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TECHNOLOGY AND THE AGRICULTURE AND MINING SECTORS

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Submission to the Committee on Investment, Industry, and Regional Development, NSW

The NSW Committee on Investment, Industry and Regional Development's inquiry into technology and the agriculture and mining sectors is extremely relevant and important to contribute to future-proofing both industry and research in NSW. Technology continues to reshape our lives and environment, bringing new opportunities and challenges, particularly in the agriculture sector. In this submission, we focus on the opportunities and challenges presented by blockchain technology applications in the food and drinks sector focussing on Australia's highly export-oriented wine industry. We discuss the demand for better provenance and authenticity information, the nature of blockchain technology, its potential in the current and future Australian wine landscape, barriers to its adoption, measures to support the use of blockchain technology, and its potential impact on the wine sector workforce.

Globalisation, the recent Covid-19 epidemic, concerns over business continuity, supply chain resilience, product authenticity, food safety, and the environmental and social impacts of consumption have all increased consumer demand for transparency, traceability, and verifiable information about provenance, sustainability, and ethical production. Technological advancements including blockchain technology provide new opportunities to build resilient supply chains, reduce counterfeiting risks, and grow relationships with consumers while creating new challenges.

In simple terms, a blockchain is a digital database of information shared across a network of peers. Inside a chain, each block contains a time-stamped copy of a transaction. Because each peer (entity) on the network possesses a copy of the transaction, tampering with the information is virtually impossible. Blockchain technology is versatile and compatible with other technologies already applied in agricultural supply chains such as IoT (Internet of Things), RFID (Radio Frequency Identification), NFC (Near Field Communication), digital labelling, and digital certificates. The benefits of blockchain technology applications for the agriculture sectors include secure supply chain traceability, automation of processes using smart contracts, integration of other technologies including IoT, instantaneous information sharing among the supply chain stakeholders, predictability of

complex supply chains, secure transactions domestically and internationally, and anti-counterfeiting protocols. Furthermore, in the case of wine and food, blockchain applications can be leveraged to communicate authenticity, safety, sustainability, certifications, and other product attributes to consumers. Blockchain can not only provide authentication and certification information for the interested consumer but can also include specific information about location, brand and destination.

However, such new technologies are not always conducive to technology acceptance and consumer trust[1]. Major barriers to the diffusion of blockchain technology remain stakeholders‘ (including consumers) lack of knowledge. experience and trust, implementation costs, perceived negative security and governance issues. We recommend increased government support, regulations, funding, education, and information on the technology's benefits[2] for both industry and consumers.

We welcome the inquiry and the opportunity to prepare this submission.

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This submission stems from our research on blockchain-enabled wine labels and their impact on consumer trust in the Australian and international wine markets. This 3 year research project is conducted as part of Ms Irma Dupuis‘ PhD under the supervision of Dr Sidsel Grimstad, Dr Tamara Bucher, and Professor Lisa Toohey at the University of Newcastle. The project is co-funded by The University of Newcastle 2021 UNIPRS and 2021 Business and Industry scholarships provided by industry partners First Creek Wines, MCC Label and Tamburlaine Wines and conducted in partnership with Laava (technology partner). The study seeks to provide evidence-based knowledge around how consumers interact with blockchain-enabled product labels and to what extent these impact on consumer's trust and purchasing behaviour. . This submission synthesises findings from a literature review of the topic. The opinions expressed in this manuscript are those of the researchers/authors and do not necessarily reflect the views or recommendations of their affiliated institutions.

[1] Siegrist, M., & Hartmann, C. (2020). Consumer acceptance of novel food technologies. *Nature Food*, *1*(6), 343–350.
[2] Helliar, C. V, Crawford, L., Rocca, L., Teodori, C., & Veneziani, M. (2020). Permissionless and permissioned blockchain diffusion. *International Journal of Information Management*, *54*, 102136.

