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It's real, trust me! Establishing supply chain provenance using blockchain

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Abstract In a global marketplace, customers are often unaware of the exact sources of the products they purchase and consume. To address this lack of awareness, blockchain technology can be implemented in supply chains to increase customers' knowledge of products' provenance. Provenance knowledge—information about products' origin, production, modifications, and custody—enables customers to be assured of their purchasing decisions. This assurance comes from information on the origin, authenticity, custody, and integrity of the product that helps reduce risk perceptions. We develop a provenance knowledge framework and show how its application can enhance assurances and reduce perceived risks via the application of blockchain. We present a guide on how to implement blockchain to establish provenance knowledge and close with a kind warning on the importance of demonstrating the value of blockchain to customers.
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1. Transparency: Blockchain beyond bitcoins

Customers have limited knowledge of the products they buy. Although many firms have invested in transparency initiatives, it is often unclear to customers how value is added to a product along the supply chain. Customers typically rely on cues to assess the tangible and symbolic values of products (Berthon, Pitt, Parent, & Berthon, 2009) and use heuristics to assess the potential risks of a purchase (Folkes, 1988; Grewal, Gotlieb, & Marmorstein, 1994). For instance, country-of-origin labels (e.g., made in Italy), certifications (e.g., fair trade, non-GMO, organic), and brands themselves can act as reassurance cues or badges that can reduce customers' perceived risks (Mitchell & Greatorex, 1988). However, recent scandals involving the sourcing and supplying of products have called into question the reliability of these proxies and the

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extent to which they guarantee the real quality and, in some cases, the safety of products they are attached to. In 2013, British and Swedish customers of Findus Nordic lasagna were shocked to discover that the labeled protein contents of the package were not 100% beef when it was revealed that the protein was nearly 100% horsemeat (Falkheimer & Heide, 2015). This scandal resulted in an international scare and in a significant loss of confidence toward firms' capabilities of assuring the provenance of food products (Yeung & Yee, 2012).

Provenance is defined as "information about the creation, chain of custody, modifications or influences pertaining to an artifact" (Cheney, Chong, Foster, Seltzer, & Vansummeren, 2009, p. 960). As customers have become increasingly skeptical, firms that establish product provenance may have a competitive advantage. Provenance knowledge comes from supply chain transparency in terms of how products were manufactured, stored, and delivered to customers (Kim & Laskowski, 2018). This knowledge can add to customers' subjective opinions and experiences both pre- and post-purchase and can thus alter behavioral outcomes such as word-of-mouth and repeat purchases (Kietzmann & Canhoto, 2013).

Provenance knowledge can increase customers' trust by assuring the origin, authenticity, custody, and integrity of products. Through these assurances, provenance knowledge can reduce perceived risks that can impact purchasing decisions (Antony, Lin, & Xu, 2006; Featherman & Pavlou, 2003; Kim, Ferrin, & Rao, 2008; Mitchell, 1999; Sweeney, Soutar, & Johnson, 1999). These include perceived financial, psychological, social, performance and physical risks (Bauer, 1967; Jacoby & Kaplan, 1972). In considering an automobile purchase, customers are attracted to automobiles that are seen as having a high resale value, a prestigious social status, a degree of durability, and a proven safety track record.

Blockchain technology can offer powerful solutions to enhance customers' provenance knowledge by providing a robust system to trace origin, certifying authenticity, tracking custody, and verifying integrity of products. Blockchain uses a decentralized data infrastructure that is spread across a large network (Nakamoto, 2008). It works as a distributed ledger that records and secures transactions of data, goods, and financial services in a peer-to-peer network in which each actor has access to the entire database and its complete history (Chen, 2018). The power over the data is distributed and each actor can access and verify transaction records directly with a partner. Besides reducing transactions costs (Iansiti & Lakhani, 2017) and resolving issues of "disclosure and accountability" (Casey & Wong, 2017, p. 3), blockchain technology increases transparency across the supply chain, thus providing assurances of products' provenance.

