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Harvesting Intrinsically Verifiable Trust: Building a Honey Traceability System for Sustainable Development

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Abstract

Creating and building trust between consumers and producers is an important and challenging problem for the global economy, in particular for agricultural markets that rely on smallholder producers in mostly rural areas. We propose that Distributed Ledger Technology (DLT) can support a new, more scalable, and robust form of trust creation built on value congruence and *intrinsically verifiable trust*. A permissioned blockchain, in combination with a data-backed record-keeping system and IoT sensor data, allows producers and consumers to verify product characteristics such as provenance, production conditions, and environmental, social, and economic impacts. We study the application of DLT and our model for trust creation in the context of honey supply networks. Honey is one of the most adulterated food products globally and honey production offers high potential for rural development, livelihood fortification, and food security through crop pollination. We demonstrate how the implementation of DLT may help mitigate the deteriorating trust in honey product integrity while, at the same time, grant smallholder beekeepers greater access to markets and leverage for product differentiation.

Keywords: Economic Development, Sustainability, Blockchain, Trust, Value Congruence

1. INTRODUCTION

Research shows that consumers would be willing to pay more for a product if they knew it was in line with their values (Cazier et al., 2006 and Cazier et al., 2017). More specifically, Loreiro and Lotade (2005) show that consumers are willing to pay higher price premiums for fair trade labeled coffee over organic offerings. To underscore food labelling's importance, Tonkin et al. (2015) describe the labelling as "a channel for communication between the food system and consumers" (p.319).

Providing the consumer with choices that are specific, safe, nutritious, ecologically-viable, and profitable for the producers helps to grow markets and unlock the development potential of smallholder producers and rural areas through product differentiation. Research shows that Distributed Ledger Technology (DLT) has the potential to further enhance traceability and accountability throughout the production and transport process (Min, 2019). In addition, DLT can create an infrastructure that enables consumers to connect with producers and the origin of their produce through technology while reducing the cost of product differentiation.

To show the potential of DLT to strengthen supply networks for different groups of stakeholders, we will use honey production as a use case for the beneficial extension of trust based on three principal reasons as summarized in Table 1. First, beekeeping has been described as an ideal, accessible, and empowering opportunity for rural entrepreneurs in economically-challenged areas (Mburu et al., 2015). Start-up costs are low, the infrastructure required is minimal, and, as a non-perishable good, honey can be stored and sold throughout the year. Hence, development actors, governments, and farmers have embraced beekeeping as a means for livelihood diversification in rural and semi-urban areas contributing to the United Nations Sustainable Development Goals (see Table 1) (Mujuni et al., 2012; Ogaba, M., and Akongo, T., 2001). Second, beekeeping offers positive externalities by providing ecosystem services in the form of pollination, stabilizing yields, biodiversity, and ecologically-intensifying farming practices (Klein et al., 2007). Third, bottled honey is also among the most adulterated food products in the world, currently ranking among the highest three, creating a strong incentive for more transparent honey supply networks globally (García, 2018).

This paper studies the promise and implementation challenges of applying DLT to the beekeeping sector to enable product integrity and encourage sustainable development. The objective is to illustrate how such a system can support supply network stakeholders from beekeepers to aggregators to vendors and consumers in adopting and supporting sustainable production processes.

Beekeeping-related impact	United Nations Sustainable Development Goal
Livelihood diversification (Mujuni et al., 2012; Ogaba, M., and Akongo, T., 2001)	Goal 1 - No Poverty Goal 2 - Zero Hunger Goal 8 - Decent Work and Economic Growth
Pollination ecosystem services to farmers, stabilizing yields and biodiversity (Klein et al., 2007)	Goal 11 - Sustainable Cities and Communities Goal 13 - Climate Action
More accountable honey production (García, 2018).	Goal 12 - Responsible Consumption and Production

Table 1: Beekeeping-related impacts and their contribution to the Sustainable Development Goals.

2. RELATED WORK

Value Congruence and Purchasing Decisions A value is understood as a set of principles or standards guiding an individual's conduct. Moreover, values serve as a normative guide when choosing between various behavioral patterns (Elizur and Sagie, 1999). While consumer values are based on personal beliefs and backgrounds, a company projects a variety of values. In his work on the links between product attributes and values, Gutman (1982) finds that values significantly influence purchasing behaviors.

