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Blockchain, Enterprise Resource Planning (ERP) and Accounting Information Systems (AIS): Research on e-Procurement and System Integration

Alessio Faccia [1,2,*] and Pythagoras Petratos [1]

[1] School of Business and Law, Coventry University, Coventry CV15FB, UK; pythagoras.petratos@coventry.ac.uk
[2] Centre for Blockchain Technologies (UCL CBT), University College London, London WC1E6BT, UK
* Correspondence: alessio.faccia@coventry.ac.uk

Abstract: Accounting information systems (AISs), the core module of any enterprise resource planning (ERP) system, are usually designed as centralised systems. Nowadays, the continuous development and applications of blockchain, or more broadly—distributed ledger technology (DLT), can change the architecture, overcome and improve some limitations of centralised systems, most notably security and privacy. An increasing number of authors are suggesting the application of blockchain technologies in management, accounting and ERPs. This paper aims to examine the emerging literature on this field, and an immediate result is that blockchain applications can have significant benefits. The paper's innovative contribution and considerable objective are to examine if blockchain can be successfully integrated with AIS and ERPs. We find that blockchain can facilitate integration at multiple levels and better serve various purposes as auditing compliance. To demonstrate that, we analyse e-procurement systems and operations using case study research methodology. The findings suggest that DLT, decentralised finance (DeFI), and financial technology (FinTech) applications can facilitate integrating AISs and ERP systems and yield significant benefits for efficiency, productivity and security.

Keywords: accounting information systems; triple entry accounting; blockchain accounting; ERP; e-procurement; information systems design; triple entry bookkeeping; e-business systems; FinTech; financial technology

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1. Introduction

In this article, three domains are analysed: (a) enterprise resource planning, (b) accounting information systems and (c) e-procurement. The original approach is set to design a feasible path for their integration to benefit businesses, managers, and governance in general. While numerous other researches have focused only on theoretical aspects or on each element independently [1–3], this is the first research that attempts the application of a generalised e-Procurement system through the exploitation of the ERP systems and their core AIS functions by suggesting the introduction of an additional functional module in one of the most widespread business solutions, SAP.

Enterprise resource planning (ERP) refers to "a type of software that organisations use to manage business activities, such as accounting, procurement, project management, risk and compliance management, and supply chain operations. A complete ERP suite also includes enterprise performance management, Software that helps plan, budget, predict and report on an organisation's financial results" [4]. Accounting information systems (AISs) involve collecting, storing, and processing financial and accounting data used by internal users to report information to investors, creditors, and tax authorities [5]. AISs are generally computer-based methods for tracking accounting activity in conjunction

with information technology resources. An AIS combines traditional accounting practices, such as generally accepted accounting principles (GAAP), with modern information technology resources [6].

AIS design and analysis are challenging [7–10]. ERPs are even more complex since they need to integrate many business applications to serve multiple needs [11,12]. In addition, AISs are usually implemented before any other business application since they ensure mandatory regulations compliance (i.e., bookkeeping and financial statements disclosure) [13]. AISs (even when cloud-based) currently in use by all the companies are designed as centralised systems [14–16] to ensure security principles as confidentiality [17,18], controllability (direct access and liberate chain of command) [19] and cost-effectiveness [20,21]. Moreover, all other business applications are built in the ERPs around the AISs to gather and provide (input or output) data for further analyses, consistent with the accounting results [13,22,23].

Blockchain and distributed ledger are the technologies that enable the Internet of value, which is based on five "ingredients": network, algorithms, distributed ledger, transfers and assets. There is still a lot of confusion as to what the terms blockchain and distributed ledger mean. Distributed ledger technologies (DLTs), like blockchain, primarily aim to ensure trust, transparency and accountability (traceability), automation (smart contracts), and immutability [24–26]. DLTs can provide additional levels of security, accountability and others. Many authors support the co-existence of AIS and blockchain [27–30]. However, there is not much literature on a specific application to justify this hypothesis. Furthermore, even though ERP vendors have started many blockchain projects (i.e., SAP Leonardo Blockchain) [31,32], there is still limited theoretical applications.

A novel (and significant) contribution is provided by analysing the case of e-procurement regarding blockchain applications and integration with AIS and ERP to fill this gap in the literature. E-procurement identifies how private companies and public administrations purchase goods and services from suppliers through the Internet [33–38]. The term e-procurement means all systems that—thanks to a set of rules and procedures that include various types of software and information technology—allow the procurement of goods and services through the Internet. The e-procurement systems—used between companies (B2B commerce), between companies and individuals (B2C) or between companies and public institutions (G2B)—move online purchasing processes, drastically reducing the waste of time and resources typical of operations manuals [39]. The advantages of e-procurement are as follows: less waste, fewer costs, more efficiency. E-procurement promptly responded to the increasingly stringent demand for digitisation and innovation, structuring an online system to transparently manage tenders, awards and management control throughout the procurement phase. Thanks to the suppliers' register, in fact, the purchasing departments of private companies and public administrations now can better manage the award of goods, services or contracts. Furthermore, the integration of the e-Procurement platforms with the management systems of the purchasing companies, the so-called "ERP" or enterprise resource planning, is crucial, so that, in addition to optimal administrative management, everyone in the company can access in time real to availability or orders in process.

