DIGITAL VALUE CHAINS – AN EXPLORATORY STUDY OF THE AGRICULTURE AND FOOD INDUSTRY

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Abstract: *This research examines the potential impact of (decentral) digital technologies on value chains in the agriculture and food industry. A mixed methods approach/triangulation is used to capture research insights as this field of research is rather premature. Thus, research is done via intensively reviewing existing literature, case studies with actual examples in three sub-industries and in-depth expert interviews with experts that have different perspectives on the value chains of the industry. Findings show that value chain players might use (decentral) digital technologies to improve the positioning of products whereby sustainability can serve as key theme. Additionally, (decentral) digital technologies might have the potential to improve transparency and efficiency but are not likely to substitute incumbent value chain roles based on this exploratory research.*

Keywords: *Value Chains, Agriculture, Nutrition, Platforms, IoT, Blockchain*

I. Intro

Value chains of the agriculture and food industry are often complex, requiring various players from farm to fork to cooperate in time, ensure quality, efficiency and optimal management of interfaces. Highly globalized value chains interact with very local ones and value chain players have in many cases a high degree of interdependency to ensure a proper outcome for consumers at the end of the value chains (Rejeb, et al., 2019).

Recent research on value chains in the agriculture and food industry demonstrate the complexity and interconnectedness of value chains in this sectors, e.g., by assessing the coffee value chain with often small coffee bean farmers at the beginning of the value chain that sell their products to cooperatives or processing companies which dry and process the beans from various sources, mix and blend them. Afterwards products are roasted in mostly larger roasteries and then finally marketed, often by large global consumer brands (Grabs & Ponte, 2019). Players rely on the quality and reliability of other players to operate successful and goods are mixed, blended and processes at lot throughout the entire value chain, making tracking of goods fairly tricky. For those types of value chains with global and local dimensions and high degree of processing, only those will be effective that balance the interests of all those players in a meaningful way (Tripoli & Schmidhuber, 2018).

Looking at such types of value chains, two elements turn out to be important for effectiveness: reliable supply of raw materials (i.e., yield of coffee beans) and the transparency along the value chain to meet certain requirements towards consumers (e.g., „fair trade"), especially for homogenous products such as rice or coffee.

Assessing the power patterns within such value chains, it seems that consumer brands need to rely on farmers in order to get sufficient raw materials supplied while at the same time farmers rely on consumer brands in order to sell their goods (Taylor, 2005).

For the farming stage of the value chain, new digital technologies such as precision farming are emerging that eventually boost efficiency and effectiveness, with the potential to change the power pattern of the value chain to the benefit of farmers (Patel, et al., 2021).

Other value chains in the agriculture and food industry show similar power patterns and interdependencies, such as the value chains for meat production with feedstock supply for animals, farmers that grow animals, slaughterhouses and processors and finally distributors and supermarkets (Zokaei & Simons, 2006). Also transparency and traceability becomes more prominent recently as certain quality statements are made towards consumers such as bio-based or outdoor-breeding. Additionally, goods need to meet certain conditions along processing, for example being stored and transported at certain temperature levels.

As value chains in this industry are complex, often also depending on indirect value chain players such as crop protection companies for farming, these value chains are fragile as many problems can potentially occur from farm level to supermarkets. New digital technologies such as blockchain and internet of things with sensors might bring new opportunities to value chain players in order to properly track goods along the value chains and thus improve its effectiveness. It´s subject to research if these technologies would enable a potential evolution of value chains and open up new opportunities for its players (Rejeb, et al., 2019). Recent research raises the question if those new digital technologies would unfold an even greater value once they are combined (Patel, et al., 2021). Potential value could be seen in overcoming trust issues such as fraud, especially as many players in this industry do not only serve at subsequent steps but also partially compete at various steps of value chains (Borah, et al., 2020). Initial research suggests that digital tracking technologies have been established across different players in the agriculture and food value chains recently and should become subject to research (Schmidt & Wagner, 2019), especially due to the fact the use cases for decentral digital technologies such as blockchain are rather premature in the agriculture and food industry compared to other industries (Liu, et al., 2021). Some research might see benefits in combing new digital technologies such as internet of things with decentral technologies such as distributed ledgers, as each one could manage the challenges of the other, i.e., distributed ledgers could manage data storage challenges of the internet of things (Torky & Hassanein, 2020) and internet of things could manage data entry challenges for of distributed ledgers (Kim & Laskowski, 2017).

Accordingly, this paper examines a potential impact on value chains, once those digital technologies are used in the agriculture and food industry.