Value congruence defines the state when specific values held by consumers are congruent with the values projected by a company (Cazier et al., 2006 and Cazier et al., 2017). Cazier et al. (2007) and Zhao et al. (2012) show that value congruence increases trust and impacts the disclosure of personal information both directly and indirectly (through trust). In making value-based purchasing decisions as reflected in the choice of ethically or ecologically labeled items, value congruence takes a prominent role (Cazier et al., 2017). Namely, the congruence of values between organizations and consumers, upon which purchasing decisions rely, is facilitated through trust (Cazier et al., 2006).

Trust

Trust is defined as, "The willingness of a party to be vulnerable to the actions of another party based on the expectation that the other will perform a particular action important to the trustor, irrespective of the ability to monitor or control that other party" (Mayer, Davis and Schoorman, 1995, p. 712). Furthermore, trust is the willingness to take a risk and not the level of risk per se. In their model, Mayer, Davis, and Schoorman define the propensity to trust as a trait that "leads to a generalized expectation about the trustworthiness of others" or "the general willingness to trust others" (p. 715). While the natural propensity to trust varies among people, it can be influenced by the three primary forces of trust creation outlined below. These forces change the person's perceptions on one or more of the three dimensions of trustworthiness.

The Dimensions of Trustworthiness

Following Mayer et al.'s (1995) work, trust is commonly theorized to be built upon three dimensions: *ability*, *benevolence*, and *integrity*. Ability is the group of skills, competencies, and characteristics that enable a party to influence a specific domain. While the ability factor includes domain level expertise, it is not limited to that element. Other elements such as quality, innovativeness, and prestige can influence the perception of ability, which may disguise the true ability. Benevolence is the extent to which a trustee is believed to want to do good for the one trusting them, aside from their own self-centered motive. Integrity is the trustor's perception that the trustee will adhere to a set of principles that the person trusting them finds acceptable.

The Three Primary Forces of Trust Creation

Trust is a complex multidimensional construct that can be affected in different ways by different trust production methods (Zucker, 1986). Namely, three main forces lead to the creation of trust by producing information on and influencing perceptions of the dimensions of trustworthiness: *process-*, *characteristic-* and *institution-based* trust creation (See Figure 1) (Zucker, 1986, Cazier, 2007). *Process-based trust production* captures how information from past experiences and interactions influence perceptions of trustworthiness for future exchanges. *Characteristic-based trust production* influences perceptions of the dimensions of trustworthiness through a sense of shared commonality with the other party that may include shared values, a common background, culture, or ethnicity.

Trust is increased by having something in common with the other party or by possessing a characteristic the trustor finds desirable. Trust based on characteristics corresponds to the factor of benevolence and integrity (Cazier, 2007). *Institution-based trust* influences perceptions of the dimensions of trustworthiness through the use of a third party, which can be a government agency, a bank, or some other central organization that, in its role as facilitator or intermediary, assures the trustworthiness of the target organization. Such a transference of trust to intermediaries, then allows an entity to benefit from that trust. The concept is illustrated in Figure 1. below.

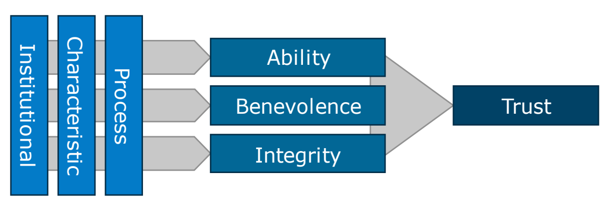

Figure 1. The Primary Forces of Trust Creation - Traditional Model For Trust Creation adapted from Cazier (2007).

Not all primary forces of trust production affect trust in the same way, and trust is not binary, it goes beyond simply trusting or not trusting (Zucker, 1986). Different types of trust creation can affect the factors of trustworthiness in various ways, prompting different behaviors in the trustors.

The three types of trust creation defined above have several weaknesses. Any recently established company faces the challenge of convincing the consumer of the integrity of its products, as both process-based and characteristic-based trust are limited in the early stages of a business endeavor where prior exchanges are absent or constrained. Furthermore, characteristic-based trust does not bridge well across cultures as regional or national borders confine shared commonalities. This has become a more prominent limitation of trust building in our context due to globalization of agricultural supply chains as it relates to fair trade products and to smallholder farmers specifically.

These limitations in scalability to new (process-based trust) or foreign (characteristic-based trust) markets have left institutional-based trust as the primary source for trust creation for international commerce. However, institution-based trust is also limited in its ability to promote rural economic growth. Indeed, institution-based trust, which in the development sector has manifested itself in labels and certificates, has been a significant barrier to entry for many smallholder farmers in rural areas due to significant requirements regarding infrastructure or production capacity and quality (Barrett et al., 2001). Therefore, institution-based trust often only scales at a high cost. At the same time, institutions may lack genuine trust, especially across borders, as they have shown to be prone to corruptibility.

