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The use of blockchain in European-listed companies: A content analysis of corporate reports

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Abstract. In recent years, the use of blockchain technologies has increased. The aim of this paper is to analyse the current state of its use in major Western European companies as reported in their corporate reports. Using automatic extraction techniques, the relevant information is collected and classified according to different disclosure categories. The sample consists of 1,409 annual/sustainability reports, published in 2018, 2019, and 2020, by 337 companies listed on 13 Western European countries' stock markets. Our findings show that, according to corporate reports, the use of blockchain is still at an early stage and the first adopters are large companies in the financial and technology sectors located in countries with a well-defined national blockchain strategy. An overview of this new phenomenon in European, as well as the way that large companies engage with this innovative technology, whether they report on it in their corporative report, the content type of such disclosure, and the factors associated with it is provided.

Keywords: Blockchain, corporate disclosure, legitimacy theory, voluntary disclosure theory, signalling theory.

JEL Code: O33, M15, G30

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1. INTRODUCTION

With technological developments such as blockchain, we seem to be entering into a new digital era, which is expected to have a significant impact on both the private and public sectors. Indeed, over the last five years, significant attention has been paid to distributed ledger technology (DLT), and there a large number of initiatives and projects on the national and international levels in different sectors that aim to benefit from this disruptive technology.

Nowadays, blockchain is no longer limited to information and communication technology (ICT) and the financial sector. Indeed, there has recently been a flow of important investments aimed at the development of blockchain projects in sectors such as retail, real estate, energy, research and education, and the food supply chain. A growing interest in this technology from the pharmaceutical and healthcare sectors has also been detected (CHAISE, 2021).

Blockchain technology offers a wide array of promising applications across various sectors of business, including but not limited to innovative traceability solutions within the supply chain, or sustainability initiatives. In the realm of supply chain management, blockchain enables transparent and immutable records of transactions, allowing for enhanced traceability of products from their origin to the end consumer. This fosters greater accountability, reduces the risk of counterfeit goods, and ensures compliance with regulatory standards. Moreover, blockchain can facilitate the integration of sustainability practices by tracking the environmental impact of each stage in the supply chain, promoting eco-friendly decisions and encouraging responsible sourcing. These applications collectively underscore blockchain's potential to revolutionize business operations, enhancing trust, efficiency, and sustainability across industries. In countries like Estonia, where blockchain proliferation is high, this technology is also widely used in public services, as patient record keeping in healthcare, electronic identification, and value-added tax (VAT) processing seem to be areas that are naturally suited to benefit from blockchain’s technological features (Information System Authority, 2020).

Europe is home to several important blockchain start-ups. The most common sources of funding are angel investors, token fundraising campaigns, national or European grants, and bank loans, as well as venture capital and private equity. Yet not all EU members enjoy the same level of blockchain maturity, and the amount

of funding for start-ups varies significantly by country. However, there is a growing trend in almost all the member states, which is helping Europe's effort to become a globally respected blockchain player. Countries such as Luxembourg and Estonia are positioned among the leading ones due to their well-developed regulatory frameworks and clear national blockchain strategies. A cluster of start-ups, think tanks, and networks also seems to be highly correlated with the success of the blockchain project. Countries where the blockchain environment might also be considered significantly vibrant include the Netherlands, Italy, France, and Germany (EU Blockchain Observatory and Forum, 2020).

According to Blockdata (2023), countries like UK, Germany, France, Estonia, Switzerland, and Cyprus are notable players in blockchain fund raising. European blockchain and crypto firms raised capital worth more than 1,2 billion dollars in the last quarter of 2022 (Blockdata, 2023). In addition, the World Economic Forum predicts that by 2025, around 10% of the world's gross domestic product (GDP) will originate from blockchain-based systems (CHAISE, 2021).

The EU recently designated EUR 347 million in funding to blockchain research and innovation projects related but not limited to public services, sustainability (production, traceability, energy, and transport), advanced manufacturing, artificial intelligence (AI) and Big Data, food security, media, and social media (European Commission, 2022). As significant investments are expected to be poured into blockchain projects over the next decade, there is increased interest in this topic from both academics and practitioners.

Blockchain's rapid evolution is also reflected in the increased number of job vacancies related to the blockchain profile. A recent analysis of the labour market showed a higher demand for blockchain-skilled employees than an offer can satisfy (CHAISE, 2021). This analysis shows how quickly this technology is proliferating into businesses and that it is becoming a trend that deserves attention.

Most countries do not have a specific domestic regulatory regime for blockchain. Their approach is rather cautious, and they seem to be waiting for a common EU approach to emerge.

As the blockchain sector is still mostly concentrated in financial services, most of the financial regulators together with the European Securities and Markets Authority (ESMA) have issued warnings related to cryptocurrencies, raising the

awareness of investors about the risks related to crypto investments. Nevertheless, crypto values remain largely unregulated in the EU (ESMA, 2021). The closest regulatory regime related to blockchain in the EU to date is the European Anti-Money Laundering regulation (European Commission, 2021).

To increase the competitive advantage of DLT businesses, mitigate fraud and market abuse on trading platforms, and enable cross-border operations, the European Commission issued a regulatory framework, the Markets in Crypto-assets (MiCA), which should help regulate crypto-assets and their service providers in the EU and provide a single licencing regime across all member states by 2024 (EUR-lex, 2021). The MiCA entered into force in June 2023 (ESMA, 2023). This regulatory framework goes beyond the financial sector and cryptocurrencies

Considering the amount of investments poured into blockchain projects, the increased demand for blockchain-related positions in the labour market, and the attention of regulatory bodies, we can expect impactful changes over the next few years originating from this technology. It may be helpful to explore the extent of the current use of blockchain in different sectors to aid us in understanding the level of the proliferation of this technology in European listed companies. Thus, this study aims to assess the state of the art of this technology by analysing companies' corporate reports and tries to shed more light on blockchain disclosure practices and factors influencing it.

Due to the importance given to this technology in the EU, we decided to analyse large listed European companies.

The research questions we aim to answer are the following:

RQ1. Are Western European companies disclosing information about the use of blockchain in their annual/sustainability reports?