In that sense, e-procurement is one of the most frequent and essential functions for enterprises, governments, and other organisations. When e-procurement platforms are effectively implemented, there are most efficient operations since the suppliers submit their application for registration with the online suppliers register and communicate directly on the platform [40,41]. E-procurement promptly responded to the increasing demand for digitisation and innovation, structuring an online system to transparently manage tenders, awards and management control throughout the procurement phase [42–44]. Because of the suppliers' registers, the purchasing departments of private companies and public administrations can better manage the award of goods, services, or contracts.

This paper finds support for blockchain applications in ERP and AIS. Furthermore, integrating the e-procurement platforms with the AIS and ERP systems of the purchasing

companies can benefit better management, security, efficiency and productivity. Systems and operations can be accessed in time real to manage the availability or orders in the process [45–47] and increase efficiency. The e-procurement software platforms have been developed and can have many forms and provide much flexibility and associated benefits (cost control, various operations, etc.) for organisations [48,49]. Finally, multi-user access allows the use of the platform simultaneously by buyers and suppliers, resulting in improved productivity. The verification of the identities is generally certified by a qualified digital signature system [50,51] and other blockchain applications, and thus, it can enhance security and privacy.

2. Literature Review and Related Work

This section provides a brief literature review that is the paper's main contribution and assists in examining some fundamental concepts and facilitating the analysis. It should be emphasised that the blockchain analysis focuses on accounting and finance, which is the main topic and common denominator of ERP, AIS and e-procurement. However, we also discuss some potential applications in the ERP context, but we do not expand on other general blockchain applications in business.

2.1. Accounting, AIS and ERP and DLT

The accounting process (Figure 1) is an essential part of any business, principally because enforced by law worldwide. All companies are required to prepare and keep the books and accounting records required by civil, fiscal, corporate and labour regulations [34]. The accounting books that companies must keep vary according to the type and size of the business. The mandatory records and accounting books are those documents that the legislation requires to draw up and support to: (a) represent and demonstrate the individual business documents, both from a quantitative and monetary point of view; (b) allow a clear and truthful representation of the company's equity, financial and economic situation [52]. The correct preparation and conservation of accounting books is an indispensable element for any company. In this sense, all companies are required to keep: (a) the journal, that is, the book in which all management operations are recorded in chronological order (purchases, sales, collections, payments, etc.); (b) the ledger, relating to all the ledger accounts that are used during the accounting entry operations [34].

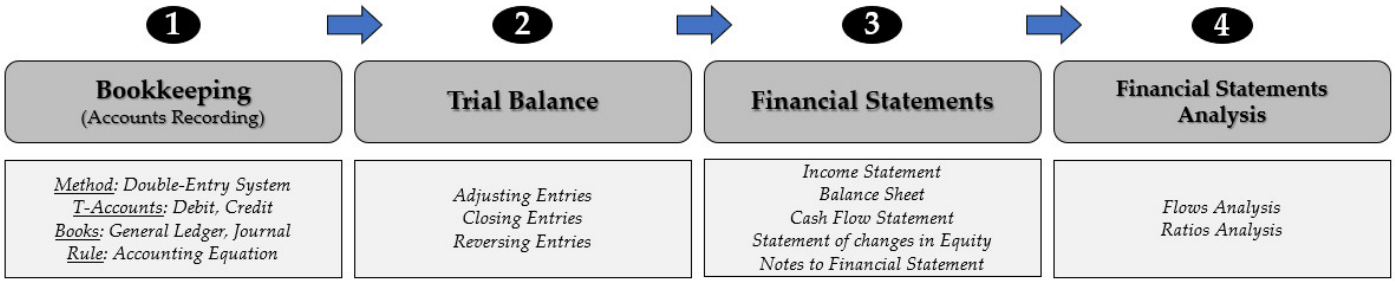

Figure 1. The Accounting Process.

It also ensures the measurement of the business financial results. Therefore, understanding and matching the accounting needs is vital to avoid compromising the company reputation, going concern, and stakeholders' trust [12,53].

Any transaction that the company performs with external entities should be recorded in the bookkeeping system (FI module) as an invoice (expenses or revenues), a payment, a payable, or a receivable, and further processed for other internal purposes (i.e., inventory management, quality, production, logistics) [54,55]. Therefore, a direct link between the AIS modules and other ERP modules can be demonstrated. For example, the same transaction, let us assume a purchase, affects the general ledger and general journal accounting books in the administration department and other departments like production,

quality, supply chain, logistics, sales, marketing, and so forth. Given the potentially significant benefits in auditing and accountability, some attempts have been made to implement blockchain-based accounting systems. Nevertheless, the literature is not much developed, especially concerning theoretical applications (i.e., e-procurement etc.). Furthermore, given the importance of a fair financial disclosure, directly related to the public trust in the financial markets, standardisation in accounting is ensured by very detailed regulations, laws, accounting standards (i.e., IAS/IFRS, US GAAP), XBRL taxonomies [56,57].

A notable example is e-invoices (which are rapidly replacing paper-invoices worldwide). However, despite the countless advantages they generate, only the enforcement of national (local) revenue agencies and governments led to their universal use in B2B, B2G, and B2C transactions [58–60]. Therefore, the expectations can be similar for implement blockchain-integrated accounting information systems. Thus, revenue agencies and public authorities policies and regulations should be considered essential in the design and enforcement of shared, public, permissioned distributed ledger platforms. The ERP vendors should follow and adjust their systems to make them compliant with the public blockchain platform.