1. The Australian wine sector: current issues and future perspectives

1.1. Consumer choices, provenance, and traceability

Australia is the fifth largest exporter of wine in the world and exported approximately 60% of its total production in 2020[3]. Its top five export markets include mainland China (35%), the UK (16%), the US (United States) (15%), Canada (7%) and Hong Kong (5%). While China performed strongly in 2020 in terms of market attractiveness, the tariffs imposed on Australian wine exports since November 2020 have led to increased uncertainty for businesses. Exports to mainland China declined by 97% in value compared to 2020[4]. Exports excluding China increased by 7% in value driven by demand in Singapore, Hong Kong, South Korea, Taiwan, and Thailand. While China is one of the largest consumers of premium wine in the world, the wider Asian wine market is growing and maturing, with consumers demanding high-quality wine at accessible prices.

Purchasing wine, like other products, is the result of a series of choices made by consumers based on multiple factors. Particularly, grape variety, region of origin, price, brand name, and previous liking of the taste have become key drivers of consumer wine choices[5]. As the wine consumer market matures and gains experience, the relative importance of wine attributes varies greatly from person to person, depending on context and consumer wine involvement. Wine involvement might be described as an individual's level of interest and enthusiasm towards wine (e.g., high, or low)[6]. In a 2008 twelve country comparison study focusing on wine purchasing in retail stores, consumers ranked the most important factors influencing their purchasing decision; most important was having tasted the wine before and having a recommendation from a trusted source, followed closely by grape variety and country or region of origin[7]. Although customers from most countries ranked having tasted the wine before similarly, in China and Brazil country or region of origin was found to be more important, highlighting the importance of country context. Recently in a 2019 Australian study, consumers reported 'regional characteristics' as one of the key factors influencing their wine choices[8], with highly involved wine consumers (enthusiasts) also interested in technical information regarding wine provenance.

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[3] Wine Australia. (2021b). *Market insights – Australian wine exports*. Wine Australia.
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[6] Johnson, T. E., & Bastian, S. E. P. (2015). A fine wine instrument - An alternative for segmenting the Australian wine market. *International Journal of Wine Business Research*, *27*(3), 182–202.
[7] Goodman, et al., (2008, July). International Comparison of Consumer Choice for Wine: A Twelve Country Comparison. *4th International Conference of the Academy of Wine Business Research*.
[8] Kustos, et al., (2019). Using consumer opinion to define New World fine wine: Insights for hospitality. *International Journal of Hospitality Management*, *83*, 180–189.

For wine especially, provenance is part of the consumer's perception of the quality of a bottle of wine[9]. Provenance is linked to the idea of terroir: an interactive ecosystem, in each place, including climate, soil, and the vine[10]. Research conducted in Britain in 2013 confirmed that respondents now defined provenance beyond the place of origin of a product. They also expressed a variety of concerns regarding the manufacturing, distribution, and commercialisation of wine within the wider ethics of food production and consumption[11]. This suggests a definition including the region, but also the skills and winemaking associated with it. Provenance is often included in the rules governing geographical indication (GI). However, as wine is a product that can easily be altered, traceability is essential to guarantee the authenticity of GI wines. For example, Wine Australia under sections 40ZC and 40ZD of the Wine Australia Act 2013 (the Act) provides for the annual verification of compliance with rules associated with GIs, traditional, and quality wine terms. To comply with regulations, producers need to be able to document how and where (within a defined region) grapes were grown and wine produced using reliable traceability systems. Traceability is defined as the ability to follow a product batch and its history through a production chain from raw materials to sales[12]. In a 2010 wine quality consumer study, while "reputable region" ranked second or third in the United Kingdom, Ireland, Canada, Sweden, and the U.S. West Coast, and quality control ranked second in three of the five countries, traceability ranked last in all countries[13]. Indeed, while GIs are valued by wine consumers, especially those with high wine involvement, consumers are not yet aware of the advantages and importance of a robust traceability system[14].

In addition to provenance, an increasing number of consumers now include sustainability in their wine purchasing considerations. However, most consumers associate the term "sustainable" with environmental sustainability without incorporating its social and economic dimensions[15]. Research conducted in Australia found that for 15% of respondents environmental and organic claims accounted for 20% of their decision to choose a wine with the influence of environmental claims increasing ten times between 2007 and 2009 alone[16]. Consumers typically rely on external cues to