II. Research Design

The research is conducted via a mixed methods and triangulation approach based on literature review, case studies and in-depth expert interviews (Mayring, 2015) as this might offer comprehensive insights and improve quality for exploratory research (Johnson, et al., 2007).

The case studies relate to value chains of different sub-industries within the agriculture and food industry that differ among each other in terms degree of processing of goods, importance of consumer brands and level of globalization vs. localozation: (a) meat & fish value; (b) coffee & cocoa and (c) wine & beer.

For the interviews, experts had been selected that provide various different perspectives on the potential impact of digital technologies on value chains.

The research evolves around three key themes to assess what impact digital technologies such as distributed ledgers and internet of things can have on value chains in the agriculture and food industry:

- Trust
- Coordination
- Business Models

Based on this, 5. key research questions have been defined:

1. Can (decentral) digital technologies help to overcome issues related to trust and transparency?
2. Can (decentral) digital technologies help to allocate resources more efficiently and/or generally optimize flow of goods and processes within the value chains?
3. Can (decentral) digital technologies enable new business models, i.e., new forms of value creation and/or value capture and if so who is creating and capturing it?
4. Can the deployment of (decentral) digital technologies change the way how value chain players interact with each other and how would this influence their relationship among each other then?
5. Can (decentral) digital technologies trigger the rise of new players in the value chains or the disappearance of others and how would this influence the distribution of power along the value chains?

All three sources, literature, case studies and expert interviews are compared to each other in order to identify commonalities that can be explored by future research.

III. Findings

Trust & Transparency

A potential beneficial impact of new digital technologies for trust-related issues such as food safety such as transparently tracking temperature levels along value chains had been pointed out by recent research (Lin, et al., 2018) (Markovic, et al., 2020). Other research shows that especially the distributed ledger technologies such as blockchain can be beneficial for food safety in complex value chains (Antonucci, et al., 2019) or unfold even more value potential if combined with internet of things solutions (Yadav & Singh, 2019). Such technologies could be used instead of other incumbent quality management institutions such as laboratories institutes and by this eventually be more cost-effective (Verma, 2021). Although this might be possible, some research point out the importance that all value chain players that make use of such digital technologies apply the same rules and use the same technology which might not always be easy in practice (Lucena, et al., 2018). Hereby decentral digital technologies such as blockchain can be beneficial as efforts of usage are distributed equally among all participants and no superior institutions is required (Borah, et al., 2020). The topic around trustworthy data entry can be tackled by newer digital technologies such as smart sensors (Sengupta & Kim, 2021) or using infrared technologies and sensors (Tripoli & Schmidhuber, 2018). However, some recent research also point out that some issues related to trust could prevail even if those decentral digital technologies are applied as trustworthy data entry remains a challenge (van Wassenaer, et al., 2021). In essence, mass balance concepts might be a useful approach to manage these challenges that will be subject to further research to investigate (Caro, et al., 2018).

The case studies show similar finding, e.g., a case study on a distributed ledger-based network around the fish value chain called OpenSC that was initiated by the NGO WWF and several digital companies in order to prevent bad fishing practices (Whiting, 2020). Similar practices can be observed for a case study around a blockchain initiative by the Norwegian Seafood Association that offers consumers to track information about the heritage and processing of a fish along the value chain in (Chase, 2020) with the aim to improve trustworthiness towards consumers (ocean.economist.com, 2020).

This could also be observed by assessing use cases of decentral digital technologies across various players in the value chains for wine such as for the TATTOO Wine Platform that aims to prove authenticity of wine towards consumers especially in Asia (Khatri, 2019) or the Everledger wine platform that tracks the flow of wine bottles from one owner to another (Everledger, 2016) that also provides information around the heritage and processing of raw materials for the wine to manage fraud-related issues (Banham & Alper-Leroux, 2021).

A similar rationale was subject to a case study for the meat value chain in South America whereby a blockchain-based system was established by meat producer JBS together with a Brazilian company Ecotrace to assess if farming practices match certain sustainability requirements (Feedtsuffs.com, 2021) whereby data privacy is managed via the decentral digital technology (Ferrer, 2021). Also in other value chains of the agriculture and food industry, such as the coffee value chain, case studies show that decentral digital technologies are used to support trust as with the Massimo Zanetti Beverage Group that established a tracking system for coffee in order to proof the origin of coffee towards consumers (Ferrer, 2021). Similar case studies such as a tracking system for cocoa show that such systems can even benefit farmers that might have a lower bargaining power within the respective value chain (Newar, 2022). Essentially, positioning towards consumers by traceability is key to all case studies that make of decentral digital technologies, e.g., to improve sustainability claims towards customers. However, integrating all those decentral technologies and data points can remain a key challenge for value chain players (Schleicher, 2020).

