parameters of traditional platforms. They mainly present the same traditional collaboration models (proprietary and licensing) with a closed collaboration model, as they do not open governance to third parties and present an inferior level of collaboration with developers. This type of entity mainly uses a utility token that allows them to monetize their platform mainly through a transaction fee or by offering enhanced curation.

The federated model is mainly used by start-ups that create their ecosystem in collaboration with the community (joint venture); they are much more open than the previous ones. In many cases, they have three singular characteristics: the exchange of information on the platform is their main objective, which is why they stand out using enhanced curation as one of their main monetization strategies and producer evangelism as a marketing strategy. These initiatives are clearly committed to the use of utility and governance tokens, the first to encourage prosumers (users who produce and consume) and the second (which can be the same token with two different types of use) to share governance with the community.

Last, the shared model is the most open of them, sharing governance with the community, not having a clear or visible monetization strategy, and being a totally free ecosystem in 21.05% of the analyzed cases. The lack of clarity in monetization strategy could be an indicator for the creation of new innovative business models, considering that some emerging business models are focused on saving resources, rather than generating new revenues. The shared model is therefore the most disruptive and the one that clearly threatens the current economy, which is largely based on platform business models.

One of our most relevant findings is that approximately two-thirds of the evaluated platforms, namely, federated and shared models, are proposing new approaches to relationships with the community and business models. The results suggest different motivations of developers and entrepreneurs, who cooperated for a common goal.

To the best of our knowledge, the contributions of the paper are unique, and it could be of great use in both industry and academia. The identified taxonomy will be the basis for future research in relation to the new decentralized platform business models, and the three archetypes will also help researchers and practitioners study this new decentralized platform ecosystem, which threatens traditional platform ecosystems even at its early stages of development.

References

Alt, R. (2020). Electronic Markets on blockchain markets. Electronic Markets, 30(2), 181-188.

Alt, R., & Zimmermann, H. D. (2019). Electronic markets on platform competition. Electronic Markets, 29(2), 143-149.

Bachmann, N. M., Drasch, B., Fridgen, G., Miksch, M., Regner, F., Schweizer, A., & Urbach, N. (2021). Tarzan and chain: exploring the ICO jungle and evaluating design archetypes. Electronic Markets, 1-24.

Bailey, K. D. (1984). A three-level measurement model. Quality & Quantity, 18(3), 225–245. https://doi.org/10.1007/BF00156457.

Blashfield, R. K., & Aldenderfer, M. S. (1988). The methods and problems of cluster analysis. In Handbook of multivariate experimental psychology (pp. 447-473). Springer, Boston, MA.

Chakravarty, A., Kumar, A., & Grewal, R. (2014). Customer orientation structure for Internet-based business-to-business platform firms. Journal of Marketing, 78(5), 1-23.

Chen, Y., Pereira, I., & Patel, P. C. (2021). Decentralized governance of digital platforms. Journal of Management, 47(5), 1305-1337.

Crosby, M., Pattanayak, P., Verma, S., & Kalyanaraman, V. (2016). Blockchain technology: Beyond bitcoin. Applied Innovation, 2(6-10), 71.

De Reuver, M., Sørensen, C., & Basole, R. C. (2018). The digital platform: a research agenda. Journal of Information Technology, 33(2), 124-135.

Drasch, B. J., Fridgen, G., Manner-Romberg, T., Nolting, F. M., & Radszuwil, S. (2020). The token's secret: The two-faced financial incentive of the token economy. Electronic Markets, 30(3). https://doi.org/10.1007/s12525-020-00412-9 .

Eisenmann, T. R. (2008). Managing proprietary and shared platforms. California management review, 50(4), 31-53.

Eisenmann, T. R., Parker, G., & Van Alstyne, M. (2009). Opening platforms: how, when and why?. Platforms, markets and innovation, 6, 131-162.