[9] Lockshin, et al., (2006). Using simulations from discrete choice experiments to measure consumer sensitivity to brand, region, price, and awards in wine choice. *Food Quality and Preference*, *17*(3–4), 166–178.
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[12] Palade, M., & Popa, M. E. (2014). Wine Traceability and Authenticity - a literature review. *Scientific Bulletin*, *XVIII*(Series F. Biotechnologies), 226–233.
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[16] Mueller, S., & Remaud, H. (2010). Are Australian wine consumers becoming more environmentally conscious? Robustness of latent preference segments over time. *5th International Conference of the Academy of Wine Business Research*, 1–9.

assess the value of a bottle of wine, therefore verifiable information around GIs, environmental certifications, and brands can help consumers mitigate the risks associated with a purchase of a new product. Certifications, however, do not come without cost as they typically require expensive and regular third-party audits. Despite the costs, a growing number of Australian wine producers have chosen to move towards more sustainable farming and business practices[17] and have adopted a variety of environmental and social certifications including certified Organic, Biodynamic, ISO 9001 etc.

In a market like China where customers are wary of counterfeit products, being able to access information on the product's journey may help mitigate perceived risks with the purchase. Blockchain technology has the potential to streamline GI and certification verification by creating a more secure and transparent system, reducing the cost of third-party audits[18]. Montecchi et al., (2019) infer that blockchain-enabled technologies could create a transparent supply chain that could allow the tracking of products, from origin to its destination, to certify the authenticity of wine and to track custody from the producer to the consumer[19]. This has been recognised as an important technological advancement by producers with certifications and geographical indications to guarantee provenance and authenticity. In addition, blockchain technology can offer more than quality assurance to consumers. Since the beginning of 2020 and the COVID-19 pandemic, supply chains have been disrupted more than ever before in critical sectors. Encouragingly, a 2021 BCI report found that 55.6% of organisations are now using technology to analyse and report on supply chain disruptions[20]. Among those technologies, blockchain applications can be leveraged to implement traceability systems at all levels of the supply chain, facilitate information exchange between stakeholders, build supply chain resilience, and facilitate transactions to prevent shortages and mitigate unforeseen disruptions.

1.2. Wine fraud and counterfeiting

Globally, food fraud is becoming a significant challenge, estimated to cost $40-50 billion per year, and $2-3 billion in Australia alone[21]. In a 2021 report written by Deakin University, wine fraud was estimated to cost $150-205 million in 2018-2019 in Australia alone, making wine a high vulnerability product along with beef, fish, and seafood[22]. Unfortunately, wine fraud is not a new phenomenon. High-profile wine counterfeiting scandals (Rudy Kurniawan, 2012; Penfolds, 2021) highlight the issue of wine authenticity and quality assessment before purchase. While consumers rely on the

[17] Sustainable Winegrowing Australia. (2021). Annual Operating Plan.
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[20] BCI. (2021). *Supply Chain resilience report 2021*. www.thebci.org
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information provided on labels, expert opinion, and winemakers' reputation, even experts may experience difficulties when attempting to authenticate old or rare wines[23]. Defective labelling and repeated fraud scandals increase consumer uncertainty in the authenticity of a product[24] and although producers are taking steps to prevent future counterfeiting, authentication techniques for older wines remain in development.

While blockchain-enabled technologies can create a transparent supply chain other applications of blockchain technology for premium wine could be used beyond supply chain management; they would allow greater control over the conditions under which their wine has been stored, transported (RFID, NFC) and traded (NFT) to ensure its integrity and authenticity for the final consumer. Indeed, the widely held belief that wine becomes better with age entirely depends on the conditions in which it is stored. Temperature control and tracking are two of the many features that could help mitigate risks when purchasing an expensive bottle and help producers substantiate their premium claims in high-risk markets.

2. Blockchain technology for wine supply chains

2.1. What is blockchain technology?

Distributed ledger technology (DTL) more commonly called "blockchain" is a decentralised list of records called "blocks" distributed across a peer-to-peer network, which are linked and secured using cryptography. Each block usually contains a record of the previous block along with a timestamp and transaction data[25]. This system makes the information stored within the blockchain virtually unalterable and unfalsifiable as to change the details of one transaction, one would need to modify every copy within the peer-to-peer network (Fig. 1).