RQ2. What is the content of those disclosures?

RQ3. What are the factors associated with blockchain disclosure?

Our study shows that 32% of Western European companies engage with blockchain technology to some extent. According to the blockchain disclosure provided by these companies, their level of engagement varies from general statements, participation in blockchain projects/alliances, and functional blockchain solutions, to awards received. In addition, the size of the company, national blockchain

strategy, and sector seem to be factors associated with blockchain disclosure. Despite the extensive literature on blockchain in accounting, to the best of our knowledge, this is one of the first studies to focus on the aspect of reporting. Thus, our study aims to fill this gap by analysing blockchain disclosure in corporate reports.

2. LITERATURE REVIEW

2.1. Advancements in technology and innovation: A focus on blockchain

Literature on technology and innovation

Technology is a complex system selected and adapted in the environment to satisfy the needs or solve the problems in human society (Coccia, 2019). Several authors agree that technological evolution plays a key role in the economic and social changes in society and represents a key aspect in the competitive advantage of organizations and nations (Bryan et al., 2007; Coccia, 2019).

Innovation might be approached from different perspectives. Schumpeter (1939) and Pavitt (1984) defined it as a process consisting of the conversion of new ideas into marketable products and processes (Wonglimpiyarat & Yuberk, 2005). Others defined innovation as a process encompassing the technical design, management, manufacturing, or commercial activities of new or improved products (Freeman & Soete, 2009). Link (1988) presented the chain-link model that represents the process of innovation. Schmookler (1962) argued that the development of technological innovation is correlated with the market demand.

Wonglimpiyarat and Yuberk (2005) analysed the effective mechanisms by which government innovations are brought to commercialization, and they pointed out the important role of research and development (R&D) in innovation. Cooper (1994) focused on the innovation development process of the manufacturing industry. Blockchain is currently one of the most discussed technological advances since the Internet, and it is expected to cause upheavals in different industries (Swan, 2015). Colomo-Palacios et al. (2020) examined blockchain assessment initiatives from a technology evolution viewpoint.

Blockchain technology

Blockchain was initially created as a supporting technology for cryptocurrency called Bitcoin (Nakamoto, 2008). Nevertheless, DLT, which is the main feature of

blockchain, has given rise to a wide range of applications that take advantage of its characteristics to record and manage different kinds of information (Bonsón & Bednárová, 2019). Blockchain is essentially a distributed digital registry, where the information is recorded and shared in a peer-to-peer network. When information is recorded into a block, this new block is added to a chain of blocks, which are chronologically connected through a cryptographic validation called "hash". Distributed means that the identical copy of the ledger is stored on different nodes instead of a single location. Any changes to it would be reflected in all copies almost immediately (Bonsón & Bednárová, 2019). Therefore, once the data are recorded, they are immutable because a change would be required in all previous hashes on all nodes simultaneously, something very unlikely to be manageable. These features imply the usefulness of blockchain in many applications and processes across almost all industries.

Literature on blockchain

Numerous blockchain-related projects are being carried out, largely surpassing the initial interest in this technology in the financial and technological sectors (Bonsón & Bednárová, 2019). Over the last few years, several studies related to blockchain have been conducted in different domains, including but not limited to computer science, telecommunications and communication, mathematics, engineering, business economics, government law, energy fuels, automation and control systems, and science technology (Zhang et al., 2024).

Although much of the attention surrounding blockchain is still focused on financial services, Nanayakkara et al. (2021) argue that there is a high demand for blockchain 3.0, which would focus on using this technology for various applications in industries other than finance. Their study introduced a methodology for selection of a suitable blockchain platform for resolving industry- or enterprise-specific issues. Similarly, Morkunas et al. (2019) analysed how different types of blockchain might impact business models and outlined the effect that this technology can have on each element.

Lu (2019) provided a comprehensive overview of the state of the art as he reviewed studies on blockchain and its components, such as the Internet of Things (IoT), security, data management, and main blockchain applications. The work of Casino et al. (2019) provides a systematic literature review of blockchain applications in different domains. In addition, they introduced a comprehensive classification of

blockchain-enabled applications in supply chain, business, healthcare, IoT, privacy, and data management. Another systematic literature review on blockchain focused on how blockchain might affect and facilitate business-to-consumer, business-to-business, and business-to-government relationships (Grover et al., 2018).

Another widely studied domain related to blockchain is supply chains (Etemadi et al., 2021). A multitude of academic studies have focused on how blockchain might reshape the contours of accounting and auditing (Bonsón & Bednárová, 2019; Dai & Vasarhelyi, 2017; Ferri et al., 2021; Lombardi & Secundo, 2020; Marrone & Hazelton, 2019; Rozario & Vasarhelyi, 2018; Schmitz & Leoni, 2019).

Lim et al. (2019) pointed out a dynamic and rapidly-evolving blockchain ecosystem in Asia in terms of fast-growing blockchain hubs in Singapore, China, Japan, South Korea. Similarly, according to Blockdata (2023), countries like Singapure, UAE, Israel, South Korea, Japan, Thailand, China, and Hong Kong are referred to as strong players in blockchain funding. Denter (2021) points out that Asia could advance over the USA and Europe in terms of magnitude and type of inventive activity related to blockchain by analysing patent applications.

Despite the extensive literature on blockchain in accounting, to the best of our knowledge, this is one of the first studies to focus on the aspect of reporting. Thus, our study aims to fill this gap by analysing blockchain disclosure in corporate reports.

Whether and to what extent a company integrates blockchain in its business processes is difficult to assess without access to internal corporate information. However, according to theories such as voluntary disclosure theory, signalling theory, or legitimacy theory, companies might disclose this information on their website, corporate reports or even in the press to appeal to their shareholders and other stakeholders. A corporate report is a communication platform, which represents a public formal reporting tool for transparency. Therefore, we assumed that it would be the most reliable available source of information related to innovative technological projects such as blockchain.

