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Adapting Blockchain Technology in the Wine Industry to Curb Wine Counterfeiting

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Abstract

The need for a blockchain-based wine supply chain traceability system is now critical because of a surge in forging and adulteration, and the utilization of additives and dangerous synthetic compounds. To defeat these issues, the wine industry needs a traceability system which empowers a buyer to confirm each batch of wines from the grape growers to the retailers. However, the vast majority of the current traceability frameworks are RFID and web based, and consequently it is conceivable that stored data may be counterfeited as well. This study proposes a blockchain-based wine supply chain traceability system where each and every transaction is recorded as a block in the chain and is visible to the relevant participants. These blocks of information are immutable, that is unchanging, since any change to the recorded information will break the chain. In addition to providing quality information and a detectability management framework, the proposed traceability system enables safety, transparency, and security in the overall process from the grape to the bottle.

Keywords: Wine supply chain; blockchain; traceability; transparency

Introduction

Modern wine supply chains are tightly structured, global and interconnected. To verify the overall process from sourcing raw materials to selling wine to consumers, a number of traceability systems and standards have been developed to automate some supply chain activities. However, despite considerable attention on the traceability area of these supply chains, the statistics show a rapid increase in wine counterfeiting (Biswas et al., 2017).

In lay terms, wine counterfeiting occurs if wine is made in unlicensed distilleries or in people's homes to be sold; packaged to look like well-known brands; or contains chemicals, such as screen wash, cleaning fluids or nail polish remover (Food Standards Agency, 2017).

This situation can be considered as fraud or corruption. It does not just steal potential revenue. It poses threats of deteriorating alcohol quality, unfair competition, death, diseases, job losses, financial losses for businesses and tax losses for governments, and thereby, a reduction of general welfare (Swahn, 2019). It also fundamentally damages brand positioning and undermines the value of the real wine, by allowing consumers to get the premium product without the premium prices or customer experience (Wilcox, 2009).

Like any market, counterfeiting exists because of supply and demand: forgers who will produce and deliver, and purchasers who will purchase. On both sides, counterfeiting flourishes for a similar reason: fake products look like real and genuine products, but at a fraction of the price. Shoppers who intentionally buy fake items are unlikely to have purchased certified and genuine counterparts and frequently do so in light of the fact that the fake adaptations are a lot less expensive. This implies that authentic organizations face contenders that steal their intellectual property (IP) without paying taxes or agreeing to the guidelines and quality principles that the former do. So it is a governance failure issue, not a market failure one. Yet a clear and actionable understanding of the motivations underlying consumers' purchase of counterfeit luxury brands remains elusive (Wilcox, 2009).

In 2018, INTERPOL, the International Criminal Police Organization, claimed that counterfeit alcohol is a top concern globally. It accounts for almost 5 per cent of the current secondary market worldwide that would amount to $US15 billion dollars (INTERPOL, 2018). The size of global wine consumption has skyrocketed to 246 million hectolitres in 2018 (Statista, 2020). Counterfeiting is not limited to super-high-end wines. Even small, relatively inexpensive labels are also at risk (Swahn, 2019). Furthermore, it has affected prominent wine-export and import countries (Table 1).

Table 1. Some countries affected by wine counterfeiting

Australia	Europe	USA	China
In 2018, owing to counterfeiting issues, YPB Group Ltd reported a post-tax loss of $AU4.3 million in the $AU2.8 billion Australian wine industry.	The European Union Intellectual Property Office (EUIPO) estimated that wine counterfeiting costs the region €2.7 billion in direct sales each year, a 7 per cent reduction in sales, and the loss of over 7,000 jobs.	In 2017, the Namibian Customs Agency uncovered $US1.5 million of counterfeit liquor brands. The shipment received at Walvis Bay, Namibia originated in the United States, indicating that there is a major counterfeit alcohol enterprise operating that has access to a United States Port.	In 2002, wine counterfeit activities comprised 57 per cent of the total amount of wine (400,000 tons) sold in China annually. This proportion has since risen, and it is now estimated that over 70 per cent of wines sold in China are not original.

Source: (The Sydney Morning Herald, 2018; INTERPOL, 2019; VINEX, 2019; SafeProof.org, 2017; Shen, 2018)

Currently, barcodes, radio frequency identification (RFID), Quick Response (QR) codes, Electronic Product Codes (EPC), EPC-global, and wireless sensors are the technologies used in the wine industry to track objects and business activity. But three major problems have been identified with these technologies (Li, 2013):

- ***No end-to-end security (encryption):*** It means there is a lack of communication using codes to prevent unauthorized access.
- ***Easy to replicate:*** The information is retrieved manually. Hence, it is easy to reproduce or forge the information at any time.
- ***Poor authenticity of the source information:*** Because information is stored in a central database, having no end-to-end encryption, the whole custody of the supply chain remains unknown.

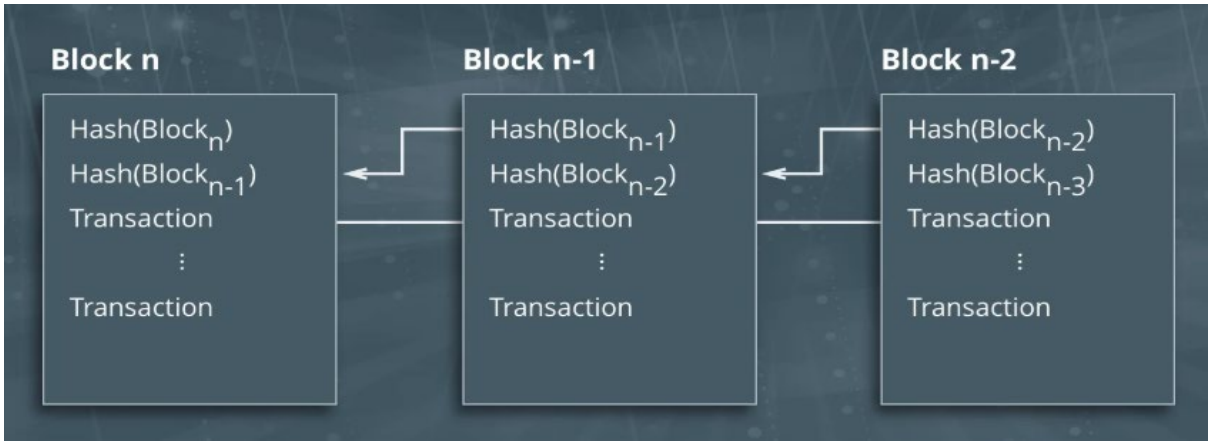
Thus, the wine industry needs a new solution which involves a high-tech encryption to ensure authenticity and provenance of every bottle of wine it produces. To address this challenge, blockchain can bring more efficiency and resilience to the process. The benefit which comes from the technology adoption is an improvement in chain governance that addresses the significant cost issues (financial, health, public safety, brand etc.).

What is Blockchain?