[23] Holmberg, L. (2010). Wine fraud. International Journal of Wine Research, 2(1), 105–113.
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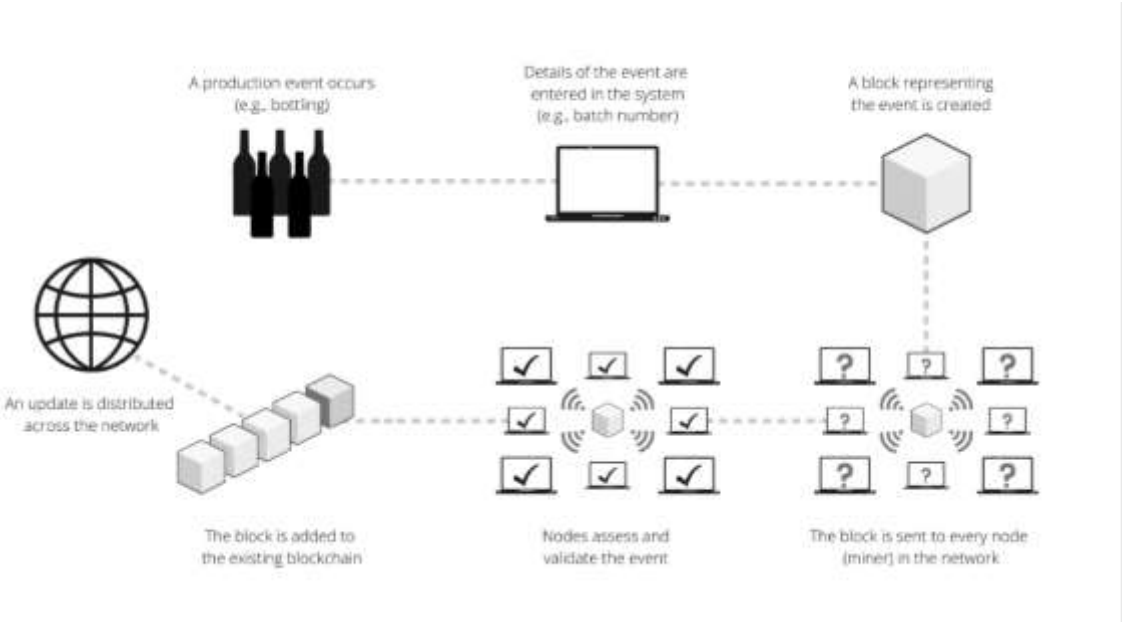

Figure 1. Blockchain technology process in a wine supply chain

Blockchain was introduced in 2008 as the engine of cryptocurrency (Nakamoto, 2008) to provide secure, transparent, and anonymous transactions between peers without the need for third-party trust. Since then, two types of blockchains have emerged – permissionless and permissioned blockchains[26]. Permissionless blockchains are the basis of cryptocurrency. They are open, public, and anonymous. Each block is solved by competing miners (nodes) and verified by other miners through a consensus process. Miners who successfully solved the block's algorithm get paid for their work, this system is called Proof of Work (PoW). Access to the information encrypted on the blockchain is granted through public keys and personal information can be accessed through private keys. As a result, blockchain has been called a "trust-less" or "trust-free" technology (Hawlitschek et al., 2018) as the responsibility of validating each block is shared and does not rely on the good faith of a single organisation. A permissioned blockchain usually involves a consortium of organisations where blocks are verified by authorised gatekeepers instead of anonymous peers[27]. This evolution saw the development of two new operating systems: Proof of Stake (PoS) in 2016 and Proof of Authority (PoA) in 2017 bringing governance and oversight to blockchains[28]. Access to the information stored on a permissioned blockchain is granted based on the rules agreed by the consortium. In addition to governance, PoS and PoA require less electrical power for their consensus process compared to PoW and protect organisations' reputations and proprietary information.

[26] Helliar, et al., (2020). Permissionless and permissioned blockchain diffusion. *International Journal of Information Management*, *54*, 102136.
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Blockchain technology now powers applications in many industries, from finance, trade and commerce to health, government, arts, and culture (blockchain 3.0) (Swan, 2015). Among rapidly developing applications, blockchain for provenance and authenticity is being implemented by global companies including Carrefour, Nestle, Unilever, and Walmart. Starbucks is leveraging Microsoft's Azure Blockchain Service to track coffee production; Wallmart now tracks over 25 products and requires all suppliers of fresh leafy greens to use their blockchain-based system[29]. Governments are also experimenting with blockchain for land ownership (Honduras, Ghana, Georgia, and India) and voting[30].