2.2. Blockchain

Blockchain technologies are included in the broader family of distributed ledger technologies to which they add some features typical of other technologies and solutions. Distributed ledger technologies (DLTs) are systems based on a distributed ledger, i.e., systems in which all nodes of a network have the duplicate copy of a database that can be read and modified independently by the individual nodes. Suppose all the nodes that own a copy of the database can consult it in the so-called distributed database but have to go through a central body (or more validators) to modify the data. In that case, the distributed ledger systems change the register are regulated through consent. These algorithms make it possible to reach a consensus between the various ledger versions, although they are updated independently by the network participants. In addition to the consensus algorithms, to maintain the security and immutability of the register, distributed ledger and blockchain also make extensive use of cryptography [32].

Precisely due to the particularity and relevance of how the network updates the ledger, the fundamental characteristics that distinguish the various distributed ledger systems are three: (a) type of network; (b) consent mechanism; and (c) register structure. The more adequately called blockchain solutions, those inspired by the Bitcoin platform, add two more features that are not necessarily found in distributed ledger systems: (d) transfers; and (e) assets [32].

Based on the type of network, a distinction is made between systems: (a) permissioned—networks in which to access one must register and identify oneself and therefore be authorised by a central body or by the network itself; (b) permissionless—networks that anyone can access without permission. In permissioned systems, the consent mechanism is more straightforward. When a node proposes to add a transaction, its validity is checked, and a majority vote is taken on whether to add it to the ledger. In permissionless systems, on the other hand, the consent mechanisms are more complex (based, for example, proof of work or proof of stake) to prevent a malicious person from creating numerous fictitious identities and influencing the registry modification process [61].

Another feature of distributed ledger systems is the ledger structure [62]. Blockchain solutions are those in which the ledger is structured as a chain of blocks containing multiple transactions. The blocks are linked together via cryptography (such as in Bitcoin or Ethereum platforms). There are also solutions in which the register is formed by Tangle, i.e., where the transactions are processed in parallel (for example, IOTA—https://www.iota.org accessed on 23 July 2021) or still other cases in which the record is formed by a chain of transactions (for example, Ripple—https://ripple.com accessed on 23 July 2021). Blockchain systems generally allow you to make transfers or, more generally, transactions. These transfers can be simple or more advanced depending on the level of

programmability allowed by the platform. For example, the Ethereum platform will enable the management of smart contracts that facilitate arbitrarily complex transfers. Finally, the last feature of blockchain systems is that there is a unique asset to be transferred which can be a cryptocurrency or a token. This asset can be natively digital or physical with a digital consideration. Internet of things technologies can help match physical and digital assets [32].

The blockchain can be considered a digital register whose transactions are grouped into blocks, linked in chronological order, and cryptography guarantees its integrity [32]. The current size of blockchain networks is still limited but destined to grow over time. Therefore, the blockchain is comparable to a distributed database managed by a network of nodes (computers), each of which has a private copy containing identical information. Generally, the involved nodes do not know each other's identity. A shared protocol allows new blocks to be added to the "chain" to ensure consistency between the various copies. Each time a new block is approved-chained (consent), all nodes update their private copy. This structure ensures that no manipulation, modification or deletion of data is possible [63].

The blockchain is, therefore, a decentralised system. Figure 2 below graphically displays three different system structures [64].

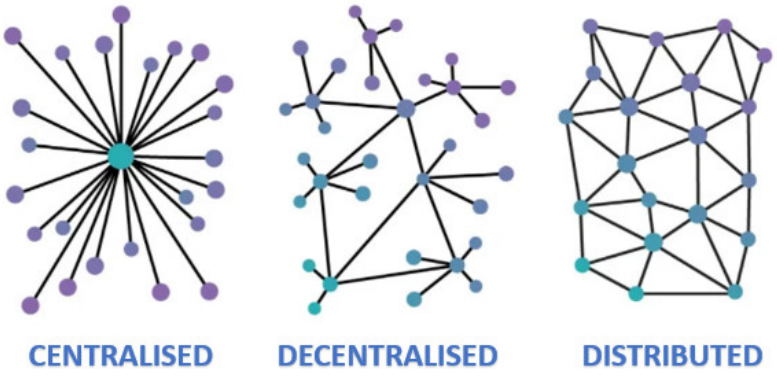

Figure 2. Centralised vs. Decentralised vs. Distributed Networks.

Centralised and decentralised networks refer to the level of control of the system. In a centralised system, the control is performed by a single entity (person, company, institution). There is no single control entity in a decentralised system, but control is divided among many independent entities. The distributed network refers to the different locations. Within a non-distributed system, all its components are located within the same physical place. In a distributed system, part of the system is located in several separate locations [65].

2.3. Blockchain Applications in Business Areas Other Than Accounting

Blockchain implementation has been discussed in particular regarding supply chains to ensure transparency, traceability and accountability. Related modules like QM—quality management, SRM—supply relationship management, and SCM—supply chain management can undoubtedly become part of (or integrated with) public, permissioned distributed IT system architectures [66–68].

Various applications could be designed for all the other ERP Modules if private blockchain systems are considered, potentially replacing the centralised data warehouse-based systems. Blockchain is becoming popular thanks to cryptocurrencies and related payment systems based on the concept of blockchain. A peer to peer exchange network in which there is no central authority that validates and records transactions. The differences with the current payment system immediately emerge decentralisation, low transaction costs, and total anonymity [69]. Performing transactions with cryptocurrencies will re-

quire specific management within an organisation that range from the exchange rate constant monitoring (given their volatility) to safe encrypted storage of the cryptocurrency itself.