Blockchain technology was first applied to the cryptocurrency industry as it provided a secure yet anonymous way to transfer wealth between two people or organizations across national boundaries (Hughes, Park, Archer-Brown, & Kietzmann, 2019; Yli-Huumo, Ko, Choi, Park, & Smolander, 2016). While applications outside of cryptocurrency are currently uncommon (Angelis & Ribeiro da Silva, 2019; Ghose, 2018; Halaburda, 2018; Morkunas, Paschen, & Boon, 2019), this technology promises to revolutionize the way firms monitor transaction transparency across their supply chain (Casey & Wong, 2017; Gupta, 2017a; Min, 2019). Blockchain makes it possible to record transactions across supply chains in an irreversible manner and gives supply chain partners access to this transaction history (Abeyratne & Monfared, 2016; Alzahrani & Bulusu, 2018). It also allows customers to trace the source and track subsequent modifications of products, thus potentially mitigating customers' perceived risks (Yeung & Yee, 2012).

By showing how blockchain technology can increase products' provenance knowledge, our article offers several contributions not only to the emerging literature on blockchain but also to the supply chain, marketing, and management literature. First, we discuss how perceived risks impact purchase decisions and how customers' knowledge of products' provenance can reduce these risk perceptions. Second, we develop a framework that shows the connection between the dimensions of provenance knowledge and risk perceptions. Third, we illustrate how blockchain technology can be applied to provide provenance knowledge by adding assurances and thus reducing perceived risks. Fourth, we offer managerial guidance on the appropriateness, utility, implementation, and risks of blockchain technology applications that enhance customers' product provenance knowledge. Fifth, we close with a cautionary note to ensure that blockchain is applied in a meaningful way to increase transparency.

2. Customers' perceived risks

Customers can perceive risk when there is information that is hidden from them in a product's supply chain. This perceived risk can influence customers' purchase decisions and attitudes (Antony et al., 2006; Featherman & Pavlou, 2003; Kim et al., 2008; Mitchell, 1999; Sweeney et al., 1999). Bauer (1967, p. 24) defined perceived risk as "any action

of a customer [that] will provide consequences which he cannot anticipate with anything approximating certainty, and some of which at least are likely to be unpleasant." Thus, customers perceive risks because firms and customers have different information.

This information asymmetry can lead to undesirable consequences or outcomes for the customer. Prospect theory predicts that customers will try to reduce the likelihood of negative outcomes as they are generally averse to losses (Kahneman & Tversky, 1979). Therefore, the lack of information about the characteristics of the product increases customers' perceived risk of negative outcomes that may come from purchasing and using that product. These negative outcomes could include feelings of uncertainty, discomfort, anxiety, concern, psychological conflict, and cognitive dissonance (Featherman & Pavlou, 2003). These perceived risks can be grouped into five dimensions: financial, psychological, social, performance, and physical risk (Bauer, 1967; Jacoby & Kaplan, 1972). Each risk dimension can be understood as an expectation of a future cost of a product, which impacts its perceived value (Sweeney et al., 1999). The dimensions are individually described and elaborated on below.

Financial risks are created when it is uncertain as to the extent of the opportunity, time, or monetary costs of using and owning a product (Kim et al., 2008). Financial risks come from potential threats to the value of products and can be increased by the likelihood that products might need to be repaired or replaced (Jacoby & Kaplan, 1972; Kim et al., 2008; Sweeney et al., 1999). Consider a customer who purchases a used Apple iPhone that keeps breaking down and is in constant need of expensive repairs. The customer faces substantial financial costs because they did not have the provenance knowledge of how the past owner looked after the product.

Psychological risks are perceived when a product purchase decision could threaten customers' self-images or self-concepts (Dowling & Staelin, 1994; Featherman & Pavlou, 2003; Jacoby & Kaplan, 1972; Mitchell, 1999). This could include a potential loss of self-esteem (Featherman & Pavlou, 2003) or a negative impact on self-perception or peace of mind (Mitchell, 1999). For example, customers avoided purchasing instant cake mixes when they were first introduced, as making a cake with such little effort felt like cheating. A solution to avoid a negative impact on the customers' self-concept was to have them add an egg to the mixture to make them feel as though they actually did something to bake the cake.

Perceived *social risks* originate from negative evaluations of others (Featherman & Pavlou, 2003; Jacoby & Kaplan, 1972). This could include the loss of status or power in an important social or reference group, because of the purchase or use of a product (Featherman & Pavlou, 2003). For example, an employee wants to purchase a birthday gift for their boss who is a connoisseur of fine Champagne but ends up buying a California sparkling wine that may be of high quality, yet it is not Champagne. That employee now may suffer a loss of face and status among their colleagues. Social risks come from unfamiliar purchases or unknown social information that can cause a loss of status, power, or face within an important social group.

