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Smart contracts for smart rural supply chains

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Abstract

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Rural economy is often associated with small firm size together with low level of business sophistication, thin business networks, limited ability to attract investments, regional orientation and weakness in entrepreneurship. Nevertheless, there are strong activities towards smart rural development by applying recent advances in information technology (IT) to foster new development paths of Europe's rural areas. A new and promising IT invention is related to blockchain technology and smart contracts, i.e. to computerized transaction protocols intended to digitally facilitate, verify, or enforce the negotiation and execution of the terms of an underlying legal contract designed to fulfil common contractual conditions comprising payments, legal obligations, and enforcement without third party. But the potential of smart contracts goes far beyond cost reductions by facilitating entrepreneurial collaboration of cross-organizational business-processes in the context of smart rural supply chains.

An analysis of existing or ongoing smart contract projects reveals that the majority of smart-contract applications in business life are linked to industrial solutions. But a closer look to all successfully applied cases of blockchain technology and smart contracts also shows high potential for integrating fragmented rural supply and value chains towards smart rural development. Hence, one important development perspective lies in the use of digitalization approaches to overcome rural shortcomings in rural networks of small and medium enterprises (SME) and value chains by coordinating and optimizing their supply chains and to market their products in order to reduce or even avoid the dependency of multinational agricultural commodity traders.

This paper discusses the research question how and to which extent smart contracting and blockchain technology can be applied to empower rural SME in smart rural supply chains. The research results will be empirically validated by two case studies from the area of smart supply chains in a rural context.

Keywords: smart; supply chains; rural areas; SME networks; smart contracts; blockchain; rural development

Introduction

Recent research highlights the potential of blockchain technologies for facilitating entrepreneurial collaboration in networks and smart supply chains to solve problems related to fragmentation and distributed autonomous entities (Norta et al., 2014; Hoffmann et al., 2018). Scholars argue that blockchain technology enables an evolving set of parties to maintain a safe, permanent, and timestamped ledger of transactions without a central authority. Thus, the underlying transactions are not recorded centrally and each party maintains a local copy of the ledger consisting of a linked list of encrypted blocks comprising a set of transactions that are hashed and grouped in blocks and thus broadcasted and recorded by each participant in the blockchain network. After proposing a new block, the network participants agree on a unique copy of this block by following a consensus mechanism that is practically impossible to change or to remove after acceptance, i.e. a blockchain represents a replicated append-only transactional data store, which is able to replace a centralized register of transactions of a trusted authority (Udokwu et al., 2018).

Blockchain platforms usually offer additionally the possibility of executing scripts on top of a blockchain, which are called smart contracts, allowing parties to encode business rules like negotiated legal agreements. Thus, a smart contract can be considered as a computerized transaction protocol to enforce digitally the negotiation and execution of the terms of an underlying legal contract designed to fulfil conditions like payments, legal obligations, and enforcement without third parties. Such a smart contract realises the digital execution of legal agreements and linked transactions between distributed units within a network or supply chain with reduced transaction costs by being trackable and irreversible. Thus, smart contracts together with their transactions are executable due to blockchain technology without the involvement of a third-party and current research points out to tackle important challenges in smart supply chain management (SCM) by using these technologies (Pfohl & Gomm, 2009; Bodo et al., 2018; Hofmann et al., 2018).

These unique characteristics of blockchain technology and smart contracts have promoted ideas of the application of these technologies in different markets beyond financial sector also in agricultural and real estate sector (Spielman, 2016; Lin et al., 2017; Veuger, 2017; Dimitrova, 2018; Green, 2018; Kamilaris et al., 2018; Lin et al., 2018; Shedroff, 2018; Tripoli & Schmidhuber, 2018). This decentralised character of blockchains can facilitate smaller, independent users like entrepreneurs and SMEs competitiveness and efficiency enabled through the improved information accessibility, reduced risks and layers of middlemen, and thus declining intermediary and transaction costs (Wu, 2018).