Distributed Ledger Technology

Distributed Ledger Technology (DLT) enables the secure functioning of a decentralized digital database through a defined protocol. The distributed architecture of the network eliminates the need for a central authority to guard against manipulation (Swan, 2015).

DLT utilizes cryptography to store all the information in a secure and accurate manner. Once stored, the information becomes an immutable database and is governed by the rules of the network. Stored data can be accessed via keys and cryptographic signatures (Olnes et.al, 2017).

The nature of a decentralized ledger makes it immune to a cyber-attack, as all the copies stored across the network must be attacked at the same time to be successful. Additionally, the peer-to-peer sharing and updating of records make the whole process more effective, faster and cheaper (Nakamoto, 2008).

For additional information, the reader is referred to Olnes et.al. (2017).

3. THEORY DEVELOPMENT

In light of the limitations of traditional forces for trust creation outlined above, nascent DLT may help pave the way for a new force for trust creation. We model intrinsically verifiable trust as a force of trust creation, similar to institution-based trust creation, that influences a stakeholder's perceptions of the dimensions of trustworthiness. Driven by its underlying consensus mechanism, explained in more detail below, DLT's decentralized, immutable and secure nature, allows anyone, anywhere - in theory - to verify trust beyond processes, institutions, and characteristics. We define this new force for trust creation as follows.

Intrinsically Verifiable Trust describes the characteristic of being verifiable by itself in an independent way. Notably, intrinsically verifiable trust influences perceptions on the dimensions of trust through an underlying automated cryptographic and algorithmic mechanism that allows any user to verify the existence and veracity of the provided information independently.

The intrinsically verifiable nature of DLT, among many other applications, allows consumers to gain confidence through verifiable and potentially real-time traceability of marketed goods along a digitized supply network. Since trust has been proven to increase price premiums (Cazier et al., 2017), DLT-enabled intrinsically verifiable trust should also positively impact prices vendors can charge for agricultural and other products. Figure 2. Illustrates this additional force for trust creation.

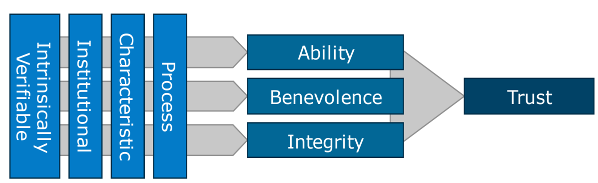

Figure 2. Updated Model for Trust Creation adapted from Cazier (2007).

The distributed ledger allows those in the value chain with limited influence, time, resources, or technical abilities to see the actions of other organizations with more power. For consumers, intrinsically verifiable trust helps to unveil the actors at stages further up the supply chain toward the producer. The consumer may not have the time, resources, or technical

capabilities to evaluate all of the information on the blockchain, but knowing it exists could still influence perceptions of dimensions of trustworthiness in other players across stages of the supply chain.
Intrinsically verifiable trust allows the producers to see further down the supply chain toward the consumer and trust that their product has not been adulterated along the way and that they are receiving a fair price for the product. Throughout the network, intrinsically verifiable trust helps to enable greater information sharing and more accurate forecasting as upstream players have a clearer picture of end consumer demand, which helps to support supply chain coordination and address issues with the bullwhip effect.
Intrinsically verifiable trust will likely play a more prominent role as the supply chain becomes longer, more complex, and increasingly globalized. Let's consider some simple examples in our context of honey supply chains to illustrate this point.

- Case #1: Suppose the consumer purchases the honey from a favorite small local producer who sells it at the local farmer's market or a roadside produce stand. In this case, a blockchain or IoT sensors may help the seller to build trust by verifying where certain actions were taken in production; but given the proximity, the consumer would likely rely more on process-based and characteristic-based forces of trust creation. For example, the consumer drives by the producer's farm on the way to work, the consumer has purchased honey with that producer in the past, or the consumer and the seller attend the same faith community or drive the same model of car.

- Case #2. Suppose the consumer purchases the honey from a favorite small local bakery that procured the honey directly from a small producer within the same region. In this case, blockchain technology could help to verify the producer's actions as in Case #1 and now also the seller's actions, e.g., the product was not altered, damaged, or stored incorrectly. However, process- and characteristic- based trust still play prominent roles. Perceived shared characteristics due to local sourcing could promote trust between the consumer and the producer. Past experiences and shared characteristics with the bakery could promote trust between the consumer and the seller, e.g., the consumer also buys bread and jam from this bakery and has had favorable past experiences.