Customers perceive *performance risks* when the functionality of products are uncertain due to malfunction or unexpected performance (Grewal et al., 1994; Jacoby & Kaplan, 1972; Kim et al., 2008; Sweeney et al., 1999). The customer experiences a loss if a product does not perform as expected and this directly impacts the perception of product quality (Grewal et al., 1994; Sweeney et al., 1999). Consider a customer who purchases a new tablet to be more flexible and work remotely but then discovers that the device has limited battery duration due to its large display. The customer will experience a loss due to the poor performance which will reduce the expected value of the tablet as a flexible and fully mobile solution. Thus, performance risks are formed when it is unclear if products can meet performance expectations.

Physical risks are perceived when products could result in harm to customers or other people (Berman & Swani, 2010; Jacoby & Kaplan, 1972; Mitchell, 1999). This type of risk can be assessed by experts and scientific methods or tools and are therefore often regulated by government or industry standards (Mitchell, 1999). Consider a snack food product that contains peanuts. Some people develop serious allergic reactions to peanuts and can suffer devastating consequences by ingesting even small traces. To avoid dangerous incidents, regulations dictate how food products must be labeled in order to communicate clearly which allergens may be present in these products.

Firms can anticipate the development of these perceived risks and apply transparency interventions that offer additional information to resolve any information asymmetry perceived by customers. As risk perceptions direct customer behavior, these inventions can limit or mitigate risk and favorably benefit the firm (Jacoby & Kaplan, 1972; Roselius, 1971). Traditionally, firms have used third-party rating services (e.g., ISO 9001 certification) to reassure customers of their processes. Customers may also seek product reviews from other customers to add information and reassurance

(Kietzmann & Canhoto, 2013). Blockchain technology offers firms another solution to reduce these risks by transparently recording all transactions related to a product, thus increasing provenance knowledge.

3. Establishing provenance knowledge through blockchain

As discussed earlier, the concept of provenance incorporates information about a product's origin, creation, chain of custody and subsequent modifications (Cheney et al., 2009). Buyers and sellers of expensive collectibles (e.g., fine art, antiques, and jewelry) are often preoccupied with knowing the provenance of products. These people often rely on various sources of information (e.g., certifications, third-party accreditations) to establish origin and authenticity. Products that have a documented history and are fully traceable provide knowledge on their provenance. This provenance knowledge justifies and protects the value of products.

Provenance knowledge is becoming critical in many other consumption contexts. For example, following the string of European food industry scandals, customers are increasingly concerned about the products they purchase and consume (Barbarossa, De Pelsmacker, Moons, & Marcati, 2016). These cases mirror past scandals in mainland China where several products, including baby formula, were produced with unsafe materials or through unsafe processes (Qiao, Guo, & Klein, 2012). In light of these issues, customers are demanding greater transparency and more secure knowledge of product provenance from manufacturers and retailers (Agnoli, Capitello, De Salvo, Longo, & Boeri, 2016).

Establishing provenance knowledge is often challenging as supply chains have become more complex and products travel through vast networks of operators often across national boundaries. This complexity requires a precise system that follows products throughout their entire lifecycle, from the initial sourcing of raw materials to manufacturing, distribution, and consumption (Awaysheh & Klassen, 2010). Typically, product information is stored in multiple locations and is accessible to certain supply chain partners; this makes it difficult to establish an overall picture that can be trusted by all partners including customers.