Various interviewed experts state that transparency will be a key benefit and driver for using decentral digital technologies across value chains, especially pointing towards making claims around sustainability towards consumers. Some of the experts see the rise of those decentral digital technologies being linked to the increase of regulations in the area of sustainability whereby these technologies can help value chain players to manage those regulatory requirements more efficiently. Not fully consistent with recent literature, experts confirm that managing trust-related issues can be a valid challenge for the value chains of the agriculture and food industry but with rather minor importance compared to the literature. However, some interviewed experts point towards geographical differences for the importance of managing fraud-related issues.

Coordination & Process Efficiency

Recent research points out that especially in highly fragmented and complex value chains decentral digital technologies can be supportive to improve process efficiency and speed as it helps with coordination across various players along value chains in the agriculture and food industry (Kamble, et al., 2020). Some authors see benefits in improving speed for commercial transactions, e.g., via smart contracts (Tripoli & Schmidhuber, 2018) while others see benefits of connecting various players that would not have been connected before using such decentral digital technologies, eventually reducing the number of players being required to operate a value chain up to consumer level (Linsner, et al., 2019). Consequently, recent research focuses on the potential of reducing intermediary players (Surasak, et al., 2019) whereas smart contracts, i.e., executing pre-defined actions if certain prerequisites are met, could play a key role (Yadav & Singh, 2019). In line with this thinking, some authors see those decentral technologies and smart contracts that are enabled by them as enabler of a potential circular economy if those technologies would be scaled (Casado-Vara, et al., 2018). However, the integration of all those systems and the commitment to one unilateral standard

that might be required for those technologies to work seamlessly will likely remain a key challenge according to recent research (Kim & Laskowski, 2017).

Case studies that apply decentral digital technologies show that process efficiency within value chains of the agriculture and food industry could be supported, e.g., by saving time for validation across different value chain players as a recent example for a meat value chain in Ireland shows (Green, 2020). However, process efficiency is one benefit but much less in focus compared to creating transparency when looking at the different case studies.

These findings are also echoed by the interviewed experts, with many stating that process efficiency is linked to the usage of decentral digital technologies, enabling the reduction of admin work and maybe even making some incumbent administrative steps abundant. Public data sharing is seen by some experts as vital instrument to boost for process efficiency for individual value chains, especially in agriculture and food, e.g., sharing data points for animals during breeding phase by farmers so subsequent value chain players can already take action. However, some experts state that real improvement will be established if all participants of a value chain will be connected via such technologies, connecting only a few might have limited benefit though.

Business Model Evolution

Smart contracts, using various decentral digital technologies in order trigger certain actions if predefined requirements are met, can have a significant impact on business models according to recent research (Patel, et al., 2021), especially for smart farming practices in the agricultural space (Torky & Hassanein, 2020) and to manage overall supply chains efficiently (Antonucci, et al., 2019). However, increased transparency that might come with the rise and usage of such decentral digital technologies might also put data privacy issues more into focus and some value chain players could refrain from sharing data points across various players in a value chain (Liu, et al., 2021). Business model evolution along decentral digital technologies is perceived in the context of cost savings for the agriculture and food industry, especially certain technologies can be combined in a smart way such as distributed ledger technologies with smart sensors and Internet of Things solutions whereby distributed ledgers can help to reduce energy consumption of Internet of Things-solutions (Awan, et al., 2020). Additionally, cost savings potentially is seen by recent research by the reduction of administrative activities for value chain players (Tripoli & Schmidhuber, 2018). Notwithstanding, if the combination of decentral digital technologies might have the potential to reduce administrative tasks on one hand, its usage across various value chain payers might require a superior coordinating entity that facilitate that usage of those technologies, resulting in other forms of administrative activities being required (Linsner, et al., 2019). However, recent research might see significant benefits for using such technologies to have shared databases across various players that could combine various data sources, enabling new forms of cooperation. Especially existing institutions that serve as validating points for various value chain players could be substituted by such decentral digital technologies and thus enable business model evolution (Osmanoglu, et al., 2020).