2.2. Theoretical background

Because a corporate report is a communication platform, which represents a public formal reporting tool for transparency, information related to innovative technologies such as blockchain are expected to be found in annual or, due to their

non-financial character, sustainability corporate reports. Yet, the question arises as to what the motivation and the drivers of companies' willingness to voluntary disclose information about blockchain in their annual/sustainability reports are.

Previous studies on corporate disclosure have used economic-based theories such as voluntary disclosure theory (VDT) and signalling theory (ST) or socio-political theories such as legitimacy theory (LT) to explain voluntary non-financial reporting (Cho et al., 2015; Van Zijl et al., 2017).

VDT and ST, as economic-based theories, consider the financial community, shareholders or investors, the centre of their attention (Lu & Wang, 2021). On the other hand, LT, as a socio-political theory, focuses on the dialogue with the society (Gray et al. 1995). Blockchain is a complex phenomenon with both economic and social implications. Therefore, a combination of economic and socio-political theories has been applied to help provide a comprehensive interpretation of voluntary blockchain disclosure.

Economic-based theories

VDT has its roots in game theory and its main objective is to extend a minimum amount of mandatory information by providing additional favourable information, while avoiding the disclosure of unfavourable facts, to appeal to financial community members such as shareholders and investors with the aim of obtaining economic benefits (Dye, 2001). This theory was initially only applied to financial information. Nevertheless, recently it has been extended to non-financial reporting as well (Araújo et al., 2014; Zhou et al., 2017). A connection between VDT and new technology disclosure has been indicated in recent studies (Bonsón et al., 2021a). According to this theory, companies might be motivated to disclose information about the development and application of blockchain technology, as it is a positive information that might appeal to investors, who can then perceive the company as more innovative and attractive due to its investments in smart technologies and digitalization.

The second economic-based theory used in this study is ST. The concept of ST is to reduce information asymmetry between organization, which represents a signaller, and stakeholders (receivers) (Connelly et al., 2011; Cotter et al., 2011). Similarly to VDT, whose main receivers were initially only investors and shareholders, thus the financial community, the concept of receivers now includes

all stakeholder groups (An et al., 2011; Lu & Wang, 2021). A signal in the ST is a tool by which the information asymmetry is reduced. Previous literature has distinguished three main categories of signals: intent (related to strategy), camouflage (related to avoidance of a negative message), and need (related to resource allocation decisions) (Albertini, 2019; Connelly et al., 2011). For the purposes of our study, we focus on the intent signal, which relates to a signaller's future strategies.

According to ST, the intent signal is used to indicate a company's future actions with the aim of attracting the investors' attention by trying to highlight its positive aspects which are hidden to external subjects (Lu & Wang, 2021). By increasing transparency, the information asymmetry between the company and its stakeholders is reduced, which can lead stakeholders to reassess the company's value and make decisions that would have a positive effect on the company (An et al., 2011). For instance, companies following the ST disclose unobservable company characteristics, such as excellence over competitors in terms of R&D in new technologies and digitalization with the aim of attracting potential investors, but also to increase the trustworthiness of their products and processes.

In this regard, sector peers might put pressure on companies. Therefore, if one or more companies in the industry start engaging with the new technology, such as blockchain, and report on it, others might join in order not to be perceived as laggards by their shareholders and other stakeholders.

Socio-political theory

Previous studies suggest that legitimacy theory provides an explanation of voluntary non-financial reporting (Bonsón & Bednárová, 2013; Bonsón et al., 2021a; Campbell et al., 2003; Deegan et al., 2002; Ellerup et al., 2018; Gray et al., 1995; Hahn & Kühnen, 2013) or claim that legitimacy theory also seems to offer a reasonable explanation for voluntary disclosure related to AI. Considering the similarity between AI and blockchain, as both are new technology developments, legitimacy theory might explain voluntary disclosure related to blockchain as well.

According to Suchman (1995), a company's legitimacy is a general assumption that its actions are following general values and norms of a society. An organization must gain acceptance by society to conduct business successfully (Deegan et al., 2002). To obtain such acceptance, companies must prove that their actions follow

stakeholders' expectations, and to so they adopt different strategies to legitimate their activities, with transparency being one of them (Bonsón & Bednárová, 2013). In terms of transparency, the disclosure practices and content must be continuously adjusted to the issues that matter the most at a particular moment in time. Only then does the increased transparency help to boost legitimacy (Bonsón et al., 2023).

To understand the motivation of companies to report on blockchain, it is necessary to comprehend a wider social context, which is affected by the sociocultural and political situation. This context shapes the norms and values of the society and, in turn, influences technology adoption. Therefore, national blockchain strategy, which depends on the blockchain ecosystem and regulatory maturity, or the level of digitalization of a country, might play an important role in the level of blockchain adoption and the motivation of a company to report on it, which would justify a company's anchoring to societal expectations.

Over the years, several factors have been used to test legitimacy theory (Bonsón & Bednárová, 2015), and many studies have pointed to size as one of the most important explanatory factors. Large companies normally have more resources to invest in new technologies and also tend to invest more in advanced voluntary disclosure (Bonsón & Flores, 2011; Brammer & Pavelin, 2006; Clarkson et al., 2011). Bigger companies are also under stronger stakeholder scrutiny due to their impact on a society. Therefore, they need to explain their business conduct and transmit credible information, as they have a greater social impact. Hence, such companies might feel obliged to report more and use disclosure as a tool to align corporate behaviour with stakeholders' expectations, gain their acceptance and obtain legitimation. Thus, the size of the company has a positive effect on corporate transparency in terms of scope and report quality (Bonsón et al., 2021a).

Generally, companies marked as sustainable leaders by a wide array of rankings tend to disclose more non-financial information (Bednárová et al., 2019; Bonsón et al., 2020; Hummel & Schlick, 2016; Rezaee & Tuo, 2017). Therefore, according to legitimacy theory, they might want to maintain their leadership by communicating their participation in blockchain initiatives, which are the latest trend across many industries.

On the other hand, their motivation might also stem from the fact that blockchain might not be clearly distinguished from Bitcoin by a general public (Zhao et al., 2016) and Bitcoin raises certain environmental, social, and corporate governance

(ESG) risks due to the amount of energy being spent on its mining and generation of e-waste (Ganapathi, 2022). Therefore, in order to legitimate their sustainability, it is in their interest to report on what type of blockchain initiatives they are involved in, as many functionalities of blockchain technology improve sustainability performance (Park & Li, 2021; Poberezhna, 2018).