Hence, blockchain technology and smart contracted legal agreements seem to be suitable concepts to redesign and optimise collaborative business processes and supply chains. They also open the opportunity to facilitate the integration of SMEs into cross-organizational business-processes by creating open IT-environment, in order to realise the possibility of a fair participation of SME sector in supply chains, since currently linked IT-systems and underlying business structures are still often closed due to domination of big players with their dedicated IT-systems together with their business rules that dictate the market conditions within the supply chains and cause high entry barriers to SMEs and entrepreneurs (Prause, 2014b; Prause & Hunke, 2014; Bruni & Santucci, 2016; Prause & Hoffmann, 2017).

The paper discusses the research question how and to which extent smart contracting and blockchain technology can be applied to smart rural supply chains and how new business models for rural companies could look like. Therefore, the research showcases two important components smart supply chains in logistics, which will be discussed by means of the case of autonomous delivery robots as well as with the help of the creation, coordination and empowerment of SME in smart rural supply and values chains. The research is based on expert interviews, surveys and case studies which took place in the context of related EU projects in order to investigate extensions of blockchain technology and smart contracts to smart rural development.

Theoretical Background

The term blockchain indicates two things, a distributed database as well as a data structure consisting of a linked list of cryptographically chained blocks containing transactions, including its hash value and a cryptographic signature, so it is impossible to alter an earlier block without re-creating the entire chain. Linked to the blockchain technology is the concept of smart contracts representing scripts that are executed whenever a certain type of transaction occurs and that may read and write from the blockchain. Smart contracts allow parties to enforce that whenever a certain transaction takes place, other transactions also take place (Norta, 2017).

As an example, let us consider a delivery of a product in a supply chain where all data about suppliers, recipient, goods and business conditions is distributed over data bases of the supply chain. Selling goods or services can be implemented with blockchain technology as a transaction that is cryptographically signed by both the vendor and the buyer and by attaching a smart contract for sales transactions. The execution of the transfer of the corresponding funds and rights can be enforced when the sale takes place and all other agreed conditions like documentation, tax payments or quality checks are realised, i.e. smart contracts can enforce the correct execution of collaborative entrepreneurial processes. The underlying business processes and related legal agreements are often mathematically modelled by Petri-Nets describing the underlying workflows together with tokens that represent mostly permissions (authorization tokens) or information. Thus, an important informatics task represents the translation of a standard Business Process Model and Notation (BPMN) into a Petri-Net and hence to compile this Petri-Net into a smart contract. The technical implementation of a smart contract, called distributed ledger technology (DLT), requires a formal language like eSourcing Markup Language (eSML) for specifying the interactions of a smart contract (Norta et al., 2014; 2015; Norta, 2017). Distributed-Ledger-Technologie

A smart contract has to enforce an underlying legal agreements, a successful general implementation of smart contracts in business world requires a general framework for functioning and development of blockchains including legal protections afforded to technological protection measures as well as rights management information that are jointly referred to as Digital

Rights Management (DRM) (Bodo et al., 2018). Technical protection measures define technologies that restrict acts that can be performed in respect of a copy of a work whereas right management information relates to electronic information attached to a work. The current DLT offers built-in tools to automate transactions enabling users to write complex software with the smart contracting language like eSourcing Markup Language (eSML) that interacts with the distributed ledger, and shares the same characteristics comprising self-enforcing or immutable. Thus, smart contracts can be considered as algorithmic account holders on a blockchain, i.e. they represent pieces of code that execute transactions if their encoded conditions are fulfilled. Generally, a smart contract encodes 'if-then' conditions so that a user pays an amount to the smart contract account if all preconditions of the underlying contract are accomplished. Hence, a smart contract can distribute revenues based on conditions represented by coloured tokens in the sense of Petri-Nets. (Norta et al., 2015; Norta, 2017; Bodo et al., 2018).