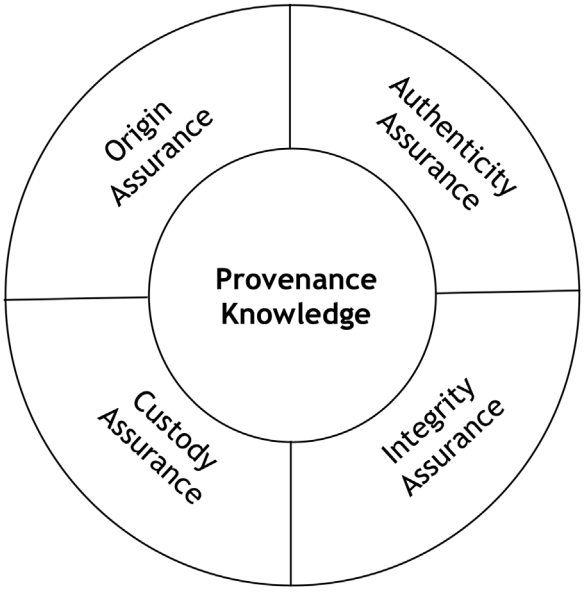
Blockchain technologies promise to enhance provenance knowledge by providing the infrastructure necessary to build, store, and manage products' footprints more efficiently and effectively (Casey & Wong, 2017). By improving transparency and traceability through blockchain technology, manufactures and intermediaries can monitor the chain of custody and ensure quality and safety of products for final customers.

Blockchain can deliver information about the source of a product and the stages the item went through from its source to the point of consumption and potentially after consumption (Abeyratne & Monfared, 2016). This is critical to establish products' provenance knowledge. From the perspective of customers, interventions aimed at improving their knowledge of a product's provenance can impact evaluations of that product by providing four types of assurances: *origin, authenticity, custody, and integrity* (Figure 1). Blockchain technologies deliver these assurances by providing *traceability, certifiability, trackability,* and *verifiability* of product information along the supply chain.

3.1. Origin assurance

Origin assurance involves an assessment of several interconnected aspects linked to the place of origin of brands and products. Where the product is manufactured (country of manufacture) and the place customers associate with the brand (country of brand origin) can impact customers' product evaluations (Hall, Pitt, & Wallstrom, 2015; Laufer & Wang, 2018; Ulgado & Lee, 1993). Similarly, the origin of key components and ingredients (country of ingredient) also influences customers' opinions and purchasing intent (Cheah, Zainol, & Phau,

Figure 1. The assurance wheel of provenance knowledge



2016). These effects are based on stereotypical views of countries associated with products' and brands' origin. Such beliefs streamline customers' information processing and provide mental shortcuts in evaluating products' features and performances (Cheah et al., 2016). In addition to their past experiences, customers form images of countries based on several dimensions including innovation, design, prestige, and workmanship (Roth & Romeo, 1992). These stereotypes are subsequently used to evaluate the quality of products. When customers hold favorable associations towards the country and its image, origin assurance can reinforce their perception of product quality and reduce perceived risks associated with the purchase and consumption.

By enhancing product traceability, blockchain allows customers to discover the origin of a product and of its components or ingredients. Blockchain enables traceability because every transaction concerning the product's lifecycle is entered into the blockchain ledger. The blockchain ledger cannot be altered as it is linked to every transaction before and after. Hence, this chain of transactions is irreversibly recorded. Because these records are accessible to every member of the blockchain, the technology allows to trace transactions back in time. This traceability is enforced by various algorithms that make sure that the record on a database is "permanent, chronically ordered, and available to each actor on the network" (Gupta, 2017b, p. 3). This means that transactions related to a product can be traced back to their sources and can be subject to future scrutiny.

3.2. Authenticity assurance

Authenticity assurance is critical in many purchasing contexts because customers tend to pay greater attention to product cues that communicate authenticity (Beverland & Farrelly, 2010). In their purchasing and consumption decisions, customers might find it challenging to discern between true authenticity and staged or fake authenticity (Lu, Gursoy, & Lu, 2015). Increased provenance knowledge can provide authenticity assurance by establishing stronger associations with the product's or brand's place of origin and also by tapping into that place's history and heritage (Iversen & Hem, 2008).

Firms use various types of policies and trademarks to certify products' authenticity and origin. Conventional certifications typically are costly and require strict audits by a third-party authority (Abeyratne & Monfared, 2016). For the customer, certifications are only accessible through the proxy of a seal that requires them to trust the seal without being able to verify the authenticity themselves. Blockchain technology offers new options to certify products in a more secure and transparent way by helping all parties involved to collectively agree on protocols, which do not rely on expensive intermediaries (Tucker & Catalini, 2018). It offers an alternative to authenticity seal because supply chain partners have to verify and agree on every transaction related to the product. The consensus among those involved partners verifies, or certifies, transactions that have impacted a product, and, therefore, can assure its authenticity.