To provide some insights into the level of blockchain proliferation by analysing companies' corporate reports, the first research question was formulated:

RQ1. Are Western European companies disclosing information about the use of blockchain in their annual/sustainability reports?

To shed more light on what is being disclosed, a second research question was formulated:

RQ2. What is the content of those disclosures?

Different theories were applied to test which factors are associated with blockchain disclosure such as country, size, sustainability position of a company (legitimacy theory), and sector (voluntary disclosure theory and signalling theory). Thus, the third research question was formulated:

RQ3. What are the factors associated with blockchain disclosure?

3. RESEARCH METHODOLOGY

3.1. Sample and data collection

The study analyses the companies listed on the stock exchanges of the 13 countries in Western Europe. The sample is composed of 337 companies. The period of the study is the years 2018, 2019, and 2020. In this way, the annual/sustainability reports of the stock companies published during those three years are considered. As indicated in Table 1, a total of 1,409 documents were obtained for analysis.

The analysis process is presented in Figure 1. It shows the three well-differentiated stages that were followed. The first consists of searching for the documents. These documents were downloaded in PDF format from the companies own websites. This stage was carried out manually, while the following ones used an automatic process created in the open-source R statistical advanced software (R Core Team, 2018) that allows for all the files to be analysed together.

Country	Index	2018	2019	2020	Total
Austria	*ATX 20*	32	33	29	94
Belgium	*BEL 20*	22	23	22	65
Denmark	*OMXC 25*	45	46	47	138
Finland	*OMXH 25*	39	38	37	112
France	*CAC 40*	41	41	41	123
Germany	*DAX 30*	49	52	45	144
Greece	*FTSE 20*	23	22	22	66
Ireland	*ISEQ 20*	19	22	22	61
Italy	*invit40*	67	68	56	189
Netherlands	*AEX 25*	27	31	28	86
Portugal	*PSI 20*	23	23	22	66
Spain	*IBEX 35*	43	44	40	127
Sweden	*OMXS 30*	44	45	36	125
		474	488	447	1.409

Table 1. Number of documents analysed from Western European countries

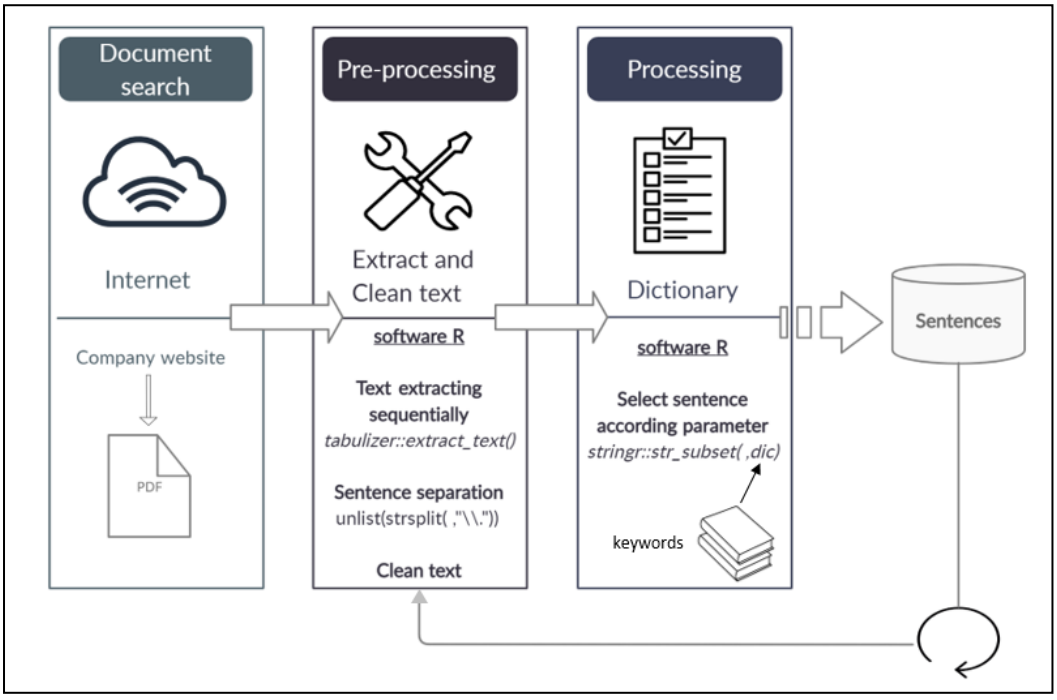

Figure 1. Process of extraction of sentences from the documents

The next stage is the pre-processing one in which the text is prepared for analysis. All the text is extracted from the documents and cleaned to remove all irrelevant elements, as well as stop words, extraneous characters, and noise words. Text is sequentially extracted from each PDF using the "extract text()" function of the "tabulizer" R package (Leeper, 2018). In this way, we manage to overcome the

obstacle of the small semantic structure of the PDF format, and it is possible to convert the text of a complete PDF file or specific pages in a vector of a single character (1 × 1). Once all the text is extracted, the programme removes the symbols, replaces some words, and converts uppercase to lowercase. The last task in this second stage is to separate all the extracted text into independent sentences, converting the vector (1 × 1) to a vector (number of sentences × 1). The R functions used for this are "strsplit()" and "unlist()". The former splits the elements of a character vector into a list of substrings according to the given parameter, in this case a period (end of sentence), and the latter produces a vector containing all the atomic components that occur in it.

Once all the text has been extracted from the PDFs and has been prepared for analysis, the processing stage occurs, in which only the sentences that meet certain parameters are selected. The keywords related to blockchain make up the dictionary presented in Table 2. This automatic analysis is carried out using the "str_subset" function of the R package "stringr" (Wickham, 2019).