- Case #3. Suppose the consumer purchases honey from a local franchise of a large grocery store chain that stocks honey produced by a small producer of similar size to Cases #1 and #2 in a country on a different continent. The product must pass through multiple hands including an aggregator, exporter, and distributor before reaching the grocery store. The product is labeled "organic fair trade certified", but the consumer recently read a news article discussing corruption in fair trade certification. In this case, the intrinsically verifiable trust will play a greater role by allowing the consumer to see further up the supply chain across a wider scope of activities and by addressing the gaps in process-, characteristic-, and institution-based forces of trust creation due to globalization and the complexity for this scenario.

Intrinsically verifiable trust may play a crucial role in the development sector. Enabling smallholder producers backed by DLT to access both local and the global supply networks can allow them to sell agricultural produce based on verifiable provenance and characteristics to markets of value congruent consumers. As Barrett et al. (2001) show, currently, smallholder producers often rely on prohibitively expensive third-party assessment to prove the integrity of their products.

Distributed ledger-based systems, however, allow for a low entry-barrier implementation, as access to the internet is the driving requirement to start recording time-stamped and immutable activities throughout the production process. Consumers, then, being able to verify the integrity of the product, would be more willing to pay price premiums, which eventually help smallholder farmers in rural areas strengthen their livelihoods. Thus, the factors of trust creation mentioned above, upon which value congruence has a positive effect through a more generous perception, heavily influence the way trust is created, mostly through the Characteristic Based Trust-creating mechanism. Furthermore, trust is facilitated through the congruence of values of consumers and organizations (Cazier et al., 2006).

Blockchain
The value of DLT, such as the blockchain, is the underlying process that validates blocks and

records them on the public ledger (Swan, 2015). Through a mechanism of consensus, each DLT and its supporting network use a protocol to make the inclusion of a new block intrinsically verifiable. In the case of the Proof-Of-Work (PoW) mechanism, solving a cryptographic puzzle requiring critical amounts of computer processing power grants a miner the right to add the next block to the chain (Nakamoto, 2008).

The public ledger is valuable for its transparency and integrity of transactions in the form of data stored within each block. On a public or permissionless ledger, all non-identifiable information related to a transaction within a block is viewable to any entity at any time. Moreover, information stored within a block is immutable as cryptographic hashes, integral components of the blockchain, and included within each transaction, providing blocks with an identity (Nakamoto, 2008).

As new blocks must include the prior blocks' cryptographic hash (e.g., a hash point), the blockchain can quickly identify ostensibly altered blocks. Since the nodes recognize a new block using the verifiability provided via the ledger-inherent consensus mechanism outlined above, any alteration disrupts the chain and disallows access. The consensus mechanism illustrates the value in being distributed as the community of nodes (e.g., miners in the PoW case) that are responsible for the blockchain's network as this community of nodes contributes to the verification of transactions within a block on the blockchain. Thus, to take control of the blockchain, a majority of nodes would be needed (i.e., 51 percent attack). By default, the decentralized architecture of the blockchain has enormous value as it manifests intrinsically verifiable information.

Indeed, the unique features of DLTs in general and the consensus mechanism-backed blockchain, in particular, may open a new era in the age of data analytics. First, the combination of cryptographic features, the consensus mechanism, and their decentralized nature ensures the integrity of data once they are stored on the blockchain, thus generating trust through intrinsically verifiable information. Second, data stored on the blockchain enables data analytics as data is available in a standardized manner. Third, data is easily tracked and shared across peers to facilitate analytics. Fourth, timestamps on each data entry on the blockchain allow the accurate visualization of the data history and near real-time analysis (Brooke, 2019). Rünzel et al. (2021) show how a blockchain traceability system could be built and the type of data that would be needed to be effective.

Data-Driven Beekeeping for Development

Beekeeping has been described as an ideal, accessible, and empowering opportunity for both men and women who are rural entrepreneurs in economically challenged areas (Mburu et al., 2015). Hence, development actors, governments, and farmers have embraced beekeeping as an alternative for livelihood diversification, particularly in rural areas (Mujuni et al., 2012; Ogaba and Akongo, 2001). Comparatively low labor requirements and start-up costs in combination with minimal land use are just some of beekeeping's competitive advantages for on-farm integration (Ogaba, 2002; Ndyomugyenyi et al., 2015; Gupta et al., 2014). Beyond stable year-round financial contributions that strengthen smallholder livelihoods, bee pollination benefits not only the beekeepers but also helps the farmers by increasing their yields. Providing more plentiful food in the region reduces hunger and helps alleviate poverty by reducing food costs in rural areas (Sacco et al., 2014).