Key business model evolution potentials are seen by research literature once players from the beginning of value chains such as farmers, can directly interact with consumers at the end of the respective value chain, offering new opportunities for marketing and commercial activities (Linsner, et al., 2019). Additionally, these decentral technologies could enable new forms of banking and risk management, enabling new business opportunities especially in agriculture (Sengupta & Kim, 2021). Insights that can be drawn from data being processed across those technologies could also enable the rise of new business models, potentially

leading to forms of a data economy (Tripoli & Schmidhuber, 2018) with some authors seeing scoring systems across different products that are fed by data points along the entire value chain as key driver (Patel, et al., 2021). Assessing new business potentials, it remains subject to research who might be initiating the usage of decentral digital technologies across various players of value chains in the agriculture and food industry. Some see public stakeholders and institutions and key actors (van Wassenaer, et al., 2021). However, this might be subject to further research (Kim & Laskowski, 2017).

Assessing the case studies, it can be observed that using decentral digital technologies could enable new forms of e-commerce as with the TATTOO Wine Platform whereby digital twins of wine bottles are created and being shared and eventually sold as tokens, turning the digital tracking system into some kind of digital commerce platform (Williams, 2019). However, other case studies do not show any similar developments (yet). Key element of the case studies was creating transparency up to consumer level in order to boost marketing claims for consumers, potentially increasing willingness to pay by consumers once they have access to such proof of authenticity as with the tracking systems for Downstream Beer (Brannigan, 2017) that was established in Ireland to differentiate the beer from other beers towards consumers (Brody, 2017).

The majority of interviewed experts see a big value creation potential for using decentral digital technologies across value chains in the agriculture and food industry in supporting marketing activities towards consumers, while some experts point out that the availability of tracking opportunities at consumer level might be sufficient to improve the perceived value of goods as many consumers would not actually use the digital tracking possibilities.

Also some experts see benefits of data sharing across different value chain players in order to improve resource allocation, for example in the area of CO2 emissions-certificates trading across various players in the context of animal breeding. This could enable new roles and business models such as optimizing companies that support farmers during the breeding phase in order to minimize costs according to some experts. Also, the experts mention that the data that might be generated once those decentral digital technologies are used across whole value chains might be a valuable asset whereby many valuable insights can be generated and eventually be sold to other parties, also raising the question of data ownership of such systems.

Many experts point out that most initiatives to use decentral digital technologies across entire value chains in the agriculture and food industry are driven by some kind of consortium approach with at least one powerful value chain players participating. Hereby access to consumers is not necessarily a prerequisite to establish such systems initially. However, some experts see those decentral digital technologies playing a vital role in (further) consolidating value chain and powerful value chain players becoming even more powerful and aiming to explore new roles or orchestrate whole value chains by themselves. Hereby experts perceive a mix of competition and cooperation between powerful value chain players that strive to improve their current position and get access to data and set standards in their interest. However, some experts state that it will be very challenging to govern large value chains in the agriculture and food industry and setting one standard to which all relevant value chain players commit to, so this might be rather effective for smaller or more local value chains in this industry. Notwithstanding, there was no common theme across the interviewed experts when it comes to creating and capturing value by using such systems. Some experts mention increased willingness to pay of consumers by having traceability systems in place for food while for others this is seen rather as an investment to support and safeguard the existing

business. Thus, the predominant incentive for value chain players to establish and/or participate in such systems is to shape any potential future market standard.

IV. Discussion & outlook

The usage of decentral digital technologies will enable traceability across value chains in agriculture and food industry and thus improve transparency. That this transparency can be used to improve marketing claims towards consumers is recognized by recent literature, case studies and the interviewed experts. Also, this transparency can contribute to manage fraud-related issues as outlined by literature and case studies whereby the experts seeing this as rather less of importance. Thus, it will be subject to further research if the benefit of using such technologies is rather perceived as marketing support or as fraud management instrument in this industry.

Research has associated the role of the initiator for such traceability systems via decentral digital technologies with those value chain players that have access to consumers which was not validated by the case studies and expert interviews that rather point towards consortia that have at least one powerful incumbent player participating. It will be subject to future research how the role of the initiator will evolve and especially what is driving to initiators to establish such systems and convince others to join in. For the agriculture and food industry, it seems that consortium approaches might be instrumental according to this exploratory research, especially as most players might be driven by the aim to shape future markets standards. If this is true due to the fact that those decentral digital technologies are new or this could evolve as theme for this industry in particular needs to be further explored.

Minor evidence in research and across the interviewed experts point towards the evolution of a so called data economy. However, as this might relate to a rather mature usage of systems of decentral technologies, this will be subject to further research as literature, case studies and interviewed experts might see a larger value potential if this happens. However, it seems to be less likely according to this exploratory research that entire players will be fully substituted once those technologies are used in a systematic way across different players, but likely to improve the way how incumbent players interact with each other and improve process efficiency.

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