Keywords
blockchain
decentralised ledger
distributed ledger
smart contract

Table 2. Dictionary

When repeating the process for each file, only the sentences that mention blockchain are obtained. This processing facilitates and speeds up manual reading, where each sentence is studied independently to indicate the content and categorize it. After the content categorization, to explore the determinants of blockchain reporting, we create a dummy variable, the "blockchain disclosure level" (BDL) which is assigned a value of 0 when companies have not reported any relevant mention of blockchain in their reports or they have recently reported general mentions. Otherwise, when there are disclosures about projects, alliances, products or awards, the assigned value is 1.

3.2. Associated factors

To answer RQ3 ("What are the factors associated with blockchain disclosure?"), we used the following independent variables: the digital level of the country where the company is listed, the sector in which the company operates, the level of national strategies regarding blockchain that the countries have, the company size,

and the company's sustainability leadership position. These variables were selected from the previous literature on companies' non-financial information disclosures.

World digital competitiveness ranking

Taking country into account as a possible determining factor in blockchain disclosure is a consideration based on previous literature (Hassan et al., 2013; Mikkilä & Toppinen, 2008; Sotorrío & Sánchez, 2008; Thanetsunthorn, 2015) that determines that a company's country or region affects its social behaviour. The role of the company is influenced by the cultural characteristics and trends of a specific region (Welford, 2005). It turns out that the strategies of organizations depend to a great extent on the institutional characteristics and the legacy that reflects the culture of a country (Doh & Guay, 2006). One of these strategies is disclosure, and the presentation of the reports varies according to the different cultural and social considerations of a country (Golob & Bartlett, 2007). Certain determinants, such as the country's legislation, risk, social and political awareness, and the level of development or digitization, influence transparency and reporting (Bonsón & Bednárová, 2015; Haniffa & Cooke, 2005).

This implies that the level of digitization of a country can affect its disclosure. According to Alcaide Muñoz et al. (2016), online reporting in developed countries may not be identical to that in developing ones due to the "digital divide" that arises from society's ability to access new technological trends. However, Desoky (2009) shows that profitable companies in emerging countries tend to disclose more voluntary information than developed economies by legitimizing their results to obtain greater investment. For this reason, in our analysis we use the country variable, associating a value according to its level of digitization. We use the World Digital Competitiveness (WDC) ranking (International Institute for Management Development [IMD], 2020), which analyses and ranks the degree to which countries adopt and explore digital technologies that lead to transformation in government practices, business models, and society in general, assuming that the digital transformation occurs primarily at the enterprise level.

National blockchain strategy

EU member states are currently at different maturity levels in terms of blockchain regulation and blockchain ecosystem developments, which we might consider the two main dimensions of the national blockchain strategy of a country. Therefore,

the EU Blockchain Observatory and Forum (2021), an institution financed by the European Commission, has categorized each country into three stages of maturity based on these two dimensions.

Regarding the dimension regulatory maturity, three stages have been identified. Stage I means that no specific crypto-asset legislation has been enacted in the country. Stage II implies signs of significant involvement of the country in the blockchain field through the adoption of regulatory schemes explicitly involving crypto-assets, other measures such as government-sponsored studies or pilot projects related to blockchain in the public sector, or the existence of an established framework for digital currencies and digital asset taxation. Stage III refers to the countries where specific legislation for blockchain has been enacted or a national strategy/vision related to blockchain has been announced by the government. Similarly, the existence of sandboxes, innovation hubs, or other relevant initiatives would be characteristic of countries in this stage.

Ecosystem maturity focuses on the degree of bottom-up development in the local ecosystem in the country considering indicators such as a) the presence of a local start-up ecosystem, b) blockchain-related formal education and the level of academic research related to blockchain, or c) the existence of blockchain communities. Thus, if there is evidence of sizeable and dynamic initiatives in one of these areas (start-up, academia, communities), the country would be categorized into Stage I. If these were evident in two areas, Stage II would be assigned, etc. (Table 3).

Ecosystem maturity	Regulatory maturity	Level	Country
Stage I	Stage I	1	Belgium, Greece
Stage II	Stage I	2	Denmark, Ireland, Sweden
Stage I	Stage II	2	Finland, Latvia, Poland
Stage II	Stage II	3	Austria, Italy, Portugal, Spain
Stage III	Stage II	4	Lithuania, Netherlands
Stage II	Stage III	4	France, Germany, Luxembourg

Table 3. State of European blockchain ecosystem

For the purposes of our study, we have considered the classification provided by the EU Blockchain Observatory and Forum and categorized the countries from our sample into four levels based on their regulatory and ecosystem maturity. We believe that these dimensions might create a contextual framework for companies

and therefore potentially impact the involvement in blockchain projects, products, initiatives, and reporting.

Sector

One of the most used factors in empirical research in the corporate field is the company's sector. Numerous researchers (Bonsón & Bednárová, 2013; Bonsón, et al., 2021a; Bonsón et al., 2021b; Brammer & Pavelin, 2006; Hahn & Kühnen, 2013; Hassan et al., 2013) have shown evidence that disclosure depends on the company's sector. That is why, depending on the sector of the company, its corporate disclosure strategy is different from those that operate in other sectors (Aljifri, 2008; Cooke, 1992; Javaid et al., 2016). It turns out that depending on the sector in which the company operates, it will face different pressures to disclose information (Nguyen, et al., 2020).

In this case, we consider two sectors for the analysis, the financial and the technological, since both are closely related to the blockchain. Therefore, we consider the 11 sectors defined by the Global Industry Classification Standard (GICS) in two segments. The first group contains companies that operate in the financial services and technology services sectors. The second group consists of all the others.

We start from the basis that when companies in the financial sector stop showing their stakeholders that making a profit is not their only goal, they disclose more non-financial information (Giannarakis, 2014), and that companies related to technology must respond to possible changes in their environment (Dolinšek & Lutar-Skerbinjek, 2018). This is linked to the fact that one of the main applications of blockchain services is found in the financial technology (FinTech) industry. The term FinTech represents a new reality that combines both sectors, financial and technological. Blockchain technology opens the door to smart technology and new business models in the FinTech industry (Harris & Wonglimpiyarat, 2019). Although blockchain-focused studies predominate in the financial sector (Ali et al., 2020; Othman et al., 2022; Wang et al., 2020; Xu et al., 2022) compared to the technology industry (Al-Megren et al., 2018), it is essentially the FinTech sector (Lee et al., 2018; Mosteanu & Faccia, 2020; Osmani et al., 2021; Sangwan et al., 2020; Yen & Wang, 2021) where more attention is devoted.