In simple terms, it is a modern version of a record-keeping system. When we say "block", it means digitally storing information of any transaction that could be in the form of a contract, agreement or sales. For example, in a sales transaction, information like the date, place, time, product details, participants involved in the transaction and payment procedures would be stored (English, 2017)[1].

Blocks store information using a unique code called a "hash". This distinguishes them from other blocks (as shown in Figure 1). Hashes are cryptographic codes created by special algorithms. These are used to trace back all related information and the data flow from the retailer to the producer (Investopedia, 2020).

Figure 1. Confirmation of a transaction in each block formation



Source: CoinTelegraph.com (Proof-of-work)

The network can be public and accessible to any person in the world or it can be private with restricted membership (Jiang Duan, 2020). This means the stored transactions could be seen and verified by relevant participants, which further makes it interconnected. In addition, once information is stored in a block, it cannot be changed in any way. This makes it immutable and tamper-proof (Motta, 2020).

Since the blockchain stream is immutable, counterfeiting and re-labelling would not be successful in the proposed system. Therefore, blockchain technology can resolve the issue of data tampering and ensure the credibility and transparency of the wine supply chain traceability system.

The reason behind suggesting this technology is because of its special security system which until now has not been seen in any other technology. It hinges on strong cryptographic schemes that verify and chain together every block of transactions. An attacker would have to compromise 51 per cent of the systems to surpass the hashing power of the target network - a computationally impractical and unfeasible task to tamper with transactions stored in a blockchain. Hence, it provides benefits of

[1] Appendix 1 provides a glossary of this terminology. Appendix 2 reports some usual myths regarding blockchains, and explains in a more practical portrayal of the circumstance for each one of these issues.

security, immutability, information authenticity, traceability and transparency in the supply chain (Jiang Duan, 2020; Banerjee, 2018).

The aim of this review is to understand and investigate how blockchain could be used in the wine supply chain area, and how it could help to address current wine security issues. Although some previous researchers have introduced the idea of integrating blockchain technologies and wine supply chains, those discussions of a blockchain-based traceability system have been from a theoretical perspective. Therefore, this review aims to fill this gap by taking an implementation perspective, focusing on the current situation in the Australian wine supply chain and how it could become more transparent through the use of blockchain technology.

To investigate this concept, this paper thoroughly reviews the blockchain technology, and then considers its functional applications in food supply chain management. Some benefits are presented, such as improving traceability efficiency, improving supply chain transparency, but there are also challenges, including scalability, lack of legislation, and immature technology. Finally, the paper concludes and discusses future research directions.

Literature Review

In this section, a case study on tuna fish organization is discussed. This industry has implemented a blockchain system in a real-world case scenario in the agri-food sector, i.e., they have (self-)reportedly passed the "proof-of-concept" stage. Four other case studies have also been identified: Ambrosus (olive oil tracking); OriginTrail (Celeia Dairy); TE-FOOD (pork meat traceability); and FoodCoin (global market of food and agricultural products) (Motta, 2020). They all exhibit diversity in their application areas and in the use of the blockchain technology.

"Provenance" blockchain tool for tuna tracking and certification

Indonesia is the largest tuna-producing country, so it is an ideal case for assessing opportunities to drastically increase transparency in fish and seafood supply chains. Due to a number of illegal and unregulated practices happening in the seafood industry, a coalition of the National Oceanic and Atmospheric Administration (NOAA), customers, governments, NGOs and businesses called for more information from the tuna supply chain about the product origin and social standards of fish and seafood products (Food Safety News, 2016).

This interest caused fishing organizations to come up with a blockchain technology tool namely Provenance. This application is designed to link identity, location, material attributes, certifications and audit information with a specific item or batch ID. The data is stored in an immutable and globally-auditable format which protects identities by default, allowing for secure data verification (Project Provenance Ltd., 2013). Its operations are divided into three phases.

Pilot phase 1: Registration and data collection

The local fishermen send simple SMS messages to register their catch, thus issuing a new asset on the blockchain with each SMS. Accompanied by irreversible, unique IDs, the resources are then moved from fisherman to supplier along with the catch, in both physical transactions and in the digital register on the blockchain. Now, the assets initially possessed by the fishermen become connected to the suppliers. The identities of the fishermen are saved forever in the list of past proprietors held on the blockchain.

At the point of fish catch, the social and environmental conditions for the fishermen are verified through trusted local NGOs, whose audit systems approve their compliance to a common norm, resulting in their eligibility to participate in the Provenance-validated chain of custody (Project Provenance Ltd., 2013).

Pilot phase 2: Linking the blockchain with existing systems

To ensure trust in a system, there should be a single source of truth (SSOT) for each piece of information. In this framework, the blockchain functions as the SSOT for checking an entity's identity, their background profile, as well as the legitimacy of any certification or attribute they guarantee to have.

A unique ID in a system takes the form of an address on the blockchain and allows any entity to access details about that particular item. It is thus interoperable by default. So, when raw materials are processed and turned into new products, all the participants get the updated information. This application also uses mass balancing to account for the amounts of ingredients used in the transformation (Project Provenance Ltd., 2013).

Pilot phase 3: The consumer experience and building an interface for trust

The clutter of traditional printed communication is being replaced with Provenance online stories and journeys, accessible via in-store tablets and customers' smartphones. By scanning the product, customers can see stories for every item range, see the makers and providers engaged with cultivating or preparing. This framework engages a new era of more conscientious, trusting consumers ready to pay more for products with proven origins (Project Provenance Ltd., 2013)**.**

A diagrammatic representation of such a tuna chain of custody is shown in Figure 2.

Wine supply chain communication system

The case study described above has provided knowledge that could be used to imitate this structure in the wine supply chain. However, before going further, the current operation of the wine supply chain has described and deductions made about how it could be benefit from blockchain (Figure 3).

Presently, actors in the wine supply chain are dealing with the following issues:

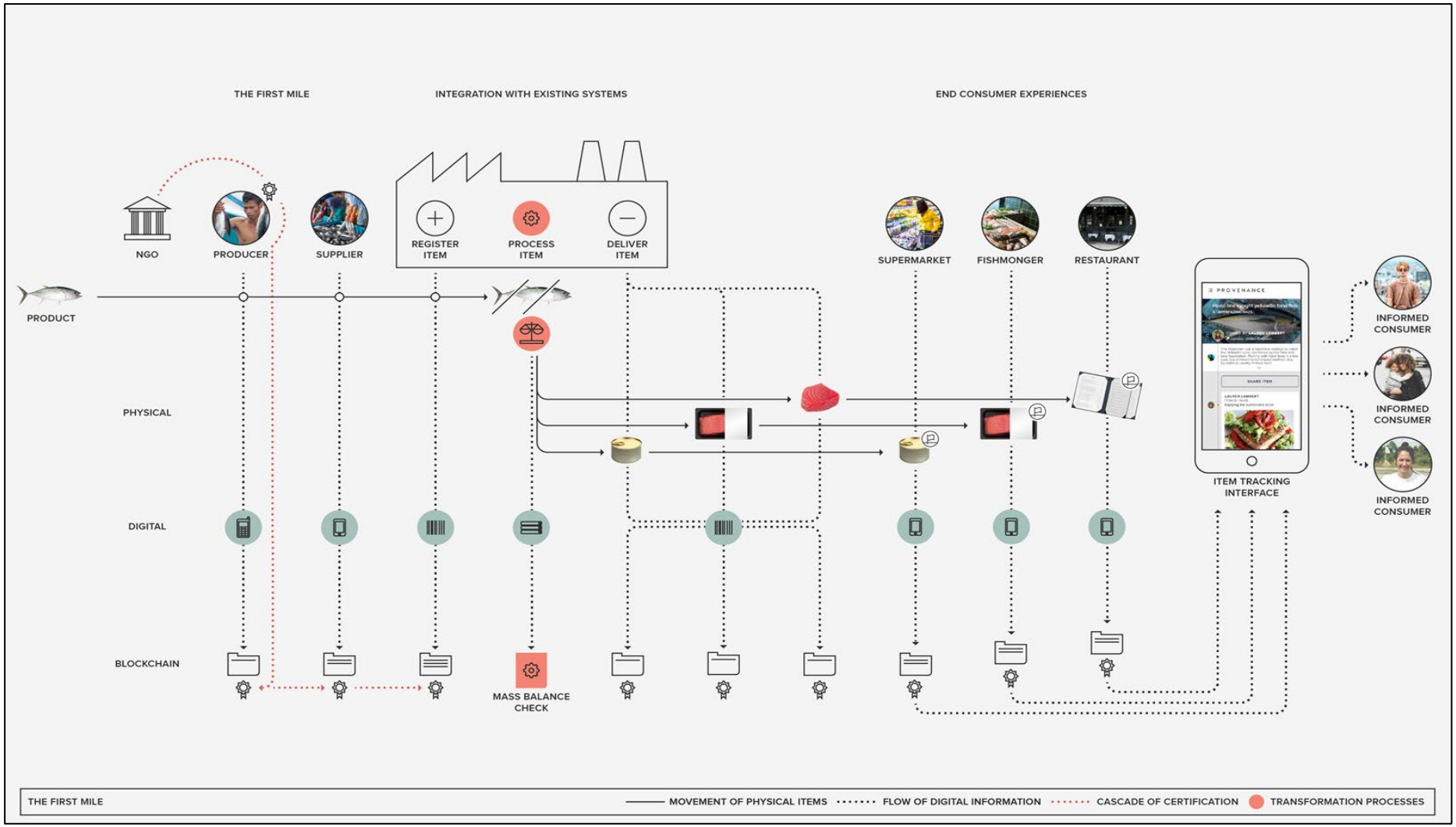
- ***Informal contracts***: Many farmers and wine producers tend to conclude business with a hand shake, i.e., proper contracts seem not to be needed. This makes them inaccessible to professional platforms for selling their products (Saglietto, 2016).

- ***Paper-based system***: When it comes to collecting information, technology does not play a big role. The current system is traditional paper-based and a lot of wineries use spreadsheets to record data for compliance or certifications (Saglietto, 2016).

- ***Time consuming audits***: Due to time, and cost constraints, government auditors do not investigate the whole supply chain (Saglietto, 2016).

- ***Ineffective communication***: There is a lack of communication coordination between all the actors. The wine producers do not attain sufficient feedback or specific information about sales and price from the distributors. The communication with retailers and end consumers is virtually non-existent for them (Saglietto, 2016).

Figure 2. Blockchain-based tuna supply chain

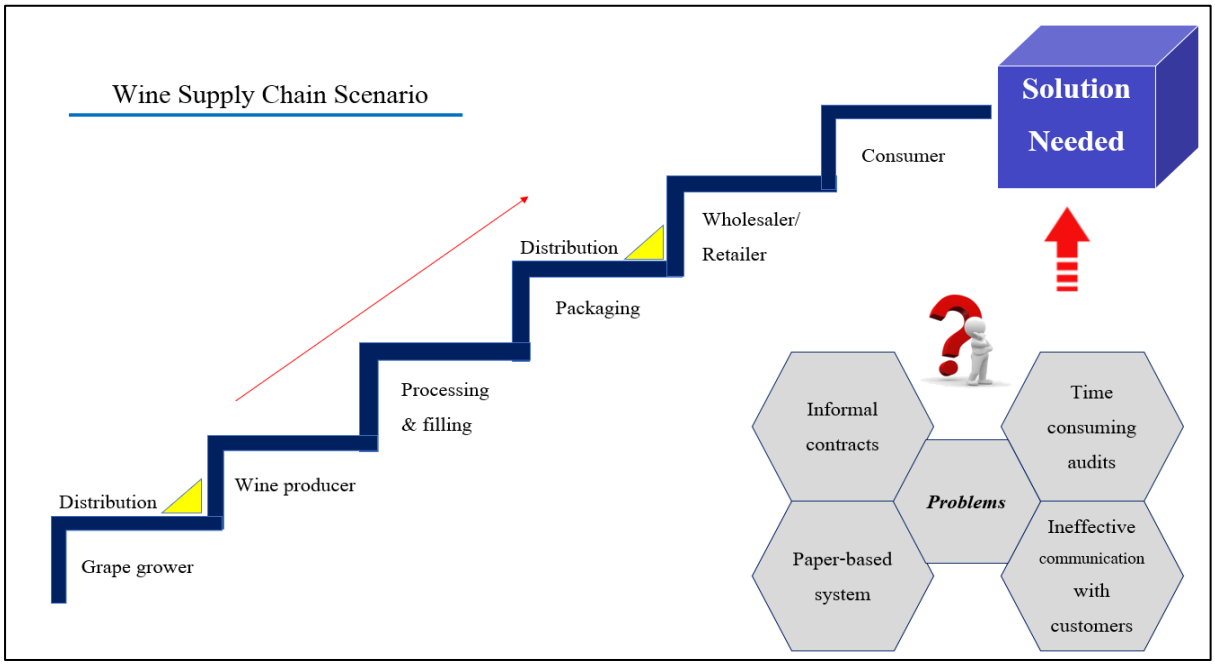


Source: provenance.org

These issues combined form a problem of "information asymmetry". It is the situation in which one of the two parties to a transaction is better informed than the other. One of the best-known applications of information asymmetry in economics is the principal-agent problem. It causes communication risk that appears in every phase of the wine-making process.

Due to the complexity of the wine-making process and the number of participants involved, blockchain technology would help to decrease information asymmetry. This technology ensures that all project participants have access to all the information exchanged between them over the duration of the process. It can thus radically reduce information asymmetries and secure more trustful relationships between project participants (Treiblmaier, 2018).