Among the implementation projects that can currently be identified for blockchain and distributed ledger technologies in the business environment, four main categories can be listed, depending on their objective: exchange of value [70], verifiability of data [71], coordination of data [72], and implementation of reliable processes [73].

Exchange of value. These applications exploit crypto-assets enabled by blockchain platforms to exchange money or other precious assets safely and disintermediated. These tools can be used to make the exchanges of value between different players more efficient by reducing or eliminating the need for intermediaries [70].

1. Verifiability of data: Applications in this category use the properties of immutability and transparency of blockchain technology by recording some characteristics of data or documents on it. These are visible and verifiable by other ecosystem players or third parties. Among these projects, there are applications commonly known as "notarisation". For example, a document is timestamped to make verifiable the date of creation and the fact that it has not been modified over time. Many projects of this type have been developed in agrifood to offer more significant guarantees to the final consumer on the traceability of products [71].
2. Data coordination: Most of the use cases implement blockchain and distributed ledger technologies in data sharing processes, not only by notarising information but also by exploiting smart contracts to bring data exchange on-chain, allowing more effective coordination and efficiency between the different actors. These applications are developed mainly to reconcile information maintained by other actors, avoiding the emergence of divergences and conflicts. In these projects, blockchain often replaces the role of intermediaries [72].
3. The realisation of reliable processes. This is the category in which the most ambitious projects fall, aiming to run entire business processes on blockchain to ensure that every step is verifiable. In these projects, the business process is coded through smart contracts using a blockchain platform. It is also clearly the most complex and challenging application scenario to be implemented [73].

3. Methods

After providing the necessary theoretical framework of AIS and blockchain, this article focuses on a specific practical application based on e-procurement. The theoretical framework is examined using the literature review methodology. The literature review attempts to analyse blockchain technologies but mainly through the accounting and management lenses. This has specific limitations that are presented below. Nevertheless, there is emerging literature on blockchain applications in accounting and related management applications [32]. In that sense, a central contribution is the literature review of such applications in the context of ERP and AIS [74].

Another fundamental method is case study analysis. We analyse the case study of e-procurement. We have justified why e-procurement is an essential module in ERP systems since it is frequently used for numerous operations. Compared to the rest of ERP modules and processes, e-procurement has a significant methodological advantage and broad applicability. In that sense, examining the hypothesis that e-procurement can facilitate blockchain and, consequently, integrating ERP, AIS (and other systems) can be much easier to gain support because of its wide range of applications concerning other procedures and operations. This also assists in the validation validation. The suggested framework, which integrates the various systems, has been validated through this case study that mapped the current SAP system (one of the most popular ERP vendors) functional modules. A general analysis of potential applications of the blockchain to those modules resulted in the identification of the AIS ones [SAP FI-CO] to be the most suitable. Furthermore, the

pivotal role of the accounting processes (linked to any other business operations that need tracking through bookkeeping) is paired with the widely used and expanding process of e-procurement.

To better facilitate this research, the authors identify the following hypotheses:

(1) ERP and AIS systems can benefit from decentralised architecture and blockchain;
(2) E-Procurement can facilitate the integration of ERP and AIS systems;
(3) The integration of these systems.

Some research questions that this research tries to clarify are:

- Which are the particular benefits from blockchain applications on ERP, AIS and e-procurement in particular?
- Does FinTech provide benefits and generate value?
- Is DeFI an effective way to integrate systems and applications?

4. Case Study Analysis and Results

4.1. ERP Mapping

On the international scene, the leading ERP solutions for large companies are SAP, Oracle and Microsoft (Dynamics 365) [75]. The use of SAP is primarily in enterprise resource planning (ERP), which works to integrate different business software applications designed to work for specific types of businesses. The use of SAP has been synonymous with large corporations. On the other hand, Oracle stands for object-relational database management systems (ORDBMS) and can be hosted on numerous platforms [76]. ORDBMS versions are available from simple arrangements that can be quite well employed for personal use to enterprise-class versions. Oracle is an object-relational database management system (ORDBMS) that comes from the massive Oracle Corporation. Its use can be scaled to personal service as broad as the boundaries of a large company.

The programming language in Oracle DBMS is SQL, commonly referred to as structured query language [77]. The most important feature of Oracle is that its scripts can be run independently. Oracle and SAP differ in that SAP consists of complex ERP software to enable the integration of multiple companies. At the same time, Oracle is delivered as an ORDBMS that can be run in business environments. Data management is possible in the enterprise using Oracle, while real-time business process management is possible with SAP [78]. SAP can be integrated with different database systems, including Oracle [79]. SAP integrates business applications using its enterprise resource planning software (ERP), while Oracle, an object-relational database management system (ORDBMS), is used in business environments. Real-time business process management is available through SAP, while Oracle manages data across enterprises. SAP development can include Oracle as a database system as it can be integrated with numerous databases.

Both SAP and Microsoft offer structured solutions, market leaders and are widely used in the essential companies [80]. Dynamics 365 delivers real-time results through a well-designed unified interface that allows employees to increase productivity even on the move [81]. It contains many functions such as sales, field service and marketing. Microsoft's main merit was to bring together the parts of CRM with those of ERP in a single environment. Therefore, ERP systems have significant similarities that can allow generalisations, but at the same time, they have differences that provide justifications to use SAP as the primary example concerning integration.