Udokwu et al. (2018) studied existing or ongoing smart contract projects in business world revealing that more than 70% of the top domains of smart-contract applications in business life are linked to supply chain management, Internet of Things (IoT) and Industry 4.0 solutions. Industry 4.0 aims to develop cyber-physical systems (CPS) and dynamic production networks in order to achieve flexible and open value chains in the manufacturing of complex mass customisation products in a small series up to lot size 1 (Prause, 2015; Prause & Atari, 2017). A closer look to the Industry 4.0 concept reveals even deeper targets for smart manufacturing and logistics like energy and resource efficiency, shortening of innovation and time-to-market cycles, as well as a rise in productivity by using 3D printing, big data, IoT and Internet of Services (Avramov, 2014; 2015). Thus, Industry 4.0 leads to new supply chain paradigms based on complex and intertwined manufacturing networks with changed roles of designers, physical product suppliers, clients and logistics service providers, making it possible to identify and to trace single products during their entire life-cycle and even more. The network approach together with the knowledge about all stages of product realisation makes it possible in Industry 4.0 that a product itself organises and chooses its own way through the production and related logistics processes (Gumus, 2008; Kagermann et al., 2013; Bauer et al., 2014; Dimitrova, 2015; Prause, 2015).

But it has also to be mentioned that smart approaches are mainly discussed in the context of urban conditions by neglecting rural environments. At a first glance this seems to be understandable since a lot of research results on entrepreneurship and innovation are related to urban or industrial contexts (Prause, 2014a; 2015). But as Prause and Boevsky (2015) point out, there are promising concepts related to smart specialisation and smart rural areas that target on non-urban areas and which try to improve the development perspectives of rural areas. An important instrument in all smart approaches is digitalization, no matter if urban or rural areas are discussed. Especially for rural areas, a better internet access can help to bridge the distance to cities, to improve the marketing situation of farms and to overcome rural shortcomings in logistics, mobility and supply problems or to medical care for more elderly population. New concepts like online presences of farm shops and related delivery services from farms to final customers are gaining constantly importance due to growing IT applications in rural areas. New IT solutions are even able to generate attractive alternatives in the countryside for new working models and remote work places, new opportunities for education and training as well as offer more tailor-made administrational services (Prause & Boevsky, 2016). In the sequel we will point out that the concepts of Industry 4.0, blockchains and smart contracts are not only fitting structurally together and complement each other; they are also transferable to rural areas and their development.

First, to see the complementation of blockchains, smart contracts and ~~the~~ smart supply chains, it can be mentioned that smart contracts add the concept of self-enforcing to the already well-known Industry 4.0 properties comprising self-organizing and self-optimizing, i.e. the three concepts are perfecting the needed characteristics for coordinating smart manufacturing and logistics systems based on fractals, networked CPS and M2M systems. Furthermore, smart contracts that are modelled by coloured Petri-Nets can be then easily coded by corresponding program languages like eSML to execute reliably automatic self-enforcing transaction in distributed systems with low transaction costs in a standardized way, i.e. smart contracts are fulfilling important main features of Industry 4.0 (Prause, 2014b; 2015).

Prause and Boevsky (2018) investigated the case study of the application of delivery robots in rural areas and stressed the importance of internet and broadband networks to overcome the rural development obstacles like low accessibility, remote location to market and public and private service providers, availability of high-qualified work-force and reduced mobility of goods and personnel. A dedicated look to specific situation in Bulgaria revealed important shortcomings in Bulgarian rural areas with underdeveloped IT infrastructure, despite the facts of high importance of agricultural sector for national economy. In this sense the case of delivery robots stresses again the findings of Prause and Boevsky (2015; 2016) who pointed out the importance of a smart rural infrastructure by discussing success stories of European SME from different branches with up to 200 employees operating from the Bulgarian, Estonian or German countryside all over the world. Comparable results were presented by Prause (2016) in the context of e-services for rural areas.

Literature Review on Delivery Robots

Punakivi et al. (2001) discussed the last mile-issue in the traditional context of B2C and e-commerce; they proposed an unattended reception of goods, which could reduce home delivery costs by up to 60%. The unattended delivery approach is based on two main concepts, being the reception box concept and the delivery box concept. The reception box is installed at the customer's garage or home yard, whereas the delivery box is an insulated secured box that is equipped with a docking mechanism. Meanwhile, new technological innovations implemented into new business models opened up new solutions to bridge the last-mile to the client by using drones and delivery robots, and food and grocery services gaining first experiences in the use of autonomous devices (Hoffmann & Prause, 2018).