Figure 3. Current scenario in wine supply chain



Source: Saglietto (2016)

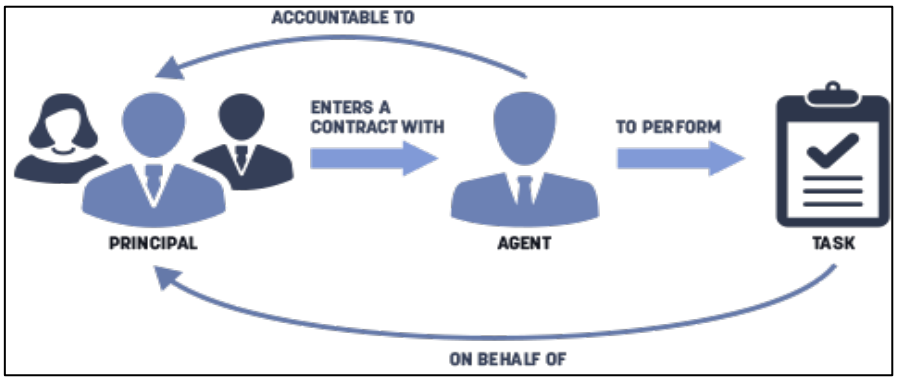
Theoretical Framework

A range of theories, such as transaction cost theory, network theory, resource-based theory and principal-agent theory, have been used to validate blockchain usage in different supply chains. Although there are range of different ways we could think about the solutions in terms of theory, if we look at the information asymmetry problem which most of these issues point to, the principal agent theory seems appropriate (Slack and Rowley, 2004; Treiblmaier, 2018).

Principal-agent theory

To simplify, take person A (a manager of a company) and person B (the manager's subordinate). When person A delegates a specific task to person B, person B holds an authority and the knowledge of that task. As a consequence, person A lacks knowledge in it. This creates an information asymmetry. As per Figure 4, person A is the principal, and person B is the agent (Corporate Finance Institute, 2015).

Figure 4. Principal-agent theory

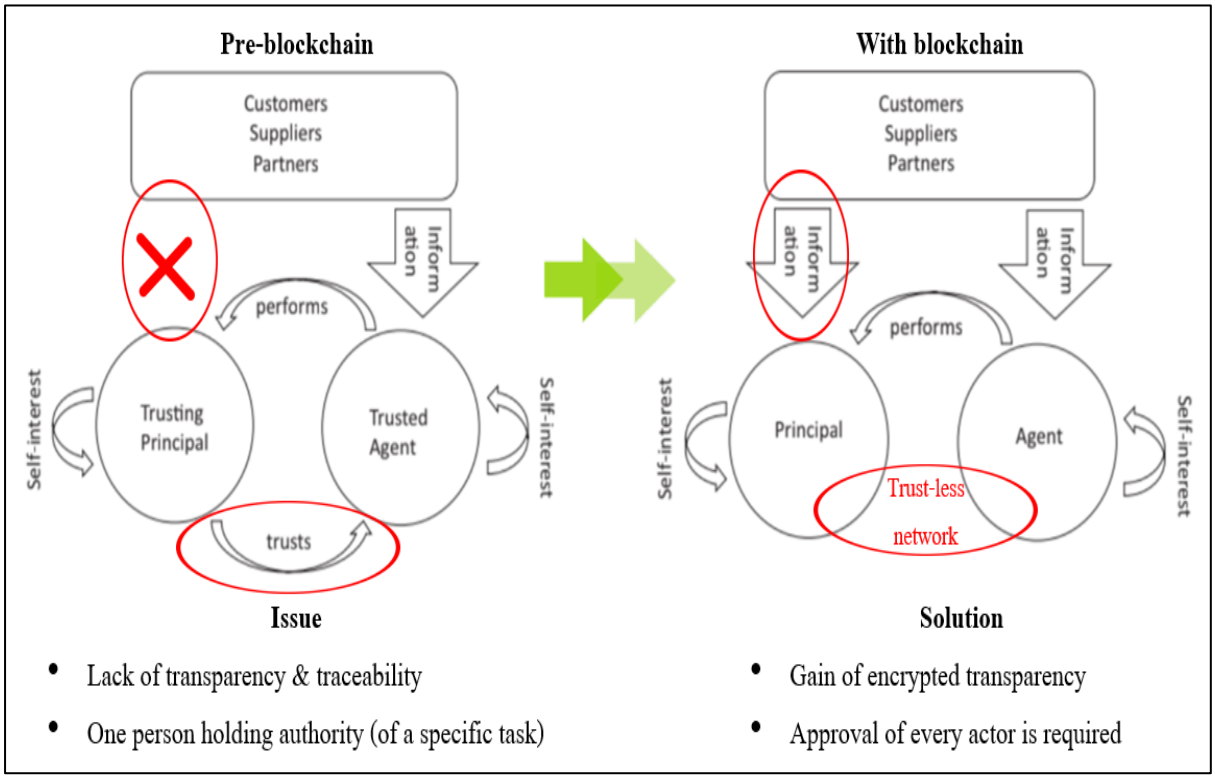


Source: Corporatefinanceinstitute.com

Blockchain execution in the Principal-agent Theory

As predicted by the theory, there is an assumption that the agent will naturally act according to self-interest and the principal has to trust that the agent will pursue the principal's interests, which may require the establishment of trust mechanisms and control systems at additional cost. But in a blockchain-based scenario, information flows are transparent and accessible to both the parties (as shown in Figure 5). As a result, the need for trust vanishes (Treiblmaier, 2018).