The need for technological intervention has been recently summarized by Lietaer (2019): "Despite the favorable natural environment existing in almost all developing countries and the potential for building sustainable livelihoods in rural areas, beekeeping often lacks the necessary financial, extension, and technological support required to fully exploit its great potential in conserving forests and natural ecosystems and in reducing poverty." A significant development in unlocking this potential could be realized by sustainably-increasing honey production through technological, data-enabled solutions that improve beekeeping practices and bee health.

Honey Traceability

In line with coffee, chocolate, and wine, among others, honey is one of the most adulterated higher-value foods (Everstine et al., 2013). Methods of EMA - commonly referred to as food fraud - in the honey sector include diluting and extending honey, and transshipping (e.g., adulterating the origin of imports to avoid the payment of tariffs or even testing) (Strayer et al., 2014).

In the U.S. particularly, several aspects render the control of honey adulteration difficult. First, given its international market status, 75% of the honey supply is imported (Mathews et al., 2019). Second, as of today, there is no identity standard for honey on the U.S. federal level, which slows down regulatory efforts that could verify honey safety and quality. Third, trade policies, such as free trade areas, lead to shared responsibilities weakening the control process. Fourth, indeed, analytical methods that may detect honey adulteration are - still - insufficient or too cost-intensive to be performed on a regular and scalable basis (Strayer et al., 2014).

Trust & Honey Traceability for Development
Having identified traceability as a critical solution to the problem of economically-motivated honey adulteration, verifiable traceability can help beekeepers as it tackles one of the emerging problems underpinning the honey business. Namely, honey adulteration and fraud are outpacing methods of detection and verification, further eroding consumer confidence. At the same time, this drives the growth of the emerging varietal and local honey markets. Smallholder producers - equipped with the right means to prove the origin and veracity of honey verifiably - may benefit significantly, both in the Global South and Global North.

Blockchain technology, product differentiation, and price premiums in the global honey market
While it is challenging to produce accurate data on the amounts of adulterated honey available, industry statistics help illustrate the size of the phenomenon. Notably, since 2007, honey exports have increased by 61 percent, while the number of beehives has increased by only approximately 8 percent (FAO, 2018).

One of the implications of this honey supply surge is deteriorating prices for international bulk import prices. As García (2018) states, honey purity is not guaranteed by a higher price. Low-priced honey, however, has a higher likelihood of being subject to adulteration. Hence, import prices serve as an indicator of the quality of honey and the need to perform further tests for quality, origin, and purity (García, 2016).

The European Union, the second-largest producer of honey worldwide and an important importer of honey, found in a recent study that 14 percent of the honey analyzed across all member states, including Norway and Switzerland, had been adulterated (Aries et al., 2016). The Canadian Food Inspection Agency even reported that 21.7 percent of the jars of honey tested showed the presence of added sugar (Canadian Food Inspection Agency, 2019). Moreover, lower prices and production costs, as well as illegal practices, affect beekeepers' income and are stated as a threat to European producers' market shares (Rossi, 2017).

To combat these problems, beekeepers across the European Union currently aim to evoke trust in their honey through 46 labels of Protected Designation of Origin (PDO) or Protected marketing advantages (Walley et al., 1999). Also, regional labels increase the Willingness To Pay (WTP) and attract consumers with higher incomes (Van Ittersum et al., 1999). Vecchio

Geographical Indication (PGI) (European Commission, 2019). Research shows that these labels add value to the product, including and Anunziata (2011) even show that these labels may be the primary purchasing motivation for people with a thorough knowledge of the labeling system.

Likewise, consumers pay price premiums for varietal types of honey. Data from Spain shows that honeydew honey's retail prices are, on average 27 percent higher than multifloral honey (European Commission, 2017).