Thus, the traditional delivery box concept of Punakivi et al. (2001) can be transferred into the smart supply chain world of internet–linked manufacturing and logistics so that autonomous delivery robots can be understood as cyber-physical systems of Industry 4.0 related last-mile delivery, including usually three stakeholders, namely the seller, an intermediary and the client. Mainly technical scholar studied machine-to-machine (M2M) systems and the realization of autonomous logistics agents in the context of Industry 4.0, i.e. systems of machines that are self-organising their workflow and communicating with each other via networks. Wu et al. (2011) investigated M2M cases for mobility support together with their frame conditions for standards of M2M networks and Zhang et al. (2011) highlighted self-organization and self-management as important factors for success of M2M systems due to low human intervention as a major requirement. Meanwhile, based on wireless internet technologies, artificial intelligence concepts and M2M technologies, some entrepreneurs founded start-ups to develop autonomous transport devices on the base of Industry 4.0 related concepts in order to serve the last-mile delivery more or less autonomously. Important agricultural applications of delivery robots exist in the supply of remote farms on islands or alps with medicines, spare parts or urgent aliments via flying drones. But recently, the focus moved from flying drones to land-based delivery robots for the last-mile delivery (Hoffmann & Prause, 2018).

A closer view reveals that autonomous delivery robots enjoy a competitive advantage compared to other delivery modes, since the underlying business model emphasizes the cost advantage for the last-mile delivery, which is estimated to be less than 1€ per unit/delivery, which is up to 15 times less than current costs. For the customer, additional convenience is gained by the aspect that robot delivery provides a 15-to-20 min delivery window as standard, which is a much more precise specification than for traditional delivery, which so far is only able to provide a general date (calendar day) beforehand. An important case for delivery robots represents Starship Technologies Ltd. that was founded in 2014 by Skype co-founders Janus Friis and Ahti Heinla in Tallinn with the aim to tackle the last-mile problem by developing autonomous delivery robots (Hoffmann & Prause, 2018).

Delivery robots are usually powered electrically, i.e. they are environment-friendly since they do not emit CO_2. Robots also contribute to reduce on-road traffic and thus congestions and they provide solutions for retailers and logistics firms to increase supply chain efficiencies and reduce costs. Starship's small self-driving vehicles with a weight of less than 20 kg are electric-powered and are designed for driving on sidewalks with a speed of maximal 6 km/h, being capable to locally deliver their goods within 15-30 min and within a radius of up to 5 km. Since the robots are able to deliver freight of up to 10 kg for a shipment price up to 15 times lower than the normal price for last-mile deliveries, delivery robots represent an interesting option for e-commerce applications as well as for food deliveries or postal services.

In order to create a smart solution for bridging longer distances of delivery, the company started collaboration with the car builder Daimler in order to develop the "RoboVan", which forms a mobile robot hub on the base of a MB Sprinter mini truck and would considerably extend the range of the robots. This approach for delivery realizes a "hub and spoke" concept, which is a well-known standard model in logistics so that the RoboVan is equipped with a storage system for 54 delivery boxes and 8 Starship robots. The RoboVan performs the long distance elements of transport as a mobile hub and it brings the robots together with the delivery boxes right into an area where a multitude of individual deliveries has to be performed. From this spot, the robots disembark from the RoboVan autonomously and cover the last-mile to the client in order to individually deliver the goods to the clients and return to the van afterwards. The approach realizes a "hub and spoke" concept with robot delivery for the last short distance.