Company size

Another of the classic elements addressed in this kind of reporting is the size of the company. However, the size can be measured based on various proxies. Deciding how to measure the size of the company is an important issue to consider, since researchers must be careful when selecting any proxy for the size of the company for their research, taking into account the scope and context of their work (Hashmi et al., 2020). Although there are many options for measuring size, Dang et al. (2018) pointed out that in corporate finance the most used proxies were total assets, total revenue, and the market value of capital.

Based on the analysis carried out by Hashmi et al. (2020), we consider that total income is an adequate proxy for the context we are studying. These authors reflected that when a company is larger, it is expected that its production will be greater, which implies more sales. Higher sales will lead to higher income, and higher income means greater investment capacity. In this case, it is expected that large companies have invested in developing blockchain applications. Therefore, it can be considered that the disclosure of blockchain information is more likely to occur in companies with more resources, considering that large companies must guarantee their legitimacy by pointing out their blockchain efforts in their corporate reports.

Numerous researchers (Bonsón & Flores, 2011; Brammer & Pavelin, 2006; Clarkson et al., 2011) have shown that the size of the company is significant when it comes to disclosure: small companies disclose less non-financial information because they are not exposed to a large number of shareholders, and large companies are more likely to divulge more due to the need to explain their business conduct and transmit credible information, as it has a greater social impact. That is why the size of the company has a positive effect on corporate visibility with the adoption, scope, and quality of its reports (Bonsón, et al., 2021a). Finally, it should be noted that the original value of total revenues is not used, since most studies in empirical corporate finance use the natural log form of firm size measures to mitigate the substantial skewness of these data (Dang et al., 2018).

Sustainability leadership

The last factor that we check to see if it is decisive when disseminating about blockchain is the performance of sustainability. This variable has been studied in

numerous investigations, which have shown that the companies that tend to disclose more non-financial information turn out to be those with adequate results in sustainability (Bednárová et al., 2019; Bonsón et al., 2020; Hummel & Schlick, 2016; Rezaee & Tuo, 2017). Brammer and Pavelin (2006), on the other hand, specify that good environmental performance influences the quality of disclosures, but not the decision to issue environmental information.

In our research, we use the Morgan Stanley Capital International (MSCI) ESG classification. In this way, we classify the companies as leaders (rating = AAA–AA) or not (all other rated and non-rated companies). However, some authors determined that the ESG rating has limitations in addressing this new technology, so one of the new challenges is to overcome this limitation and explore the possibility of building an ESG rating system for blockchain (Yu & Zhang, 2021). All of this must start with being able to actually trace the source of the blockchain's power consumption (Ganapathi, 2022).

Nevertheless, MSCI (2021) presents an analysis where the ESG risks that one of the most widespread applications of the most used blockchain technology, cryptocurrencies, brings with it are determined. Bitcoin mining, it turns out, uses an immense amount of energy, so much so that in early 2021, Bitcoin alone generated more e-waste than many mid-sized countries (Ganapathi, 2022). However, some of the other many functionalities of blockchain technology are potential tools to improve sustainability performance, as several studies have shown (Park & Li, 2021; Poberezhna, 2018). According to Hashmi et al. (2020), blockchain technology also enables effective monitoring, reporting, and verification, increases transparency and accountability, and reduces the risk of greenwashing. Regardless, whether blockchain is seen as an environmental threat or a solution for environmental issues, we believe that sustainability leaders would use disclosure to clarify the purpose of blockchain use in the company and therefore would be keener on such a disclosure. Table 4 summarizes the variables used in this study and their measurement.

To check the relationships between the factors, the generalized linear model (binomial regression) was applied.

$$\{Logit(BDL) = \beta 0 + \beta 1 WDC + \beta 2 \text{BNatStrat} + \beta 3 Sect + \beta 4 Size + \beta 5 SustLead\}$$

Variable	Full Name	Shortened Name	Description	Source
Dependent	Blockchain Disclosure Level	BDL	Dummy variable (Level 0: no report or general report; Level 1: use of a blockchain product or participation in a project or alliance or win an award)	PDF mining as shown in Figure 1
Independent	World Digital Competitiveness ranking	WDC	Measuring the capacity and readiness of countries to adopt and explore digital technologies for economic and social transformation	International Institute for Management Development (IMD)
	Blockchain national strategy	BNatStrat	1 = Belgium, Greece 2 = Denmark, Ireland, Sweden Finland, Latvia, Poland 3 = Austria, Italy, Portugal, Spain 4 = Lithuania, Netherlands, France, Germany, Luxembourg	EU Blockchain Observatory and Forum
	Sector	Sect	Dummy variable (financial sector or information technology sector = 1; other = 0)	Global Industry Classification Standard (GICS)
	Company size	Size	Natural logarithm of the total revenue of the company in 2019	Investing.com
	Sustainability leadership	SustLead	Dummy variable (leader in ESG ranking = 1; other = 0)	MSCI

Table 4. Definitions and measurements of variables

4. FINDINGS

RQ1. Are Western European companies disclosing information about the use of blockchain in their annual/sustainability reports?

After processing the 1,409 reports from Western European companies during the years 2018 and 2020, 758 sentences on blockchain were extracted to analyse their content. We identified 109 companies as those that disclose aspects of blockchain. That is, 32.34% of Western European companies are involved in reporting on blockchain.

Therefore, the answer to our RQ1 is that the number of Western European companies disclosing information about the use of blockchain in their annual/sustainability reports is not high but still considerable.

RQ2. What is the content of those disclosures?

Each company discloses different aspects of this technology and disclosures vary in both content and in depth. Table 5 shows the distribution of companies according to the content type (BDL).