Eisenmann, T. R., Parker, G., & Van Alstyne, M. W. (2006). Strategies for two-sided markets. Harvard business review, 84(10), 92.

Evans, D. S. (2003). Some empirical aspects of multi-sided platform industries. Review of Network Economics, 2(3).

Felix, T. H., & von Eije, H. (2019). Underpricing in the cryptocurrency world: evidence from initial coin offerings. Managerial Finance.

Ferrati, F., & Muffatto, M. (2020, June). Using Crunchbase for research in Entrepreneurship: data content and structure. In 19th European Conference on

Research Methodology for Business and Management Studies (ECRM), Aveiro, Portugal (18-19 June) (pp. 342-351).
Forina, M., Armanino, C., & Raggio, V. (2002). Clustering with dendrograms on interpretation variables. Analytica Chimica Acta, 454(1), 13-19.
Garud, R., Kumaraswamy, A., Roberts, A., & Xu, L. (2022). Liminal movement by digital platform-based sharing economy ventures: The case of Uber Technologies. Strategic Management Journal, 43(3), 447-475.
Glass, R. L., & Vessey, I. (1995). Contemporary application-domain taxonomies. IEEE Software(4), 63–76. https://doi.org/10.1109/52.391837.
Hein, A., Schreieck, M., Riasanow, T., Setzke, D. S., Wiesche, M., Böhm, M., & Krcmar, H. (2020). Digital platform ecosystems. Electronic Markets, 30(1), 87-98.
Huang, Z. (1998). Extensions to the k-means algorithm for clustering large data sets with categorical values. Data mining and knowledge discovery, 2(3), 283-304.
Hunter, R., Bellin, M., Liu, K., Picard, N., & Ethridge, D. (2020). Global Top 100 companies by market capitalisation. PricewaterhouseCoopers (PwC).
Irani, J., Pise, N., & Phatak, M. (2016). Clustering techniques and the similarity measures used in clustering: A survey. International journal of computer applications, 134(7), 9-14.
Kézai, P. K., Fischer, S., & Lados, M. (2020). Smart economy and startup enterprises in the Visegrád Countries—A comparative analysis based on the crunchbase database. Smart Cities, 3(4), 1477-1494.
Kolade, O., Adepoju, D., & Adegbile, A. (2022). Blockchains and the disruption of the sharing economy value chains. Strategic Change, 31(1), 137-145.
Kollmann, T., Hensellek, S., de Cruppe, K., & Sirges, A. (2020). Toward a renaissance of cooperatives fostered by Blockchain on electronic marketplaces: a theory-driven case study approach. Electronic Markets, 30(2), 273-284.
Ladd, T. (2021). The Achilles heel of the platform business model: Disintermediation. Business Horizons.
Lage, O., Saiz-Santos, M., & Zarzuelo, J. M. (2022). Real Business Applications and Investments in Blockchain Technology. Electronics, 11(3), 438.
Lang, B., Kemper, J., Dolan, R., & Northey, G. (2021). Why do consumers become providers? Self-determination in the sharing economy. Journal of Service Theory and Practice.
Li, H., Shen, Q., & Bart, Y. (2021). Dynamic resource allocation on multi-category two-sided platforms. Management Science, 67(2), 984-1003.
Ljungqvist, A., & Wilhelm Jr, W. J. (2003). IPO pricing in the dot-com bubble. The Journal of Finance, 58(2), 723-752.
Lo, Y. C., & Medda, F. (2020). Assets on the blockchain: An empirical study of tokenomics. Information Economics and Policy, 53, 100881.