The popularity of SAP is confirmed because KPMG offers specific ERP systems installation, configuration, integration services, testing, and training for these three providers among the so-called big four audit companies [82]. SAP, Oracle and Microsoft, also named "the big three" [83], are often compared in market share, users appreciation, easy-to-use, and development. Therefore, we prefer to use SAP as the leading example in the case study.

Intending to find IT solutions for companies, the multinational has produced business intelligence, CRM (customer relationship management) systems and one of the most

efficient ERP (enterprise resource planning) systems in the world. SAP, the acronym of "*systems, applications and products in data processing*", is the most widespread and practical software of the ERP array. Its characteristics make it ideal for company management; in fact, it is adopted by multinationals or large companies, but lately, SMEs are also implementing it to manage and plan all activities. The main features of this software are listed below:

- It allows combining each area of the company because all data is collected in a shared database.
- It has a modular structure that we will deepen below.
- It is customisable. That is, it presents a prescriptive approach that favours business process reengineering. This means that the program itself is implemented in such a way as to adapt it to the needs of individual companies and the particular function it will perform.

The advantages deriving from the use of SAP are many [84].

- Improves business efficiency from an operational point of view, reducing costs and increasing control over company management.
- The risk is lowered thanks to the integrity of the data and thanks to a more significant number of financial controls.
- They increased management efficiency. The data are readily available as they are present in a single database. This allows to speed up and make business and decision-making processes more reliable and reduce the costs related to operational management.
- The shared system allows more users to access a more significant number of information.
- There is better management of human resources such as workers and employees.

The SAP module FI manages the mandatory accounting process—financial accounting to generate the external disclosure (financial statements) and is further integrated by the module CO—controlling for managerial accounting (internal) purposes [54,55,85]. Moreover, many other modules deal with accounting and finance purposes, among them TR—treasury and EC—enterprise controlling [86]. The bunch of accounting-and-finance-related modules form the core of the SAP architecture, and they can be identified as the core AIS—accounting information system part of this ERP.

Addressing the first research question requires presenting an overview of the leading business processes to match the ERP modules that facilitate the operations in that specific area. The ERPs and their necessary IT infrastructures are complex systems tailored for business processes [87–90]. The complexity of ERPs depends on many factors like size, integration, compatibility, and industry. In the specific case of SAP, the German-based ERPs implemented by most multinational companies, several modules match multiple business needs and processes.

Table 1, below, displays the most used functional modules (in this particular case, in the SAP system). Technical modules are not considered as they deal with the general management of the ERP [91–97].

Table 1. SAP Functional Modules [1].

Module Code	Business Function	Module Code	Business Function
FI	Financial Accounting	CO	Controlling
TR	Treasury Management	RE	Real Estate Management
EC	Enterprise Controlling	IM	Investment Management
SCM	Supply Chain Management	APO	Advanced Planning Optimization
MM	Material Management	LE	Logistics Execution
SD	Sales Distribution	CS	Customer Service
PP	Production Management	EHS	Environment Health and Safety
QM	Quality Management	LO	Logistics General
SRM	Supply Relationship Management	PM	Plant Management
PLM	Product Lifecycle Management	HR/HCM	Human Capital Management
ESS	Employee Self Service	MSS	Management Self Service
CRM	Customer Relationship Mgmt	FSCM	Financial Supply Chain Mgmt
GCR	Governance Risk Compliance	CPM	Corporate Performance Mgmt
PS	Project System	IS	Industry Specific

[1] The list includes only the most known and used SAP functional modules [91–97].

It can be argued that centralised systems currently manage all the modules listed above. Data warehouses are used as centralised data repositories, and they can be located on-site or cloud-based [98]. An essential practical development is the project "SAP Leonardo Blockchain", which attempted to implement a blockchain platform in 2017 [99]. Leonardo was initially implemented as an IoT (Internet of things) platform, later transformed into an AI (artificial intelligence) one, and it is currently more focused on ML (machine learning) systems (an AI's subset) rather than on blockchain. However, no relevant development have been recorded so far [100,101]. Furthermore, another vendor (SAP competitor) platform, Microsoft's Azure Blockchain Service, is set to be retired on 10 September 2021 [102], which can be considered as demonstrating integration challenges with ERP systems.

4.2. The Benefits in E-Procurement and Blockchain Applications

Procurement is currently cross-managed in SAP through different functional modules, mainly MM—material management, SCM—supply chain management, FI—financial accounting [103,104]. At present, there is no specific procurement SAP module, apart from the so-called "SAP Ariba" [105]. This cloud-based solution allows suppliers and buyers to connect and do business on a single platform. Its application, however, is still somewhat limited to some companies that use SAP and volunteer in joining the network.

A necessary shift for any purchasing transaction to a shared e-procurement platform is desirable for several reasons, ranging from reducing errors to ensuring timely operations. Therefore e-procurement brings many advantages:

- Reduced procurement time and efficiency. Compared to traditional methods, the management of online purchases allows to speed up communication times between buyers and suppliers and improve order processing and thus efficiency.
- IT automation and productivity. The automation of procurement processes with the related alert system allows you to drastically reduce the preparation time of purchase

orders and the management of requests by the various company departments concerned. This can substantially save time and increase productivity.
- Costs reduction. The cost reduction is significant in many respects: from paper savings to optimising the personnel involved in managing the practices to reduce inventories and warehouse waste.
- Security, reliability and safety. The e-procurement systems guarantee the transfer and retention of data in compliance with the stringent privacy regulations in force. Furthermore, the reliability of data transmissions (via VPN and encrypted) is ensured by a timely and system-wide security check.
- Flexibility and quality. Thanks to e-procurement platforms, the accessibility of information, the analysis and verification of offers, and the timely management and control of tenders are much more flexible and effective. Furthermore, to reduce the margin of errors and facilitate the use of the platform, there is also a dedicated service desk able to provide operational and functional support in real-time [106–108].