2.2. Applications in the wine industry

Numerous blockchain applications are currently being developed for the wine industry as they have immense potential in traceability, transparency[31] and anti-counterfeiting. While studies demonstrating the effectiveness of blockchain wine labels to assure wine consumers of the provenance and authenticity of wine remain scarce, producers have recognised the potential of blockchain applications for supply chain and consumer communication. Approaches combining blockchain technology with other traceability technologies (i.e., RFID (radio frequency identification), IoT (Internet of Things) and NFC (Near-Field Communication)) are being explored to increase efficiency and provide product verification. In a 2018 international study of 49 different blockchain initiatives in agriculture and food supply chains, most projects were at the proof-of-concept stage (28.5%) and the implementation stage (26.5%) with complete integration being the smallest portion (8%). This indicates that the technology is still seen as an experimental tool and as an emerging technology future[32]. In the wine industry, blockchain technology use remains scarce, however, interest is growing with applications for traceability, marketing, and anti-counterfeiting using blockchain-enabled wine labels.

3. Barriers to adoption and consumer trust

3.1. Barriers

Despite benefits, technology adoption faces several barriers including technology expertise, inter-system compatibility, implementation costs, and technology acceptance both from a managerial and consumer point of view. The majority of research in blockchain applications focus on adoption drivers rather than barriers, with organisational studies focussing on drivers and benefits, while technology

[29] Hyperledger. (2019). *How Walmart brought unprecedented transparency to the food supply chain with Hyperledger Fabric*.
[30] Frizzo-Barker, et al., (2020). Blockchain as a disruptive technology for business: A systematic review. *International Journal of Information Management*, *51*, 102029.
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[32] Kamilaris, et al., (2019). The rise of blockchain technology in agriculture and food supply chains. *Trends in Food Science & Technology*, *91*, 640–652.

papers were more likely to address adoption barriers and challenges[33]. One of the most evident barriers to the diffusion of blockchain applications remains stakeholders' lack of knowledge and expertise. Research conducted in 11 countries in 2017 found that 60% of participants did not know what blockchain was or when they did, could not explain how it worked[34]. Recent research in the USA confirms this lack of knowledge is still an important barrier despite the recent media interest in blockchain and cryptocurrencies[35]. Additionally, the lack of participants is hindering the diffusion of this technology, as are the increasingly longer processing times due to issues of scalability, and the high implementation costs due to issues of compatibility with existing systems and processes[36]. These issues have important practical, economic, and environmental implications for the future of the technology as more organisations seek to integrate complex supply chains with blockchain technology.

The lack of adequate regulations and appropriate governance in permissionless blockchains is also a concern. However, many countries are introducing legislation to assist and regulate the development of blockchains[37]. While progress is underway to mitigate issues linked to high power requirements, compatibility, and regulations, stakeholders' lack of awareness, knowledge, and expertise in the technology remains to be addressed.

3.2. Consumer trust

Trust is an important technology acceptance factor. Despite having been branded a "trustless" or "trust-free" technology[38], consumer adoption of blockchain technology remains linked to trust. Trust is a relational construct involving the trustor (e.g., the consumer), the trustee (e.g., the wine producer or technology provider), and the goal pursued by the trustor (e.g., accessing reliable information before purchase)[39]. It cannot easily be evaluated using a binary mode of questioning – such as asking whether consumers do or do not trust the technology. Trust is an attitude and disposition towards the trustee (wine producer or technology provider) involving an evaluation and expectation of its trustworthiness in a specific context[40]. Consumers evaluate wine producers' trustworthiness based on

[33] Frizzo-Barker, et al., (2020). Blockchain as a disruptive technology for business: A systematic review. *International Journal of Information Management*, *51*, 102029.
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the producers' skills, honesty, and benevolence. In the case of blockchain technology applications in the wine industry, consumer needs to trust the wine producer, but also the technology used to inform them of the authenticity of the wine they seek to purchase. Based on the consumer's evaluation of those two trustees, the consumer will form a decision and intention to pursue its goal and rely or not on the trustee's expected behaviour[41]. However, trust in blockchain traceability also depends on the country context and consumer perspective and personal beliefs.