Lumineau, F., Wang, W., & Schilke, O. (2021). Blockchain governance—A new way of organizing collaborations?. Organization Science, 32(2), 500-521.
MakerDAO. (2020, August 16). The Different Types of Cryptocurrency Tokens Explained. Retrieved September 22, 2020, from https://blog.makerdao.com/the-different-types-of-cryptocurrency-tokens-explained/
Mancha, R., & Gordon, S. (2021). Multi-sided platform strategies for organizations: transforming the business model. Journal of Business Strategy.
Marikyan, D., Papagiannidis, S., Rana, O., & Ranjan, R. (2021, September). Blockchain in a business model: exploring benefits and risks. In Conference on e-Business, e-Services and e-Society (pp. 555-566). Springer, Cham.
Marra, A., Antonelli, P., Dell'Anna, L., & Pozzi, C. (2015). A network analysis using metadata to investigate innovation in clean-tech–Implications for energy policy. Energy Policy, 86, 17-26.
McIntyre, D. P., Srinivasan, A., & Chintakananda, A. (2021). The persistence of platforms: The role of network, platform, and complementor attributes. Long Range Planning, 54(5), 101987.
Moore, J. F. (2016). The death of competition: leadership and strategy in the age of business ecosystems. HarperCollins.
Morkunas, V. J., Paschen, J., & Boon, E. (2019). How blockchain technologies impact your business model. Business Horizons, 62(3), 295-306.
Mougayar, W. (2018, August 06). Tokenomics – A Business Guide to Token Usage, Utility and Value. Retrieved September 22, 2020, from https://medium.com/@wmougayar/tokenomics-a-business-guide-to-token-usage-utility-and-value-b19242053416
Nickerson, R. C., Muntermann, J., & Varshney, U. (2010). Taxonomy development in information systems: A literature survey and problem statement. Proceedings of the the 16th American Conference on Information Systems (AMCIS). Lima: Peru.
Nickerson, R. C., Varshney, U., & Muntermann, J. (2013). A method for taxonomy development and its application in information systems. European Journal of Information Systems, 22(3), 336–359. https://doi.org/10.1057/ejis.2012.26.
Oliveira, L., Zavolokina, L., Bauer, I., & Schwabe, G. (2018). To token or not to token: Tools for understanding blockchain tokens. In International Conference of Information Systems (ICIS 2018), https://doi.org/10.5167/uzh-157908
Osterwalder, A., & Pigneur, Y. (2010). Business model generation: a handbook for visionaries, game changers, and challengers (Vol. 1). John Wiley & Sons.
Panico, C., & Cennamo, C. (2022). User preferences and strategic interactions in platform ecosystems. Strategic Management Journal, 43(3), 507-529.

Parker, G. G., & Van Alstyne, M. W. (2005). Two-sided network effects: A theory of information product design. Management science, 51(10), 1494-1504.

Parker, G. G., Van Alstyne, M. W., & Choudary, S. P. (2016). Platform revolution: How networked markets are transforming the economy and how to make them work for you. WW Norton & Company.

Rajnak, V., & Puschmann, T. (2021). The impact of blockchain on business models in banking. Information Systems and e-Business Management, 19(3), 809-861.

Ricciardi, F., Zardini, A., Czakon, W., Rossignoli, C., & Kraus, S. (2021). Revisiting the cooperation–competition paradox: A configurational approach to short-and long-term coopetition performance in business networks. European Management Journal.

Roosenboom, P., van der Kolk, T., & de Jong, A. (2020). What determines success in initial coin offerings?. Venture Capital, 22(2), 161-183.

Schlecht, L., Schneider, S., & Buchwald, A. (2021). The prospective value creation potential of Blockchain in business models: a delphi study. Technological Forecasting and Social Change, 166, 120601.

Schmidt, A. L., Petzold, N., Lahme-Hütig, N., & Tiemann, F. (2021). Growing with others: A longitudinal study of an evolving multi-sided disruptive platform. Creativity and Innovation Management, 30(1), 12-30.

Schulze, T., Seebacher, S., & Hunke, F. (2020, February). Conceptualizing the Role of Blockchain Technology in Digital Platform Business. In International Conference on Exploring Services Science (pp. 150-163). Springer, Cham.