4.3. Blockchain and Decentralisation

The blockchain is a shared and immutable database. It is defined as a digital register whose transactions are grouped into blocks, linked in chronological order, and cryptography guarantees its integrity [32]. The current size of blockchain networks is still limited but destined to grow over time. Therefore, the blockchain is comparable to a distributed database managed by a network of nodes (computers), each of which has a private copy containing identical information. Generally, the involved nodes do not know each other's identity. A shared protocol allows new blocks to be added to the "chain" to ensure consistency between the various copies. Each time a new block is approved-chained (consent), all nodes update their private copy. This structure ensures that no manipulation, modification or deletion of data is possible [16].

Thanks to the characteristics mentioned above, the blockchain can be conceptually compared to databases and registers managed centrally by recognised and regulated authorities (public administrations, banks, insurance companies, payment intermediaries, etc.), whose fundamental difference consists in being decentralised and immutable, thus representing a valuable alternative in terms of safety, reliability and costs [109].

A decentralised network (see Figure 3) can be considered the most suitable for integrating the existing ERP systems with a blockchain-based accounting shared ledger [28].

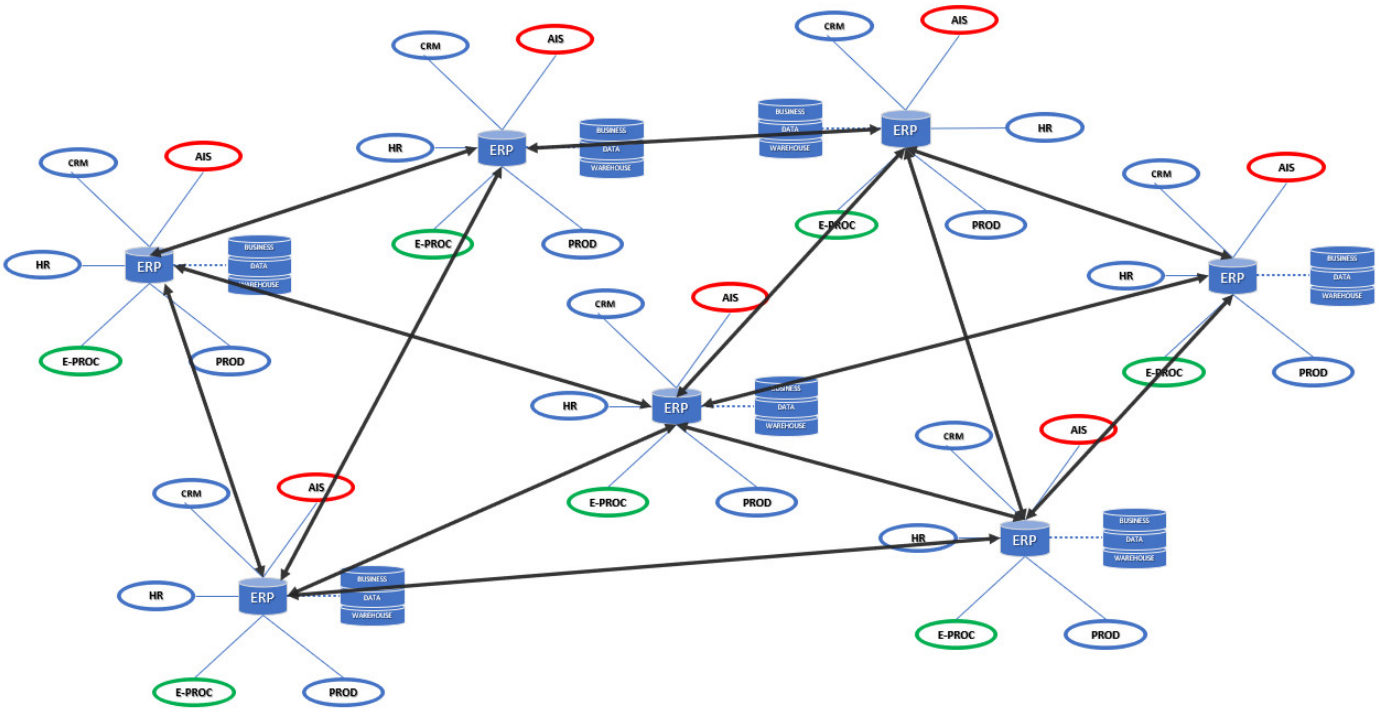

Figure 3. Decentralised Business Systems Network.

Accounting information systems (AISs) [SAP FI module] and e-procurement modules [SAP brand new module to be implemented] are expected to play the most crucial role in this integration process. Accounting information systems should include additional bookkeeping processes (i.e., hash axis and shared ledger). In contrast, e-procurement ensures digital signature processes, smart contract management and approval, becoming a critical joining link between centralised ERP system and decentralised business network (see Figures 4 and 5).