As indicated previously, most of the companies do not provide any reference to blockchain in their report (67,69%). Among those companies reporting on blockchain, the majority (10.95%) of the companies report on projects or alliances related to this technology, which have not yet resulted in functioning products or processes; 9.31% of the companies claim to have specific applications of blockchain integrated into their businesses processes; and closely following are the companies that disclose only general information (8.76%). Finally, 3.29% of companies disclose that they have received an award or recognition in the field of blockchain.

BDL	Companies
Nothing	67,69%
General	8,76%
Projects/Alliance	10,95%
Products	9,31%
Award	3,29%

Table 5. Distribution of companies

Given the novelty of the technology, many of the blockchain disclosures were related to general blockchain information, which means that although a company recognizes the disruptive potential of the technology, it is not engaged in any project or alliance related to blockchain, nor has it developed any blockchain solution yet. In total, in 2020, there were 95 blockchain mentions labelled as general.

A step further was disclosure related to either a blockchain project launch or participation in a blockchain alliance, which has not resulted in an operating product yet, but it is on the way. In total, in 2020, 32 companies (with 55 mentions) reported on a blockchain-related project they are currently developing. Thematically, they all involve supply chain traceability, sustainability, and data verification, but blockchain projects in infrastructure, transportation, and logistics are also

mentioned. In addition, there is one mention related to a company's internal training covering blockchain and other new technologies. On the other hand, some companies simply generally stated that they are developing blockchain-related pilot projects without further specification. Similarly, 19 companies (21 mentions) reported on blockchain-related alliances they have recently joined. To shed some light on the content of the disclosures, Tables 6 and 7 provide extracts from annual/sustainability reports related to successfully developed blockchain products (and awards).

Thus, another category was a disclosure related to functional blockchain solutions. Here, also for 2020, we could identify 18 companies from different sectors reporting on their blockchain products and solutions. The disclosures in this category can be further broken down into three subcategories: *innovative traceability solutions in supply chain*, *sustainability*, and *finance trading*. Table 6 displays a few examples of disclosure extracts from each of these subcategories.

Disclosure subcategory	**Company**	**Disclosure Extract**
Innovative traceability solutions in supply chain	Carrefour	*Carrefour is also introducing innovative practices to offer agroecological farm products and non-gmo or antibiotic-free meat, and implementing blockchain technology has helped to boost the transparency and traceability of its products along the entire production chain.*
	Lenzing	*lenzing's new blockchain-enabled supply chain traceability platform supports the entire supply chain in meeting increasing demands for transparency and sustainability .*
Sustainability	Iberdrola	*also notable is the development of a digital platform designed to measure accurately and standardise worldwide emissions of greenhouse gases based on artificial intelligence , blockchain technology and digital twins .*
	Melia	*emissions compensation programme "sustainable meliárewards " the growing demand for more sustainable products and services led us to offer our meliárewards members the chance to get directly involved in emission compensation , becoming the first hotel company in the world to apply blockchain technology to help the environment .*
Finance trading	Ing	*initiatives that have benefitted from this include the trade finance tools of the blockchain-based software company komgo, which grew out of ing's innovation bootcamp (see 'distributed ledger technology and blockchain' below).*
	Seb	*in 2020 contour went live , a global blockchain-based platform for trade finance transactions .*

Table 6. Blockchain disclosure index (BDI) product

The last category of blockchain disclosure was related to an award, which implies external recognition of the quality of blockchain solutions developed by a company. From our sample, in 2020, there were four companies from the financial and consumer discretionary sectors that had received such an award. Extracts of the disclosures are provided in Table 7.

Disclosure category	Company	Disclosure Extract
Award	ABinBev	*our legal team won a financial times innovative lawyers award for standout innovation in recognition of our use of blockchain technology to protect human rights of brand promoters .*
	HM	*h&m group — sustainability performance report 2020 25transparent reporting since 2002 progress : accelerating sustainable change — we collaborated with global change award winner textilegenesis , piloting blockchain technology to track and verify use of sustainable fibres within our supply chain.*
	ING	*for the second consecutive year , forbes ranked ing as one of the top $50 billion companies embracing blockchain technology .*
	Worldline	*also , through horizon 2020 framework program , the european commission has awarded two new research and innovation projects to consortiums lead by worldline , with the objective to address new challenges in the media sector and take advantage of the most innovative technologies , including blockchain .*

Table 7. Blockchain disclosure index (BDI) award

RQ3. What are the factors associated with blockchain disclosure?

To determine the factors that explain a level of disclosure in blockchain technology, a binomial linear regression model is presented, as shown in Table 8.

Independent variable	Dependent variable			
	Blockchain Disclosure Level (BDL)			
	Estimate	Std error	t value	Sig.
(Intercept)	-0.252863	0.551839	-1.468	0.1371
World Digital Competitiveness	-0.002050	0.002597	-1.972	0.1349
Blockchain strategy	0.048678	0.038804	1.644	0.0519*
Sector	0.104107	0.050807	2.001	0.0301*
Company size	0.067605	0.016047	4.392	2.05e-06***
Sustainability leadership	-0.029107	0.063387	-0.647	0.6044

* Significant at p =< 0.05 (2-tailed). *** Significant at p =< 0.001 (2 tailed).

Table 8. Generalized linear model (Binomial regression)

Of the five possible factors proposed, three are significant. The national blockchain strategy, as well as the sector and size of the company, are variables that explain

the level of blockchain disclosure. Neither the digital competitiveness of the country nor sustainability leadership were related to a company's blockchain disclosure.

5. DISCUSSION

Blockchain is gaining momentum on the global level, and DLT is proliferating in a wide range of sectors and industries. In addition, in their annual/sustainability reports companies must report on both financial and non-financial information related to the impact of their activities. While non-financial disclosure related to environmental and social issues is becoming more standardized (Bonsón & Bednárová, 2015), a new aspect of non-financial reporting related to the use of new technologies and innovation is arising (Bonsón & Bednárová, 2022). Previous studies show that although the reporting on these aspects is not yet obligatory or regulated, an increasing number of companies report on the use of new technologies such as AI, automated decision making, and ethics in AI. Nevertheless, this disclosure is still in an early stage (Bonsón & Bednárová, 2022).