3.3. Custody assurance

As supply chains become more global and complex, multiple actors contribute to a growing number of stages of a product's lifecycle. At the same time, customers' expectations of transparency are increasing, putting pressure on firms to implement systems which provide visibility of each stage. Custody assurance is concerned with the trackability of products through the different stages of the supply chain to ensure higher levels of control and confidence. Customers' confidence in the purchase is reinforced by having information on the chain of custody and its management, including transportation and storage conditions and methods.

Blockchain creates a digital trail that can be observed in real time, by recording every transaction related to a product (Tucker & Catalini, 2018). Actors along a supply chain often use smart contracts, which enables not only more efficient execution of terms and conditions by a system that is trusted by all contract signatories (Casey & Wong, 2017), but also allow the parties involved to verify who agreed on the stocking, modification, or delivery of a product. Trackability contributes to custody assurance because all decisions and modifications are tracked for each stage of the product lifecycle (Abeyratne & Monfared, 2016).

3.4. Integrity assurance

A product with integrity meets customers' expected levels of quality and reliability, delivers superior value, and ultimately represents a critical source of competitive advantage for the firm (Clark & Fujimoto, 1990). Customers assess the integrity of products by using intrinsic and extrinsic cues (Olson & Jacoby, 1972). Intrinsic cues are linked to the actual tangible characteristics and associated performances of the product, which are then confirmed during consumption and use. Extrinsic cues are

influenced by external stimuli, including marketing efforts, and knowledge of product provenance. When associations are favorable, increased provenance knowledge can have a positive impact on the perceived integrity of a product and further reinforce customer purchasing intent.

Blockchain technology can support the verification of information concerning products by providing visibility of all supply chain transactions, which traditionally have been hidden or difficult for customers to access. With blockchain, all transaction data are stored in a decentralized ledger and changes are validated by all partners in a network. This process can assure the integrity of products by providing transparent access to transaction information across the supply chain.