	Impact of Fair Trade (ie. coffee)	Impact of Organic (bulk honey)	Impact of Varietals (ie. honeydew honey)	Impact of Geographical Labeling (ie. effect of PDOs adjusted for product specificity)
Price Premiums	10%-27%	7%	27%	21%

Sources: (De Pelsmacker et al., 2005; National Honey Board, 2019; European Commission, 2017; Deselnicu et al., 2013, from left to right)

Table 2. Potential Economic Value Added Through Price Premiums

Similarly, in the international market for wholesale bulk honey, a price premium of 7 percent is charged for organic honey (National Honey Board, 2019). Given an estimated global organic honey market size of $500 million in 2017, and assuming this increase in pricing is passed along to retail consumers, verifiable organic honey results in economic value creation of upwards of $35 million. The market for organic honey is projected to increase to $910 million by 2023, driving the economic impact even larger and creating opportunities for new players to benefit (Statista, 2017).

Research on price premiums related to fair trade coffee shows that consumers are willing to pay a 10 percent price premium on average, while supporters of the fair-trade program are willing to pay up to 27 percent more (De Pelsmacker et al., 2005). Moreover, Arnot et al. (2006) find that purchasers of fair trade-labeled coffee are less price-sensitive compared to their peers. The authors use a choice model to confirm earlier WTP studies' findings that consumers are willing to pay price premiums outside of stated preference studies' hypothetical settings.

Hence, consumers who can verify the integrity, quality, and origin of the honey they buy are willing to pay price premiums. Moreover, value congruence will further increase the price premium paid, as value congruent consumers may confirm overlapping values through origin and ethical production checks. The range of price premiums cited for the impact of fair-trade coffee illustrates the market potential for products driven by value congruent consumers. Potential price premiums for blockchain-enabled verifiable characteristics are provided in Table 2.

DLT-backed and data-driven beekeeping will allow smallholder beekeepers access to markets and price premiums from both standard and value congruent consumers. At the same time, intrinsically verifiable trust in the honey will alleviate pressure from adulterated honey and protect beekeepers' livelihoods. If the price premiums observed for fair trade coffee are similar for honey with verifiable integrity and quality from developing countries, price premiums between 10 percent to 27 percent would result in economic value creation of $91 to $246 million for the African smallholder honey economy alone, which amounts to 13% of the $7 billion global honey production market (Châtel, 2017; Statista, 2018). Beyond price premiums, however, DLT can allow new forms of product differentiation and has the potential to significantly decrease the transaction costs of assessing and certifying product characteristics, unlocking the potential to profoundly disrupt and transform how value can be created in the Global South.

4. CONCLUSION

Beekeeping has been acknowledged as a sustainable and low-investment strategy to alleviate poverty, providing rural populations with a stable income. The affordability and flexibility of beekeeping lowers the threshold to enter the beekeeping business even in remote areas. We contend that distributed ledger technology may prove to be the right technology to solve two pressing problems of emerging and established beekeeping industries, mitigating the deteriorating trust in honey product integrity and, at the same time, granting smallholder beekeepers access to markets.

Value congruence has the potential to radically alter our ability to influence others in sustainable ways through our purchase behaviors. However, this can only be realized through a system that includes data, analytics, and intrinsically verifiable trust, enabled through records on a distributed ledger. Taken together, this collection of technologies can build a precise traceability and authenticity system that shows the entire history and origin for each product. This can have a profound impact by setting up proper economic incentives to align with the values of consumers and decision makers, and drive product differentiation. Nascent distributed ledger technology is disrupting the way we perceive trust. Blockchain technology extends the boundaries of the traditional model of trust creation, paving the way for new forms of data analytics.

The nature of distributed ledger technologies, such as blockchain, allows for improved data integrity, as well as complete and open data in a secure and decentralized system. Within the use case of beekeeping, we have shown the potential for improved descriptive, diagnostic, predictive, and prescriptive analytics for hive management, helping beekeepers across the globe become more productive and resource-efficient. Enabling smallholder beekeepers backed by DLT-enabled data analytics and traceability to enhance their beekeeping operations and take part in the honey value chain would unlock the development potential of rural areas while strengthening the biodiversity and food supply, and contributing to several of the Sustainable Development Goals of the United Nations.

Future research could focus on the technical and operational side of implementing and testing a DLT-backed traceability system that supports beekeepers in rural areas, proving that development can be both economically viable and environmentally sustainable. Eventually, other value chains could follow to ensure smallholder producers have a stake in the value chain and access to value congruent consumers so that sustainable development reaches even the most rural areas.

While blockchain cannot guarantee that a product is not adulterated, it can decrease the likelihood. By tracing honey production in an unalterable way and connecting it with a labeling system, adulteration due to dilution, extension, and transshipment is reduced as the source and amount of honey produced are verified along the supply chain.

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