In a 2021 systematic review on consumer trust, consumers' limited knowledge and experience with blockchain technology negatively impacted trust in blockchain applications, while several studies found trust to be the main factor determining the use of blockchain applications[42]. The application's performance expectancy (e.g., perceived usefulness, transparency, security, privacy), effort expectancy (e.g., perceived ease of use, system quality, design), the importance of social influence (e.g., subjective norm), and facilitating conditions (e.g., regulatory support, trust in government, perceived behavioural control), influenced trust in blockchain, in turn influencing consumers' intention to use the application positively and were moderated by experience (e.g., blockchain knowledge).

Therefore, rather than suppressing trust as a requirement, blockchain technology requires distinct levels of trust[43]. At first, trust is essential for technology adoption, as consumers lack the knowledge and experience needed to rationally evaluate technologies. Indeed, to trust in blockchain applications means to trust in the algorithms powering them, the developers designing them, and the stakeholders providing the information[44]. In an increasingly more complex environment, individuals rely on trust to continue making decisions when they do not possess experience or knowledge.

It would be important to communicate and inform consumers and the general public on the benefits of blockchain technology for provenance and authenticity. This would increase consumers trust in the technology and contribute to adoption. Additionally, government regulations to safeguard the authenticity and integrity of the information stored on blockchain are an important part of securing consumer acceptance and trust in blockchain technology[45].

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[41] Castelfranchi, C., & Falcone, R. (2010). Trust theory: A socio-cognitive and computational model. John Wiley & Sons, Ltd.
[42] Dupuis, et al., (2021). Blockchain: the Paradox of Consumer Trust in a Trustless System-a Systematic Review. *2021 IEEE International Conference on Blockchain*, 1–8.
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4. Measures to promote understanding and support blockchain adoption

As identified earlier, several barriers impede the adoption of blockchain applications for the wine industry. From an industry adoption perspective, large organisations and small and medium wine producers face different challenges; large wine corporations are more likely to possess the skills and knowledge required to adopt blockchain wine traceability systems, issues linked to scalability, complexity, and compatibility of blockchain technology remain. Small and medium sized boutique wineries are less likely to suffer from complexity and compatibility issues, however, they often have fewer resources and means to be able to protect their authentic brands.

Government can support the wine industry in their efforts to adopt blockchain applications to protect the authenticity of Australian wine through:

- Knowledge building opportunities made available to all producers (workshops, information sessions, communication on the benefits of blockchain traceability applications) to mitigate lack of knowledge and skill slowing down the adoption of traceability innovations
- Regulation of blockchain to prevent misinformation and counterfeiting of Australian wine and address governance issues
- Funding to facilitate the adoption of blockchain applications and traceability technologies across the industry and mitigate issues linked to high implementation costs
- Research funding to address the issues linked to technology performance, security, privacy, and running costs
- Information campaigns targetting consumers to communicate the benefits of the technology and the added protection this technology provides for Australian wine

Wine associations could support government efforts by providing:

- Training for wine producers and staff to facilitate the implementation of new systems
- Support programmes to help small and medium organisations on their blockchain traceability journey
- Grants to encourage early adoption of state-of-the-art traceability systems
- Communication campaigns to inform consumers of the benefits of blockchain traceability and the commitment of the wine industry to authenticity

Finally, consumer associations have an important role to play by providing information to consumers and educating them on the benefits of traceability for food and drink and the role of government in ensuring blockchain technology is implemented with integrity.

5. Impact on past, current, and future wine sector workforce

Blockchain applications for the wine industry have the potential to bring better traceability through the optimisation of supply chain processes and better record keeping. With greater attention to traceability, the adoption of this technology could lead to a reduction of fraud and provide producers with better means of correcting errors and responding to food safety events.

However, the adoption of blockchain applications in the wine industry would have several impacts on the current workforce:

- The adoption of innovative technologies, such as block-chain enabled supply chains will require increased skills level of the workforce involved. Wine producers may have to recruit or train staff to adapt to new processes and skills
- Investments in Information Technology (IT) may be needed to cope with the increased system complexity
- Human error may need to be reduced using other traceability technologies compatible with blockchains such as RFID and NFC

While the increase in the use of technologies in the wine sector may lead to more employment opportunities in the supply chain management and information technology fields, a less qualified workforce may need to upskill or converge to other areas in the production chain.

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