Şimşek, T., Öner, M. A., Kunday, Ö., & Olcay, G. A. (2022). A journey towards a digital platform business model: A case study in a global tech-company. Technological Forecasting and Social Change, 175, 121372.

Stallkamp, M., & Schotter, A. P. (2021). Platforms without borders? The international strategies of digital platform firms. Global Strategy Journal, 11(1), 58-80.

Stephan, D.. Crunchbase rank and trend score (2018). Retrieved September 20, 2020, from https://about.crunchbase.com/blog/crunchbase-rank-trend-score.

Subramanian, H. (2017). Decentralized blockchain-based electronic marketplaces. Communications of the ACM, 61(1), 78-84.

Tönnissen, S., Beinke, J. H., & Teuteberg, F. (2020). Understanding token-based ecosystems–a taxonomy of blockchain-based business models of start-ups. Electronic Markets, 30(2), 307-323.

Van Dyck, M., Luettgens, D., Diener, K., & Pollok, P. (2020). From Pipeline to Platform: Managing Risks of Openness in an Emerging Industrial Ecosystem. In Academy of Management Proceedings (Vol. 2020, No. 1, p. 16878). Briarcliff Manor, NY 10510: Academy of Management.

Veisdal, J. (2020). The dynamics of entry for digital platforms in two-sided markets: a multi-case study. Electronic markets, 30(3), 539-556.

Vidal-Tomás, D. (2022). Which cryptocurrency data sources should scholars use?. International Review of Financial Analysis, 102061.

Wachs, J., Nitecki, M., Schueller, W., & Polleres, A. (2022). The Geography of Open Source Software: Evidence from GitHub. Technological Forecasting and Social Change, 176, 121478.

Weking, J., Mandalenakis, M., Hein, A., Hermes, S., Böhm, M., & Krcmar, H. (2020). The impact of blockchain technology on business models–a taxonomy and archetypal patterns. Electronic Markets, 30(2), 285-305.

Wigand, R. T. (2020). Whatever happened to disintermediation? Electronic Markets, 30(1), 39–47. https://doi.org/10.1007/s12525-019-00389-0.

Yue, K., Zhang, Y., Chen, Y., Li, Y., Zhao, L., Rong, C., & Chen, L. (2021). A survey of decentralizing applications via blockchain: The 5g and beyond perspective. IEEE Communications Surveys & Tutorials, 23(4), 2191-2217.

Żbikowski, K., & Antosiuk, P. (2021). A machine learning, bias-free approach for predicting business success using Crunchbase data. Information Processing & Management, 58(4), 102555.

Žiberna, A., Kejzar, N., & Golob, P. (2004). A comparison of different approaches to hierarchical clustering of ordinal data. Metodoloski zvezki, 1(1), 57.

Zutshi, A., Grilo, A., & Nodehi, T. (2021). The value proposition of blockchain technologies and its impact on Digital Platforms. Computers & Industrial Engineering, 155, 107187.

Appendix

0x	3SPeak	aelf	Akash Network	Akasha	all.me	Althea	Appics
Aragon	Augur	Basic Attention Token	BeeChat	BitClave	CanYa	Civic	Crypviser
Cyb Protocol	Datum	DeepBrain Chain	DENT Wireless	Dfinity	District0x	DTube	Edge
Evernym	FileCoin	Flixxo	FOAM	FunFair	Golem Network	HIVE Blog	iExec
Inflow Music	IPFS	Ixo Foundation	Ki Foundation	LikeCoin	Livepeer	LoomX	MatchPool
Mercury Protocol	Mesg	Minds	MutualDAO	OpenBazaar	OpenSea	OPUS	PowerLedger
Presearch	Publish0x	QunQun	Raiden Network	Regen Network	Remme	Safe Network	Safex
Secret Network	SelfKey	Sense Chat	Sentinel	Sia	SingularDTV/ Breaker	Sociall	Sonm
Starname	Status	Steemit	Storj	StormX	Streamr	Swarm City	TheKey
Theta Labs	Tox	Trybe	uPort / Serto	Vocdoni	Voice	Wagerr	Yours
YoYow	Yup						

Figure 7. List of the 82 decentralized platforms analyzed in the research.