Figure 5. Blockchain execution in Principal Agent Theory

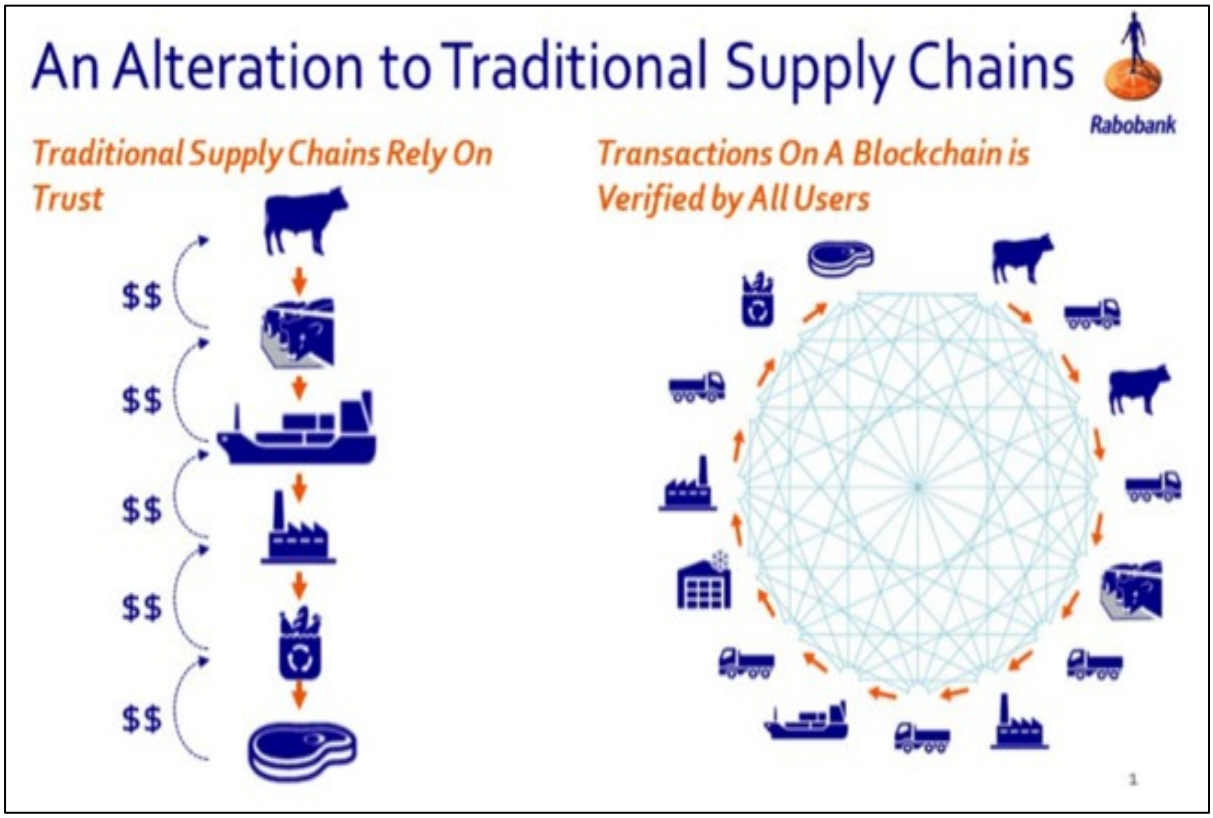


Source: Treiblmaier (2018)

This principal-agent theory has been implemented in a beef industry blockchain case study by Rabobank Australia (2018) (Figure 6). In this case study, Rabobank offered several insights into how the digital technology is already being applied to agriculture, and the potentially transformative role

it could play in Australian beef supply chains in future. In Figure 6, the flow of information on the left side supply chain depends on trust from stakeholder to stakeholder. This means that information can still be altered along the way. But in a blockchain model on the right side, the supply chain is decentralised with all the stakeholders connected with each other, and hence creates a trust-less network (Rabobank Australia, 2018).

Figure 6. Case study on blockchain-based beef supply chain



Source: Rabobank Australia (2018)

Solutions to the Key Issues

A number of potential issues in the wine industry that could be addressed using blockchain technology were listed earlier. These issues combine to form a problem of information asymmetry. This problem impacts the wine industry in two ways as explained below. These impacts are then matched to two powerful traits of blockchain that are helpful and needed in the wine industry.

Updated data consistency issue

In most supply chain systems, business partners communicate electronically using EDI (Electronic Data Interchange) or similar messaging standards. Although this allows automated processing of incoming data and reduces delays, it does not guarantee (updated) data consistency. As information flows follow the movement of the goods, updates are not propagated downstream to all the participants in the supply chain. This makes it difficult to share accurate and up-to-date information to ensure consistency among all participants in the supply chain (George Feuerlicht, 2015). The costs are high. Boston Computing Network (2014) estimate that 60 per cent of companies that lose their data get shut down within six months of the disaster.

The blockchain trait which addresses this issue is the "Data Replication" concept. This involves sharing information (distribution) so as to ensure consistency between records. It also utilizes redundant copies of information to prevent against unintentional data corruption (English, 2017). By making multiple copies of data and storing them at different locations, it helps in improving overall accessibility across a network. This action provides several types of benefits: improve the availability of data, increase the speed of data access, enhance server performance, and accomplish disaster recovery (Karamat, 2016).

Lack of trust in a network

In supply chain systems, a record of a transaction is broadcast to actors on both sides of the transaction. Each actor records this transaction message and then passes the message onto the next actor in the network, and the process continues until all actors in the network have recorded the message. However, issues arise when messages take different paths (as they propagate through large networks) and consequently arrive at different actors at different times. It could be due to technical failures causing some actors to be unable to forward the message and the message may be lost. This problem creates traceability issues in information processing through network (George Feuerlicht, 2015).

To resolve such an issue, blockchain uses its "proof-of-work" trait to examine a transaction and make sure that the information contained in each block is accurate. For these efforts, they receive a reward. So, if you are paid $10 for an item, you recognise the value of that currency, and you are confident in it since it is supported by a Reserve Bank or equivalent. These establishments act as guarantors of the value of the currencies they print.

Similarly, the "proof-of-work" protocol does the same for cryptocurrencies. The computational and network power behind the transactions match them with its authentic source using complex mathematical and algorithm riddles. And for each successful transaction, a reward has been received in the form of transaction fees and the transaction has been added to the immutable blockchain.

All of this happens in spite of the fact that there is no central institution backing it. It allows for trust between unknown parties because they share a confidence in the veracity of the consensus protocol. Therefore, by ensuring that the data contained in the blockchain is trustworthy, this technology creates a trust in a trust-less network (English, 2017; Tar, 2018; Heal, 2018).

A Blockchain-based Wine Traceability System

Through the literature review, the case-study approach, and an assessment of relevant theories, information regarding possible blockchain approaches and how these are being implemented in the agri-food industry have been gathered. Using this information, a similar kind of blockchain-based wine traceability system can now be proposed. It would have three parts.

Key management elements

The successful operation of a blockchain system relies on the following key elements (Staples, 2017):

- Appropriate integrity criteria to be checked for each transaction (and block);
- The correctness of the system's software and technical protocols; and
- Strong cryptographic mechanisms to identify parties and check their authority to add new transactions.

To make these key elements work, the following steps are mandatory:

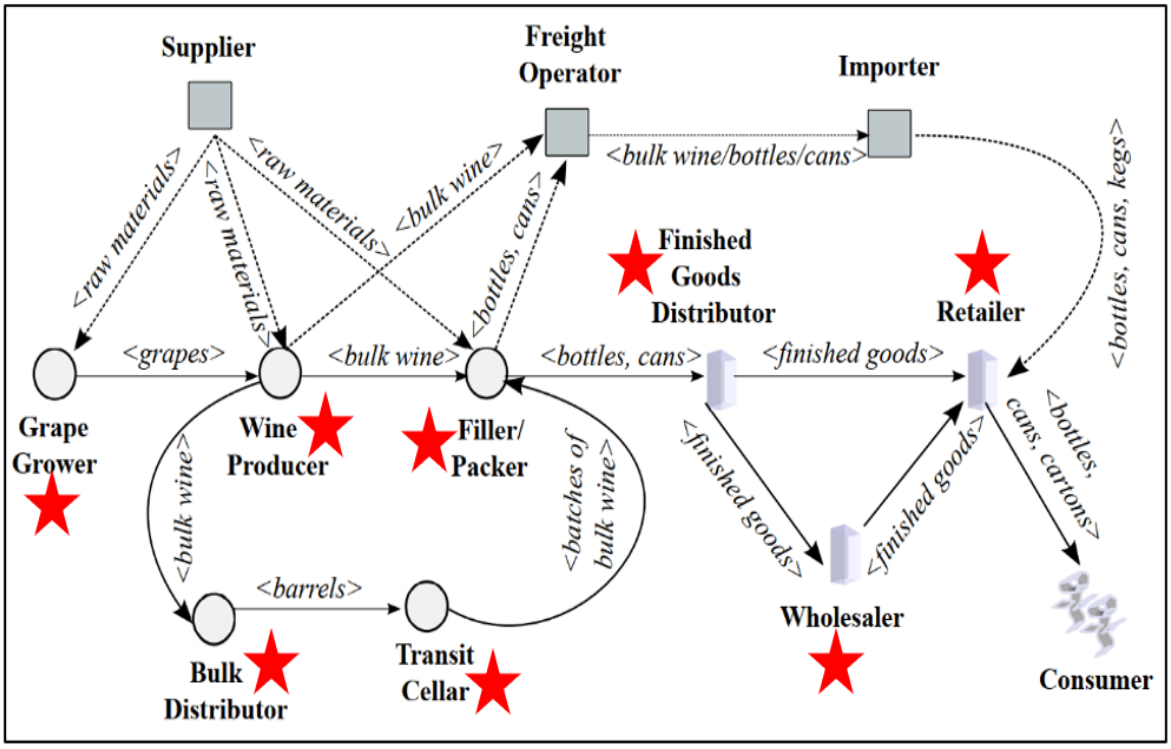
Smart Contract: This is a self-executing contract with the terms of the agreement between buyer and seller being legitimately composed into lines of code. The code and the agreements contained therein exist across a blockchain network to automatically control the transactions execution. To begin with, a contract should be made having all the rules, procedures and information of each actor. When a transaction meets the requirement of a contract, it automatically gets processed. Government regulators and auditors can watch the on-going activities anytime anywhere (Rosic, 2019).

Pin generating: It is expected that some data that is critical in a wine supply chain traceability system, such as company's special wine making techniques, are also commercial-in-confidence and must be kept hidden. To guarantee the confidentiality, a common secret key pin is pre-conveyed among all actors and must be shared with all other participants (Banerjee, 2018)**.**

Building the blocks

This proposed system will focus on eight main entities of a generic wine supply chain model for the sake of simplicity. It includes the grape grower, wine producer, filler/packer, finished goods dispatcher, transit cellar, wholesaler, and retailer. Figure 7 represents the data flow of each entity in this simplified chain. The data would be collected and then stored in blocks in terms of: what output has been generated by each entity, and how the commodity transactions are taking place.

Figure 7. Actors in the wine supply chain



Source: Biswas et al. (2017)

The supply chain starts at the vineyards and the grape grower generates the first block and adds the required information. The block is first verified by all the participants before the next block is added to the chain. This procedure would be followed until all the entities include their transactions in the chain. Required information by each (selected) actor is outlined as follows.

Grape grower: Farmers deal with the plants and control the growth and development parameters (corrosiveness and soil compaction, temperature, humidity, and so forth), and implement protection from weeds and insects as required. To correctly enter the data on weather, soil conditions and other parameters, a network of detecting sensors would be used.
Data collection includes:

- Farmer's profile, the land plot (location, height, type of soil), grape types, their origin, irrigation, handling and processing. Here it is imperative to consider everything: from what fertilizers were utilized to when and how the grape was cut.
- When harvesting, data about the date of harvest and how the grapes are delivered to the winery are entered into the system.

With such a data set, data science could be utilised to improve grape quality or wine quality (Biswas et al., 2017; Musienko, 2020).

Wine processor/maker: These are the people and companies involved in the production of wine. To ensure traceability, such entities must add to the blockchain. They would add:

- Information on suppliers, grape type(s), raw materials receipts and its quality, data on the delivery.
- Records of internal procedures, such as decantation, fermentation and preservation, as well as aeration in the production of rose wine.
- Data on temperature, chemical content and added substances or additives.
- Data on production spill and storage conditions.
- Information about yeast and its use (Biswas et al., 2017; Musienko, 2020).

Filler + packer: Their responsibility is to receive the bulk wine from the wine makers and pour it into barrels, kegs, bottles or bags. At this stage the goods are identified and labelled. For the correct use of the blockchain, it is important to ensure that each product has been allocated its (scannable) unique ID which also provides the consistency of labelling between different market participants (Biswas et al., 2017; Musienko, 2020).

Finished product dispatcher: These actors are responsible for receiving, storing, shipping, processing, sampling and analyzing bulk wine. In fact, the role of the dispatcher is similar to the role of wholesale distributors, the difference is in minor and specific details of the logistics chain. They could contribute to blockchain by providing:

- Information on product receipt, details on the storage and transportation conditions.
- Documents on processing, sampling, analysis of bulk wine and the date of dispatch.
- If the blending process is performed, this is also recorded in the blockchain (Biswas et al., 2017; Musienko, 2020).

Transit cellar/distributor to wholesalers/retailers: The duties of the distributor include the storage and shipment of finished packaged products to points of sale, as well as inventory management. To do this, the item is usually repackaged and remarked in large batches. Following data needs to be reflected in the blockchain:

- Reception date, date of shipment, and storage conditions.
- Repackaging and remarking IDs.
- Details of the destination of the goods (Biswas et al., 2017; Musienko, 2020).

Wholesalers: Their duty is to receive and store wine boxes and pallets and send them to retail stores when ordered. At this phase, the blockchain gets data regarding product's receipt, storage and delivery of goods, most of which is collected automatically using sensors and RIFT tags. These gadgets screen temperature, shaking, and other data that may affect product quality. Data about the

conditions of storage and transportation needs to be reflected in blockchain because during transportation, wine deteriorates due to non-compliance with temperature regimes or excessive shaking (Biswas et al., 2017; Musienko, 2020).

Retailer: The retailer receives finished products in the form of bottles, cans, barrels and cardboard boxes and sells them to final consumers. The retailer is responsible for displaying information about goods received, their storage and sale. The sale must be logged in the system so that the same identification tag cannot be reused (Biswas et al., 2017; Musienko, 2020).

Customers + Auditors: At last, end users can quickly and easily obtain information about the wine and its origin. It may be necessary to develop a mobile application which can be used together with a QR code located on a bottle of wine (Biswas et al., 2017; Musienko, 2020).

Trace back capability

One of the critical features of the proposed traceability framework is that the originator of each individual wine bottle can be detected. Since each product is allocated a unique ID, the purchaser can view the full information flow and related data by inserting the ID in the system. Moreover, the details of any sold wine are recorded in the blockchain, hence, it is unimaginable to expect to sell a similar item twice. In this manner, the proposed framework makes wine forging unfeasible. Here it is assumed that each crypto-block is always associated with the physical product. The validation of this is provided by the "data replication" and "proof-of-work" properties of the blockchain mechanism. Figure 8 shows how traceability table would look (Lucena, 2018; Biswas et al., 2017).