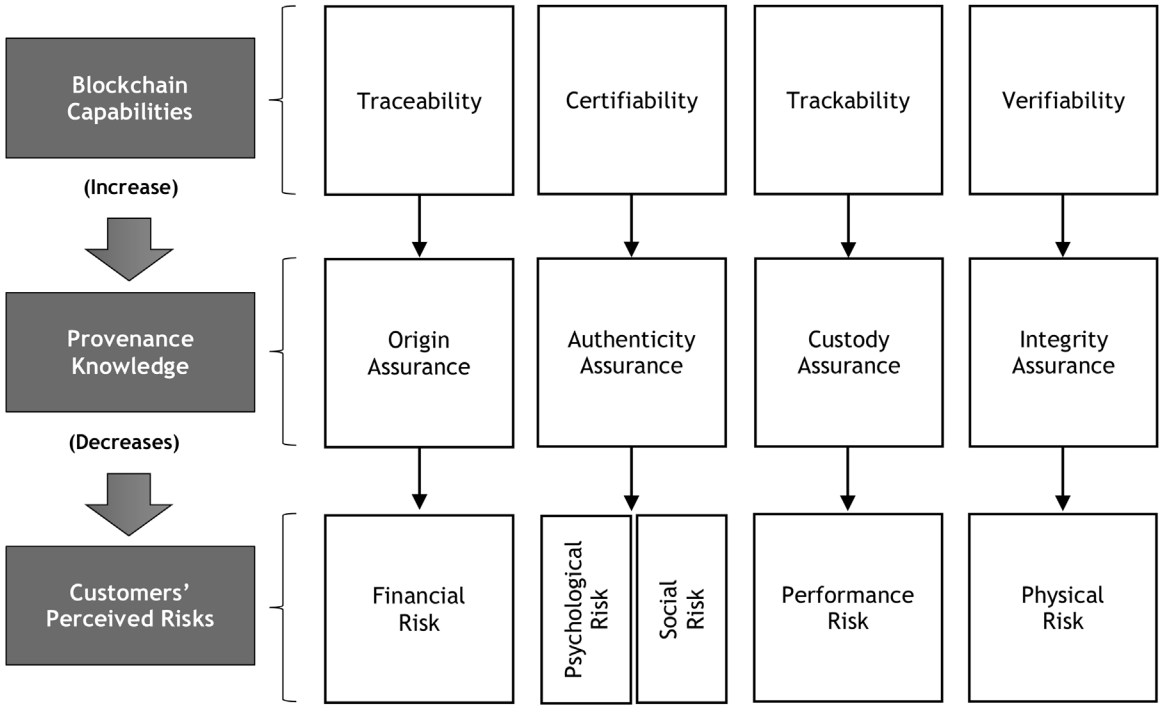
4. Constructing transparent chains

Blockchain capabilities of advanced traceability, certifiability, trackability, and verifiability can provide customers with a comprehensive assessment of provenance knowledge through four main assurances: origin, authenticity, custody, and integrity. Through these assurances, provenance knowledge can impact the different dimensions of customers' perceived risk: financial, psychological, social, performance, and physical risk. Figure 2 depicts a framework that conceptualizes these relationships. Although each category of perceived risk is represented as being directly influenced by one assurance through one type of blockchain capability, other secondary links may exist between assurances and perceived risks given their interconnected nature. The following sections illustrate the application of blockchain to establish provenance knowledge and reduce perceived risks.

4.1. How origin assurance reduces financial risk

When purchasing fashion products, customers often need to trust manufacturers and retailers that the materials that make up the product are accurately represented on the label. Consider for example fashion garments and accessories made with expensive materials such as Mongolian cashmere, Australian crocodile leather, or Japanese silk. Customers might rely on previous experiences and acquired expertise to form a general opinion about the quality of the product. In doing so, customers might miss out on important details about the quality of the materials, including their origin and sourcing. Therefore, customers would benefit from the traceability function of blockchain to secure origin assurance and reduce the perceived financial risk of paying a premium price for a product made with these unique materials.

Figure 2. Blockchain-enabled provenance knowledge



Martine Jarlgaard, a London-based fashion designer, partnered with Project Provenance (provenance.org) in 2017 to offer her customers a fully traceable garment enabled by blockchain technology. The team introduced blockchain and its uses with the Provenance app to the various suppliers that contribute to the final garment. Key to this garment is the sustainable Suri alpaca fleece from the British Alpaca Fashion Company and their alpacas at Exmoor National Park in the UK. By using the blockchain-enabled app, customers can see the fleece's authentication process and the downstream processing as well; thus, they can be reassured of the origin of the fleece. Such detailed reassurance of product origin reduces the perceived financial risk, as customers have increased provenance knowledge regarding the specific source of the materials.

4.2. How authenticity assurance reduces psychological and social risks

The market for counterfeit luxury products has been expanding rapidly in recent years, generating huge losses for luxury brands across both offline and online channels (Meraviglia, 2018; Wilcock & Boys, 2014). Copying techniques have become extremely sophisticated and detecting counterfeit is always problematic, especially if sales are happening online (Chen, Yue, & Zhao, 2018; Zimmerman, 2013). For some customers, knockoffs priced at a very small percentage of the recommended selling price can be an attractive option. These customers will actively search for alternative channels through which they can purchase counterfeit products. Other customers unknowingly buy counterfeit products at a full market price and are left inevitably dissatisfied about quality and performances (Wilcock & Boys, 2014).

Providing assurance of product authenticity is critical in order to reduce psychological and social risks associated with the purchase. Customers might want reassurance that they are not behaving unethically by contributing to the business of counterfeit and that they have not been deceived into investing money and time in purchasing counterfeit products (psychological risk). Customers also want to avoid the potential social repercussions of other people knowing that, willingly or unwillingly, they have purchased counterfeits (social risk; Wilcock & Boys, 2014).

Blockchain technology can offer a very powerful solution to tackle these issues by allowing luxury firms to create digital certificates of authenticity which accompany physical products through their lifecycle. Through blockchain, a link between a physical product and a trusted digital identity is established, recorded in the blockchain database, and the information used to guarantee product authenticity. Blockchain startup Luxchain (luxchain.org) offers the option to authenticate luxury goods through decentralized verification based on blockchain and artificial intelligence. The Luxchain solution is based on digital assets, which contain several types of information including products' brand, collection, material, history of ownership, and movements through the supply chain. Digital assets are authenticated by luxury experts and recorded in the blockchain. Customers are able to access the information included in the digital asset and confirm the authenticity of the product.