Otros artículos y capítulos de libro vinculados con la tesis

Publicados

Gutierrez, I., Bravo, Y., Landa, D., Lage, O., Seco, I., Castillo, A. (2022). Towards Cost-Efficient Management for Power Purchase Agreements Using Blockchain Technology. International Congress on Blockchain and Applications (pp. 149-160). Springer, Cham.

Regueiro, C., Gutierrez-Agueero, I., & Lage, O. (2022, June). 5G MEC deployments: Low-latency services context synchronization in mobility. In *AIIPCC 2022; The Third International Conference on Artificial Intelligence, Information Processing and Cloud Computing* (pp. 1-7). VDE.

Gamiz-Ugarte, I., Lage-Serrano, O., Legarreta-Solaguren, L., Regueiro-Senderos, C., Jacob-Taquet, E., & Seco-Aguirre, I. (2022). Secure multiparty computation for predictive maintenance: validation of scale-mamba tool in terms of accuracy and efficiency. *DYNA*, *97*(6), 613-619.

Regueiro, C., Anguita, S., de Diego, S., & Lage, O. (2022). Protocol for Identity Management in Industrial IoT based on Hyperledger Indy. *International Journal of Computing and Digital Systems*, *12*(1), 653-664.

Regueiro, C., Seco, I., de Diego, S., Lage, O., & Etxebarria, L. (2021). Privacy-enhancing distributed protocol for data aggregation based on blockchain and homomorphic encryption. Information Processing & Management, 58(6), 102745.

Lage, O., de Diego, S. & Shea, M. (2021). The Internet of Things opportunity. Self-sovereign identity. Manning Publications.

Lage, O. (2019). Blockchain: from industry 4.0 to the machine economy. In *Computer Security Threats*. IntechOpen..

Lage, O., de Diego, S., Urkizu, B., Gómez, E., & Gutiérrez, I. (2019). Blockchain applications in cybersecurity. *Computer Security Threats*, 73.

Serrano, O. L. (2019). Blockchain: aplicaciones en la industria alimentaria. *Ponencia de la XXXIII Jornada Anual sobre Digitalizacion en el Sector Alimentario*, 13-16.

Serrano, O. L., de Diego de Diego, S., Seco, I., & Larrucea, X. (2019, October). Semi-real-time Hash Comparison for Detecting Intrusions Using Blockchain. In *New Trends in Model and Data Engineering: MEDI 2019 International Workshops, DETECT, DSSGA, TRIDENT, Toulouse, France, October 28–31, 2019, Proceedings* (pp. 165-179). Cham: Springer International Publishing.

de Diego, S., Gonçalves, C., Lage, O., Mansell, J., Kontoulis, M., Moustakidis, S., ... & Liapis, A. (2019, October). Blockchain-Based Threat Registry Platform. In *2019 IEEE 10th Annual Information Technology, Electronics and Mobile Communication Conference (IEMCON)* (pp. 0892-0898). IEEE.

Serrano, O. L. (2017). Participación ciudadana y voto electrónico. Blockchain: la revolución industrial de Internet (pp. 100-102). Gestión 2000.

Serrano, O. L. (2017). La industria 4.0 y la blockchain. Blockchain: la revolución industrial de Internet (pp. 63-67). Gestión 2000.

Aceptados

Bernabé-Rodríguez, J., Galarreta, A. and Lage, O. (2022). A decentralized private data marketplace using blockchain and secure multi-party computation. *Journal of Network and Computer Applications*.

eman ta zabal zazu

Universidad del País Vasco

Euskal Herriko Unibertsitatea