Figure 8. Wine product traceability format

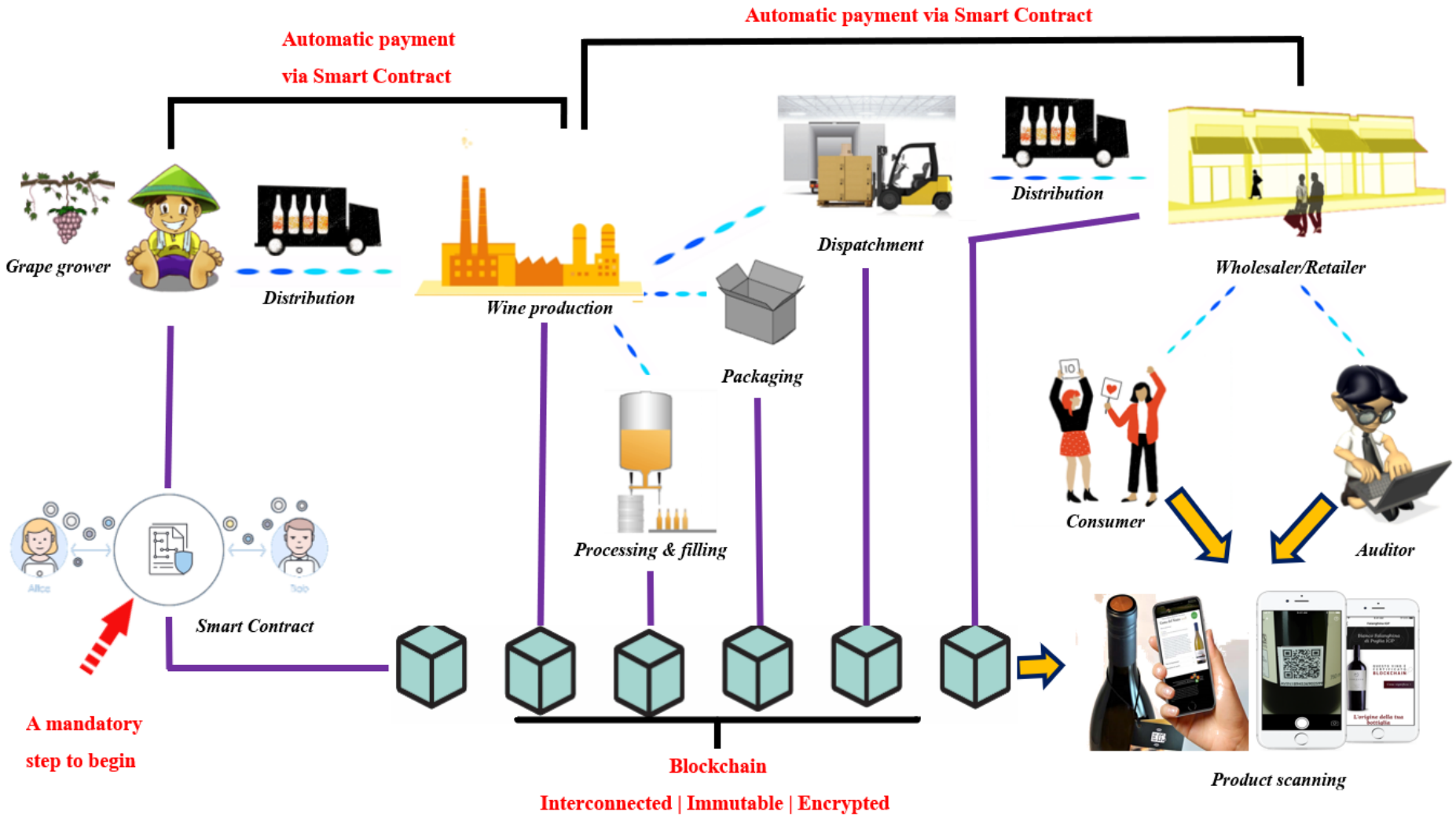
Time	Key	Value	Raw Data	Publisher	Transaction
2017-01-23 17:32:05	WineBottle001	ID: R001 Wine Bottle ID: WB001 Sold: 01	40 bytes	1MH272bjRNPVyrBxYTiVcV8mHcPSYQ9HTgfafX	5430f1366d...
2017-01-23 17:28:39	WineBottle001	ID: F001 Bulk Dist: BP001	26 bytes	1FHy38PAbrrVJxG5E3JAUxCZikyhrvAdiqLPzm	bfde181595...
2017-01-23 17:26:15	BulkWine001	ID: BD001 Wine Producer: WP001	31 bytes	1Yy1kqdze4QWgPi98jawsbPrcuSZ6GtwNbRUY7	0ea3780dec...
2017-01-23 17:22:27	BatchNum001	ID: WP001 GrapeGrower ID: GG001	32 bytes	1Kje8XUz6UVEE6NC1AD62VP5GaQYSqNsGShX3f	d60a4e3714...
2017-01-23 17:10:00	GG001	ID: G001 Origin: ABCD Type of Vine: XYZ Treatments: PQRST	60 bytes	1Xu7g5MohahCFHaMcismkKNFAC5P5vFGNPxjgE	0017839a4a...

Source: Biswas et al. (2017)

System security

What if the data in the system is tampered with? Every entity that is involved with the creation to the selling of the wine are recorded as a block in the chain and are made visible to every single pertinent member. On the off chance that any actor in the chain even attempts to alter the chain, all the interconnected individuals would know of the tamper. For every block of data added, it is confirmed by other actors and gets synchronized with their recordings and accounts. The transparency in the approval of the block data makes the system credible. Any additional change in the block gets

Figure 9. Blockchain-based wine supply chain



approved only if all of the participating entities validate the transaction, otherwise it will not be considered finalized and legitimate (Future Wine Expo, 2019). The whole blockchain-based wine supply chain flow chart has been shown in Figure 9.

Expected Benefits

Greater transparency

Blockchain's most prominent trademark comes from the way that its transactions are available to review. In financial systems and businesses, this adds an extraordinary layer of responsibility and authenticity, holding every segment of the supply chain mindful to act with respectability and integrity towards the chain's development, its community and its clients (Tian, 2016)**.**

Increased efficiency

Because of its decentralized nature, blockchain eliminates the requirement for brokers/middlemen in numerous processes, for example, bookkeeping and payments, which encourages quicker transactions with a digital currency in contrast to conventional financial services and administrations (Staples, 2017).

Better security

Blockchain is unmistakably safer than other record keeping frameworks in light of the fact that each new transaction is encrypted and connected to the previous transaction (because of hash). Its formation using a complicated string of mathematical numbers and algorithms makes it impossible to be changed once shaped. This immutable and incorruptible nature of blockchain makes it protected from distorted data and hacks. Its structure also gives it a unique quality of being 'trust-less' – meaning that parties do not need trust to transact securely (Hooper, 2018).