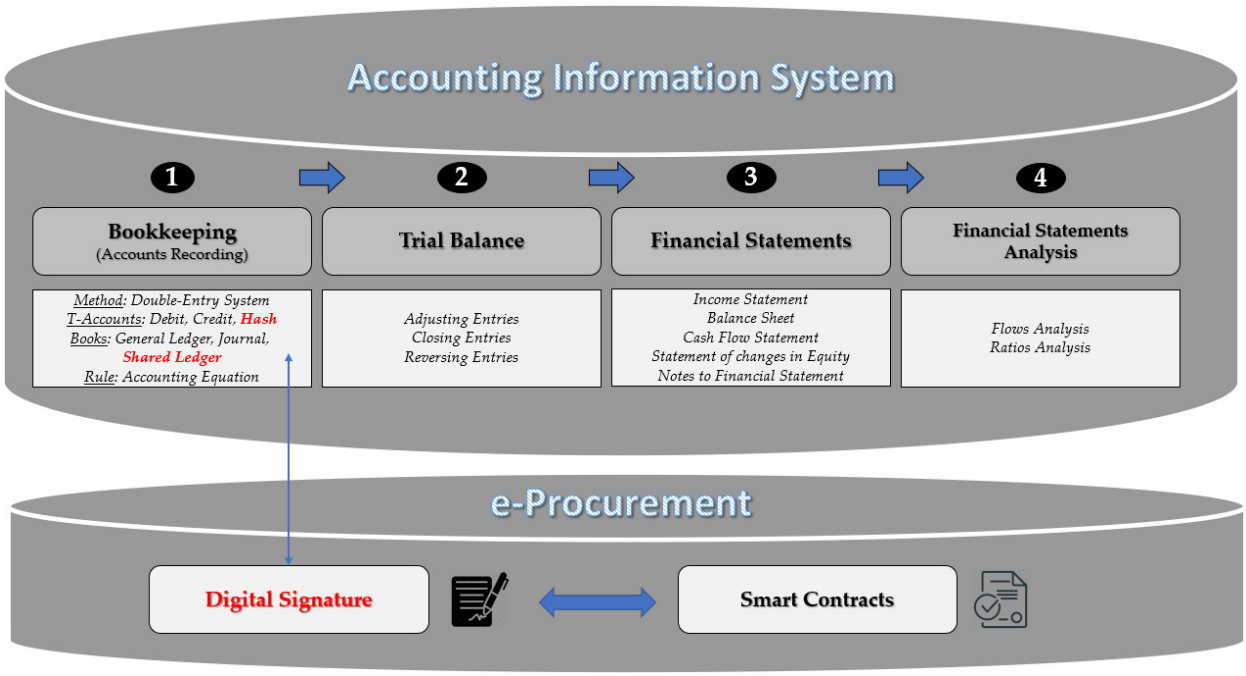

Figure 4. AIS and e-Procurement Processes Combination.

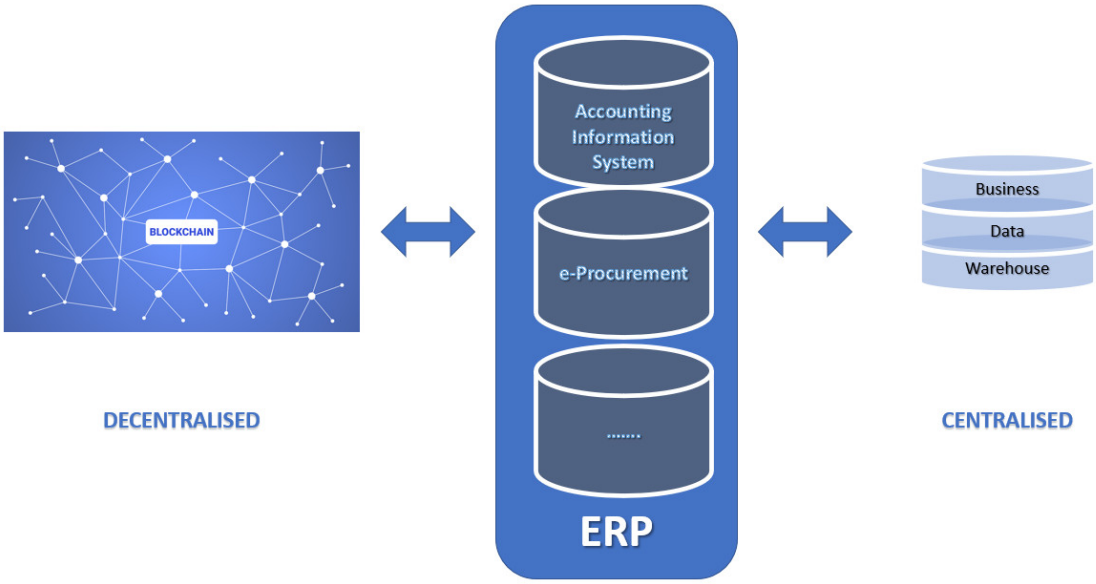

Figure 5. The ERP system pivotal role.

Smart contracts are often considered an essential part of advanced blockchain architectures since they can secure, facilitate and automate the effects agreed by companies and individuals that signed the contracts [110]. Smart contracts are programmed and stored on a blockchain and automatically execute when prearranged conditions are met without the need for any intermediary or further confirmation [33,34]. However, smart contracts approvals require digital signatures (preferably using smart cards, digital signature tokens, biometric devices) from individuals entitled to bind the entities that are part of the agreement [111]. Therefore, big companies should delegate this procurement step to ad hoc e-procurement departments, especially when the number of contracts to be signed is high. Furthermore, a specific e-procurement module (also in SAP) is highly advisable to (a) coordinate and possibly automate the smart contracts' management, (b) bridge the accounting transactions with an external shared ledger, and (c) ensure accountability, timely and smooth electronic signature processing.