4.3. How custody assurance reduces functional risk

Most people think that wine becomes better with age, and they are usually correct. However, this depends on the conditions in which the wine is stored. An expensive fine wine must be stored at a very specific temperature and humidity conditions to maintain its worth to the customer when enjoying it. By establishing a line of custody by tracking the wine through its long life from the vineyard to the customer's personal wine collection, customers can assess quality prepurchase. This type of provenance knowledge reassures customers and reduces the functional risk that wine is off because of faulty transportation and inappropriate storage.

The Bordeaux Wine Bank (maxbordeaux.com), a market leader in fine wine trading, has developed a quality label system called Five Star Provenance whereby wines are guaranteed to look, smell, and taste as if customers were enjoying the bottle at the Chateau. The five stars include:

1. The original wooden case;
2. Ex-chateau documentation;
3. Professional post-bottling storage in Bordeaux;
4. 24/7 control and monitoring of temperature and humidity; and
5. Annual procedure certification by a professional auditor.

This is topped off with a tamper-proof and radio frequency identification (RFID) traceability when transporting the wine under temperature and humidity controlled conditions to the customers'

desired location. This service is very costly and is often only viable for the best and most expensive wines, but blockchain offers a less expensive and less resource intensive solution for those who want custody assurance without the pricey process.

Catina Volpone vineyard (www.cantinavolpone.it) in Puglia, Italy, partnered with Ernst and Young's EZ Lab (www.ezlab.it) to develop the first wine case certified by blockchain technology. Volpone's application of blockchain enables full transparency of their supply chain with customers able to see every minute detail including the harvesting, pressing, and bottling dates; water consumed in production; exact GPS location of rows in the vineyard where the grapes grew; and the number of the oak barrel were the wine was made, among other details. Customers can access these details about a specific bottle or case of wine on the vineyard's website and even go into depth on the specific blocks that describe its production when considering a purchase that ranges from €9 to €20 per bottle. Volpone's customers have provenance knowledge that the wine was produced in a traditional way that guarantees quality and sustainability and this increases objective wine knowledge (Robson, Plangger, Campbell, & Pitt, 2014).

4.4. How integrity assurance reduces physical risk

Online retailers sell prescription drugs and controlled pharmaceuticals such as Viagra, hair-loss treatments, weight-loss or -gain solutions, pain management pills, among other pharmaceutical prescriptions directly to customers. For these customers, the potential value of supply chain provenance lies mainly in the assurance of the integrity of drugs, which reduces perceived physical risks. The integrity assurance and the reduction of physical risk become particularly important with the rise of counterfeit products, which are often sold through online retailers. The amount of counterfeit pharmaceutical products has dramatically increased over the last decade. According to the World Health Organization, globally 10% of medicines are counterfeit, with 30% in developing countries (Alzahrani & Bulusu, 2018). Because drugs change ownership from manufacturers to distributors, re-packagers, and wholesalers before reaching the patient, the supply chain in the pharmaceutical industry is often complex. This complexity allows counterfeits to introduce fake medicine into the system.

Counterfeiters can operate in different ways. They can forge the labels of real products (e.g., falsify expiration dates), develop imitations of genuine products, or apply real products' tags to counterfeit products. Counterfeit products pose significant physical risks for customers by causing critical illness and even death. Attempts to tackle the increasing issue of counterfeit pharmaceutical products largely rely on centralized and trusted actors to coordinate and manage verifiability of these products. These centralized architectures create a bottleneck for the tasks of validating information and increase the danger of a single point of failure.

In contrast, blockchain technology provides verifiability of information through a decentralized system that is not only hard to manipulate through cross-validation of information by peers, but also more efficient, less prone to failure, and less costly. First trials that pair blockchain technology with near field communication (NFC) labels have shown that the decentralized approach is able to track products and detect modification, cloning, and tag replication (Alzahrani & Bulusu, 2018), which are typical tactics of counterfeiters. The LifeCrypter blockchain is a system for tracking medical supply chains in which each product is marked with an unambiguous identification tag. This allows all partners in the supply chain to transfer "virtual and physical ownership" (Schöner, Kourouklis, Sandner, Gonzalez, & Förster, 2017, p. 5). Through smart contracts, actors are also able to introduce rules for trades that are transparent at every stage. Patients are then enabled to verify products independently through a mobile app. The pharmaceutical giant Novartis is also experimenting with blockchain technology to identify counterfeit drugs and track temperature with a real-time tracking system, which can verify the integrity of drugs and reduce customers' perceived physical risks.