Improved traceability

With the blockchain record, each time a trade of product is recorded, a review trail is available to trace where the merchandise came from. This cannot just assist in enhancing security and prevent fraud or extortion, but it can also help conforming the legitimacy of the traded assets. In the wine business, it very well may be utilized to track the supply chain from producer to distributer, and furthermore to give a certain proof of ownership of a product or brand (Tian, 2016).

Reduced costs

For most businesses, reducing costs is a priority. With blockchain, organizations can eliminate the need of middlemen or third parties, improve inventory management, reduce costly data errors and delays, and shorten resolution time when disputes occur. Sellers would also be able to precisely track costs, estimate delivery times for multiple routes, and make smarter decisions overall. Apart from these cost-cutting benefits, the blockchain can help transport suppliers to share insights concerning routes and vehicle storage capacity which can decrease expenses and transport time. This in turn will profit the clients with decreased products cost and delivery times (Hooper, 2018).

Overall, the proposed system benefits the organization in improved perceived value, greater sales and profitability, better cost management, and better customer service; also, it benefits the customers in better purchasing decisions owing to complete brand transparency, product authentication, and warranty management.

Limitations and Challenges

Limitations

Limited information: The immaturity of the blockchain concept in wine supply chains means that existing proposals are mainly theory-based. Practical blockchain case studies or pilot studies in the agri-food sector are required to build a base of research work (Jiang Duan, 2020).

Complicated supply chain: The wine supply chain is vast and complicated. However, the information from authentic food supply chain model(s) has helped in framing a generic blockchain-based wine traceability system (Jiang Duan, 2020).

Applications understanding: Owing to different blockchain approaches and technique utilization, it is extremely hard to choose the best approach which legitimately fits the generic research model (Motta, 2020).

Challenges

Awareness and understanding: The main challenge (especially for small businesses associated with blockchain) is a lack of awareness of the technology, and a widespread lack of understanding of how it works. This situation is hampering investment as well as the exploration of ideas, and requires better educational campaigns to make all this knowledge more accessible (Iredale, 2020).

High operating cost: In a blockchain network, every agreement, every process, every task, and every payment involve a digital record and signature that could be identified, validated, stored, and shared. Undoubtedly, it enhances the speed and effectiveness of transactions, but with high aggregate cost (Iredale, 2020).

Integration with legacy systems: The corporate sector might find it challenging to integrate blockchain with their current legacy system(s). In most cases, if an organization decide to use blockchain, they would be required to completely restructure their previous system, or design a way to successfully integrate the two technologies. However, these solutions involve a significant amount of time and resources from a business to complete the transition (Meijer, 2020).

Risk of data loss: There could be the possibility of data loss and breach that may discourage companies from transitioning to blockchain (Meijer, 2020).

Lack of adequate skill sets: From an organization design perspective, there is a lack of talent to build blockchain applications. Educating employees to work with blockchain takes time, and it's not being taught at many educational institutions. Therefore, organizations are attracting the same limited talent pool that is expanding more slowly than demand is growing (Rijmenam, 2019).

Conclusion and Future Research Directions

A continuous surge in wine counterfeiting cases which cause human as well as financial loss, compel many wine companies from diverse sectors to use advanced tracking technologies. However, these companies are still unable to achieve efficiency in transparency, provenance, safety and security in supply management. In this paper a blockchain model has been proposed as an effective solution for counterfeiting in wine supply chains, and some potential challenges and technology difficulties a company might have to face in practical terms have been addressed. This suggests a guide for new research in relevant areas.

However, blockchain is still in its infancy, and there is still much that is unknown. More work is required in terms of theory and empirical perspectives to check the effects of this technology in the wine value chain, and then formulate corresponding standards based on the research results. Issues that need addressing are adoptability, scalability and confidentiality, and the development of a trustworthy blockchain-based system and its protocols.

Further research is required to improve our knowledge about how to create a blockchain-based system that works, and how to create evidence that this system will work as required. Therefore, it's high time for curious people to be involved in this concept (H.M. Kim, 2018; Musienko, 2020).

Another suggestion is to evaluate the functioning of the blockchain through the implementation of a pilot project. Currently, IBM, Nestle and Walmart are doing a pilot study in China to examine its impact afterward. However, in the Australian wine value chain it should be implemented on a smaller scale to test its efficiency. This way industry and academia can better justify assurances about the functional and non-functional properties of blockchain and blockchain-based systems (H.M. Kim, 2018; Musienko, 2020).

The future work could also consider working on implementing blockchain to address specific production issues, such as enhancing water sustainability in the wine supply chain. More evaluation is also required in the proposed blockchain-based traceability framework effects from different perspectives, such as computation costs, transaction processing speed, storage capability and data privacy mechanisms. Additionally, future researchers could also consider involving third-party regulators/authority organizations in their proposed traceability framework.

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Appendix 1. Glossary of Terms

Block: a block in a blockchain is the container of transactions. Each block contains a time stamp and a link to the previous block.

Immutable: blockchain data cannot be easily changed.

Hash: a function that converts an input of letters and numbers into an encrypted output. A hash is created using an algorithm and is essential to blockchain management in cryptocurrency.

Cryptocurrency: a medium of exchange that exists in the digital world and uses encryption to ensure the security of transactions.

Digital currency: an internet-based form of currency distinct from physical currency that exhibits similar properties but allows for instantaneous transactions and borderless transfer of ownership.

Public key: a published number that is used as a parameter in an encryption function, to encrypt and check signed messages. Public keys are paired with secret private keys, which are used to decrypt and sign messages.

Interoperability: interact with users from other blockchain networks.

Proof of work: an algorithm that is used to confirm transactions and produce new blocks to a chain.

Smart contract: an agreement between two people in the form of computer code. They run on the blockchain, and cannot be changed.

Data replication: the copying of the same data to multiple storage locations to prevent data loss.

Source: (Blockchain Hub, 2018; Blockchain Advisory Council, 2016)

Appendix 2. Myth Busters about Blockchain

Myth 1. Blockchain solves every problem! A blockchain is a sort of linked database and computational platform, with advantages and disadvantages compared to conventional technologies. Sometimes a blockchain may be an appropriate choice in the design of a software system. But if the system is used only within a single organization or hierarchical unit, it is almost never advisable to build it on blockchain technology.
Myth 2. Smart contracts are legal contracts Presently, smart contracts are not regarded as legal contracts. Instead, it is best thought of as the code text for a program execution.
Myth 3. If beneficial, will be adopted It is often assumed that if blockchain technology has significant benefits, then it will inevitably be adopted. However, before that, many risks and limitations of blockchain must be weighed against their possible benefits. Currently, the path to blockchain adoption is significant only with large-scale adoption because of network effects.
Myth 4. Are inherently unscalable While blockchains are at present not exceptionally adaptable or highly scalable, that is not really a characteristic constraint, and might be defeated in the medium-term future.

Source: Staples (2017)