Blockchain is one of the technological advances that has drawn a great deal of attention due to its decentralized characteristics, applications in digital assets, and other features such as cryptographic sealing. Thus, it has created great expectations about how it will change business transactions in general (Yen & Wang, 2021). According to VTD and ST theory, adopting a transparent approach to the application of new technologies is in a company's interest because stakeholders can learn how new technologies can add value to the company and thus avoid generating uncertainties related to risks for companies. The adoption of blockchain can imply the transformation of the business and disruption in the entire industry (Deloitte, 2017). Therefore, disclosure related to blockchain technology may provide different value relevance for investors (Yen & Wang, 2021).

Since annual/sustainability reports represent a central and official communication tool between the company and its stakeholders, and it is in a company's interest to report on technological developments to appeal to shareholders and other stakeholders, to analyse the proliferation of blockchain within different sectors, we examined blockchain disclosure in corporate reports published between 2018 and 2020. Our findings show that a reasonable amount (32.34%) of listed companies from Western Europe disclose certain aspects about blockchain usage and projects. However, not all of them report on the same topics. The predominant disclosure

content is related to projects and alliances (11%) that companies are currently associating with. Nevertheless, although numerous projects related to blockchain are being carried out (Bonsón & Bednárová, 2019), this technology is still in its early adoption stage (Stratopoulos et al., 2020), and a limited number of companies have developed a functional product or process (9%) or have been awarded external recognition for their blockchain applications (3%).

Regarding the projects and alliances, some companies report that they are developing pilot projects related to blockchain without further specifications, while others have been more specific. Our findings show that most of the projects revolve around supply chain traceability, sustainability, data verification, infrastructure, and transport and logistics. When it comes to turning these projects into real applications, they are mostly related to innovative solutions for traceability in the supply chain, sustainability, and financial trade. Our study confirms that the interest in this technology is no longer limited to the financial sector or cryptocurrencies, since there is a great demand to use blockchain for various applications in other industries (Nanayakkara et al., 2021; Stratopoulos et al., 2022).

When analysing the factors that identify which types of companies disclose higher levels of blockchain information, we found that large companies, those based in countries with an advanced national blockchain strategy regarding the regulation and blockchain ecosystem, and those operating in the financial and technology sectors are more likely to disclose information related to blockchain. This is due to the fact that large companies, in addition to having more resources to be able to engage in projects or apply products using blockchain, are also under greater stakeholder scrutiny related to corporate transparency, which implies a wider scope and higher quality of their reports (Bonsón et al., 2021a). This finding follows the legitimacy theory.

Similarly, countries with well-developed national blockchain strategies will potentially impact companies' participation in blockchain projects, products, and initiatives, as this environment encourages and facilitates companies to advance in this technology. In addition, it is possible that the governments of these countries adopt these measures because they envision the progress of the companies in their country in terms of blockchain. Therefore, companies headquartered in these countries might be more motivated/or indirectly forced to engage in blockchain

disclosure to prove that they are in alignment with the country's strategy in this matter. These findings can also be explained by the legitimacy theory.

The significant sectors in this analysis are both the financial and technological sectors, due to FinTech applications, which, despite the fact that the interest in blockchain has spread to other sectors, continue to play a leading role in this domain (Bonsón & Bednárová, 2019), generating applications beyond cryptocurrencies (Polyviou et al., 2019). These results are in alignment with the VDT and ST, which state that a sector creates a certain contextual framework and companies operating in certain sectors are forced by their peers to adjust their strategies, in this case, disclosure practices to appeal to their stakeholders.

In contrast, the WDC ranking and sustainability leadership were not associated with blockchain disclosure. Thus, the level of a country's digitization does not seem to affect the companies' tendency to blockchain disclosure the same way as the national blockchain strategy. In terms of sustainability leadership, our assumption that sustainability leaders want to maintain their position through increased transparency in terms of blockchain, due to its connection with Bitcoin and its relation to e-waste and energy consumption, was not confirmed. Previous studies have also implied that ESG rating has limitations in addressing blockchain technology (Ganapathi, 2022; Yu & Zhang, 2021). Thus, it might not yet be officially perceived as a risk.

6. CONCLUSIONS

It appears that blockchain technology will have a significant impact on both the private and public sectors over the next decade. Some argue that this is the most disruptive technology after the Internet and that we are entering into a new digital era. In addition, recent developments have shown that blockchain is no longer limited to ICT and the financial sector. Therefore, significant attention has been paid to DLT, a main feature of blockchain, and its potential. Recently, there has been an increased number of initiatives and projects on the national and international levels in different sectors that aim to benefit from this technology.

In our research, we aimed to analyse to what extent large Western European companies engage with this innovative technology, whether they report on it in their annual or sustainability reports, the content type of such disclosure, and the factors associated with it. Our study shows that 32% of analysed companies mention

blockchain in their annual or sustainability reports. Some companies (9%) provide only a general statement, recognizing the disruptive potential of this technology, whereas most (11%) report their active participation in a project or alliance related to blockchain. On the other hand, 9% of the analysed companies provide information categorized as a product, and therefore a functional blockchain solution, while 3% mention an award, which implies external recognition or the distinction of blockchain solutions offered by a company.

Our findings also show that engagement in blockchain disclosure is affected by the size of the company, the sector where the company operates, and the national blockchain strategy of the country where the company is headquartered. Thus, bigger companies, companies operating in a country with a well-developed strategy related to the blockchain ecosystem and regulation, and companies operating in the technology and financial sectors tend to engage with blockchain reporting more than other companies. To the best of our knowledge, this is the first study providing insights into blockchain proliferation in large Western European companies by analysing blockchain disclosure in annual/sustainability reports.

Finally, a few limitations of this paper as well as suggestions for future research should be outlined. To analyse to what extent Western European companies, engage with blockchain, we analysed their annual/sustainability reports. Although these reports should provide complete and trustworthy information, due to a lack of regulation on how to report on this non-financial disclosure, future research could include other sources of information, such as news and tweets. In addition, more factors explaining blockchain adoption could be considered.

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