5. A blockchain guide for enhancing provenance knowledge

5.1. Where and when is it appropriate?

Blockchain is appropriate wherever provenance knowledge is lacking in the minds of customers. As discussed earlier, this is due to information asymmetry between customers and firms that could come from physical distance between them, an unfamiliar purchasing context, or a limited level of expertise. Moreover, blockchain would be especially appropriate for products that customers carefully consider before purchasing, such as high involvement products including those that are expensive, important, novel, or personally relevant. In these cases, blockchain technology adds valuable provenance information that can reduce perceived

risks, solidify favorable attitudes, and nudge purchase decisions.

5.2. Why is it useful?

Blockchain is useful when customers lack provenance knowledge and perceive increased risks. For example, this technology offers a powerful solution to certify the authenticity of products that can be easily counterfeited such as luxury clothing, technologies, or pharmaceuticals. Blockchain provides the systems and infrastructures to attach secure digital identities to physical materials and products rendering counterfeiting extremely difficult. Because of this capability, blockchain could represent a strategic investment for firms involved in manufacturing or distributing highly desirable products with risk of counterfeiting. Blockchain embedded supply chains foster provenance knowledge that can increase sales while protecting valuable intellectual property.

Furthermore, blockchain can also simplify supply chains by reducing the need for multiple intermediaries thus eliminating some transaction costs. A small producer of local cheese in Estonia can use blockchain to obtain a license to sell in Canada by demonstrating the traceability and trackability of their entire supply chain. Customers would have provenance knowledge that would reduce the perceived risks associated with an unknown cheese producer, thus encouraging trial and purchase.

5.3. How to implement it?

There are three considerations in implementing a blockchain in a supply chain to establish provenance knowledge. First, all partners in a supply chain need to agree on the blockchain solution and collaborate to implement it together. For example, a leather sneaker supply chain would need agreement from all the partners, from the cattle farm to the tannery to manufacturers to retailer, as well as the sneaker designer, on the process modifications needed to implement the blockchain. Second, financial investments need to be made by supply chain partners to reduce the need for manual information entry by employees as this leaves room for errors and manipulation. Investments in technologies, including sensors, artificial intelligence-enabled surveillance, RFID chips, NFC tags, barcodes, or quick response (QR) codes, help to remove this human component from the blockchain ledger. Third, customers need to be aware of and be able to access the provenance knowledge contained in the blockchain. This might mean product packaging adjustments, a promotional campaign, website modifications, or the development of a smartphone app. Thus, implementing blockchain into a supply chain needs not only the agreement and willingness of the supply chain partners, but also the financial investment to enable automatic information entry into the blockchain, as well as communicating to customers where to access the additional provenance information.

5.4. What are the risks?

As blockchain increases supply chain transparency, scrutiny from customers and other interested people becomes possible and some of this additional attention might be negative. For example, consider a Japanese Kobe beef producer that wants to protect against counterfeiting and certify the authenticity of its premium products to the customers. While blockchain would be able to do this, it would also increase the exposure of the firm to other actors, including competitors and other organizations, thus risking trade secrets, intellectual property, and supply chain details. Regardless of the specific industry context, firms considering this solution to increase customers' provenance knowledge must do a careful analysis of all stakeholders and their reactions to a fully transparent supply chain.

6. Forging meaningful chains

Blockchain technology promises to create transparent supply chains that generate provenance knowledge by allowing all parties involved—including customers—to trace the origin, certify authenticity, track custody, and verify integrity of products. Provenance knowledge reduces customers' perceived risks and reinforces customers' confidence in the purchase and consumption of products.

However, data without meaning is useless. Many current versions of blockchain solutions are overly technical and provide massive volumes of information that may or may not be of use to customers. Customers may face information overload and, in fact, experience new perceived risks pertaining to excessive volumes of data. Managers using or considering using a blockchain solution to generate provenance knowledge must develop an interface that adds value to customers' decision-making processes without overloading them with useless facts. Remember, forge chains that have meaning for customers.

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