4.4. Financial Technology and Decentralized Finance Applications and Integration

Identifying FinTech boundaries is challenging, given that financial technology is a relatively new industry [112]. However, the financial sector usually demonstrated proactiveness in using new technologies, leading economic transitions and facilitating transactions through new financial innovations [113]. Furthermore, the potential use of cryptocurrencies, payment systems and smart contracts, a better awareness of the financial markets, advanced and updated technology infrastructures, and the privileged intermediary role of financial companies can undoubtedly contribute to integrating blockchain AIS within the ERP systems [114].

In addition, cybersecurity is a significant concern in the financial sector [115]. Online fraud and attacks on major financial institutions are becoming more frequent, replacing the old thefts of gold bars and banknotes. The different dimensions of cybersecurity range from understanding possible threats, cloud space protection, identity and access management, mobile security, web security and fraud prevention. The blockchain is considered a suitable alternative to ensure transparency, accountability, security and safety in systems analysis and design. Therefore, the above designed decentralised network (Figure 3) could secure transactions, especially in the banking industry. Advanced cryptographic systems are the foundation of the payment systems, ensuring public trust, facilitating the transactions, turning the role of the financial intermediaries into an essential part of the economic growth.

5. Discussion and Conclusions

This paper tries to fill a gap in the academic literature but also industry practice. It is a theoretical effort to assess the integration of DLT and blockchain, particularly with systems, in this case, ERP and AIS.

Many authors support the co-existence of AIS and blockchain [27–30]. Blockchain applications in accounting, and consequently AIS and ERP, is rapidly changing, and it is becoming an emerging field of research. We present a literature review on this topic that, besides its contribution, further facilitates the rest of the analysis. Therefore, this research has applied scientific consequences for IT systems but also for management practice. DLT and blockchain applications through innovation transform technologies and scientific fields and can generate value for organisations and individuals.

The grounding hypotheses identified in the methods chapter has been validated through detailed analysis of the existing literature and consistently applied research in the field. It was possible to consider that ERP and AIS systems can benefit from decentralised architecture and blockchain in many ways. Indeed, business-oriented solutions always require improved security and privacy, immutability, trust and speed, and these features are the main strength of DLT systems. E-procurement can facilitate integrating ERP and AIS systems through automation (possibly also using smart contracts) and limiting paper-based processes. Systems integration will also ensure efficiency and savings in terms of costs and time.

There is considerable value created and benefits resulting from blockchain applications on ERP, AIS and, in general, the broader use of FinTech. We find evidence that there are benefits from reduced procurement time and efficiency; IT automation and productivity; costs reduction; security, reliability and safety and flexibility and quality. All these benefits can result in value creation because they enhance existing scientific applications and, most importantly, result in the discovery and enable innovative applications. In addition, there can be benefits from the integration of DLT with AIS and ERP systems, mainly through various efficiency gains.

There is not much literature on a specific application to justify and, most importantly, assess if specific applications can facilitate integrating ERP and AIS systems. We test this hypothesis by evaluating the case of e-Procurement. E-Procurement is a popular and widely applied module, and therefore the findings can be generalised under certain circumstances. Finding support for the integration between accounting information systems (AISs), ERPs and blockchain applications is the main theoretical contribution of this research. Blockchain applications in e-procurement can facilitate AIS and ERP integration except for the benefits discussed above. The core modules of any ERP are usually designed as centralised frameworks, and distributed ledger technologies (DLTs) and DeFi can overcome some limitations of centralisation.

The principal DLT application is blockchain. Implementations of the blockchain in accounting have been studies so far but not yet widespread. This work also demonstrates that the e-procurement department and its information technology (IT) application can improve operations and integration between AISs and blockchain, DLT-based systems and accordingly result in significant benefits. Another research implication suggested by this study is that Financial Technology (FinTech) could become the leading industry for transforming and integrating various management services and applied sciences, such as IT technologies. This integration can lead to the DeFi framework and applications that could benefit from the most valuable advantages: transparency, security, accountability, traceability, and other efficiency gains.

Blockchain and its applications in numerous fields are continuously and rapidly changing, so continuous update with the latest technologies and applications is critical. Moreover, there is a high level of complexity, and technical details concerning this field of knowledge and future research should find ways to categorise and examine this scientific area. The paper uses a specific application, e-procurement. However, this is only one

module of ERP and AIS systems. Future research should examine other modules and subsystems and how they can be integrated with DLT. In addition, future research could further evaluate and empirically assess the benefits of integration. Moreover, this is a rather theoretical paper, and future research could test the implementation and performance of this and similar applications. Finally, future research could analyse innovation in all of the above key areas, accounting, DLT, ERP and AIS and assess how systems and applications could be transformed.

6. Limitations

The main limitation of this study is the lack of empirical data. Indeed, the research focus is (itself) limited to the design and analysis of the systems rather than their empirical examination. We provide a theoretical study of AIS, ERP and blockchain applications, but further work is required to test this system. In particular, the ERP and SAP architecture are another limitation is the scope of the case study. E-procurement is employed because it is a widely used application that is also gaining in popularity. However, it remains a module in the ERP and AIS systems.

Further research is required to examine if the integration and application of blockchain can be implemented successfully in other modules of the ERP. The literature on blockchain is an emerging and continuously expanding field of scientific knowledge. However, for our analysis, we focused and limited on the accounting and management applications of DLT.

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