Deliveries robots are considered as a supplemental form of shipment, not as a replacement, i.e., the logistical models that can be used with robots are different from those models of traditional delivery methods. The use of delivery robots is regarded as a different area of complementing delivery with bicycle couriers operating in very dense urban environments, since they are able to overcome gridlocks and traffic jams, whereas autonomous vehicle is predestined for the delivery in suburbs with low traffic. Access to the cargo in the robots is arranged by a smartphone app, which enables the client to unlock the robot coverlid and retrieve the goods. Moreover, if someone tries to steal the robot, the cameras will take a photograph of the thief, and an alarm will sound. Additionally, multiple tracking devices can track the robot's location via GPS, and the remote operator is able to speak through two-way speakers with the thief; and, obviously, the robot will stop working and will not open the cargo unit, unless re-programmed by the robot operator.

Rural areas generally suffer under demographic change and migration to urban areas, which caused problems in supply, mobility and medical care for remaining population (Prause & Boevsky, 2018). Thus, autonomous delivery robots can be considered to contribute to new solutions for rural areas, solving shortcoming in retailing, waste disposal, postal and administrational issues, since all related services become more and more inefficient from the perspective of service providers. As already mentioned, autonomously driving delivery robots were constructed for last-mile deliveries of packages with a focus on urban environments, but the research highlights the possibility of their application in smart rural development. Basu et al. (2018) recently researched the legal framework for small autonomous agricultural robots with the restriction that agribots roam usually only on private land, the unresolved traffic law dimension has not been covered by their paper. These research results are in line with investigations of Hoffmann and Prause (2018) concerning the regulatory framework for autonomous delivery robots, comprising all issues related to liability, data protection, privacy, and legal developments around delivery robots belonging to the sphere of smart supply chains.

Smart Rural Supply and Value Chains

The global agricultural commodity trade and production sector is characterized by large companies where the four big commodity traders Archer Daniels Midland (ADM), Bunge, Cargill and Louis Dreyfus or only shortly named as 'the ABCD companies' plays an important role (Murphy et al, 2012). The importance of the ABCDs in global agro-business is related to financial power, logistics performance, vertical integration of their food value chain and the weakness and small size of agricultural producers and farms. Hence, the ABCD complex does not just trade physical commodities, they operate from the farm level all the way to food manufacturing, they provide seed, fertilizer and agrochemicals to growers, and they buy agricultural outputs and store them in their own facilities. Thus, they act as landowners, cattle and poultry producers, food processers, transportation providers, biofuel producers and providers of financial services in commodity markets. Traders have been integral to the transformation of food production into a complex, globalized and financialized business. Food prices, access to scarce resources like land and water, climate change and food security are all affected by the activities of traders. By doing so, ABCD traders, share a significant presence in basic commodities, controlling about 90% of the global grain trade. Other emerging market trading companies such as Olam, Sinar Mas and Wilmar are also quickly establishing a global presence.

This extraordinary concentration of power and money in the global food trade has been identified by Oxfam in a report as one of the structural flaws of the system. At each stage a handful of players dominate, not just in primary agriculture but in food manufacturing and retailing. The result, according to Oxfam, is that "they extract much of the value along the chain, while costs and risks cascade down on to the weakest participants, generally the farmers and labourers at the bottom" (Herre, 2017). The ABCD group have said they welcome informed debate but that, as far as they are concerned, their operations are the vital waters that keep food and its finance flowing from those who can grow it to those who need to consume it. Scale enables them to be highly efficient. The grain trade is capital intensive; they invest heavily in storage facilities and port and transport infrastructure. As well as being a leading player in the trading, processing and transporting of the most important agricultural commodities, fertiliser and meats, it is one of the world largest hedge funds.

Prause and Hunke (2014) studied business structures of logistics corridors, which are currently dominated by big logistics service providers. The related IT systems of such corridors are often closed with dedicated IT-systems of dominant logistics companies that dictate their business rules and market conditions. Thus, these supply chains are causing high entry barriers for farms and entrepreneurs. By crossing over from hierarchically organised logistics corridors to green transport corridors with more cooperative governance structures, smart contracts and blockchain technology can generate opportunities to facilitate the integration of SMEs into cross-organizational business-processes by creating open and harmonised IT-environments in order to realise the possibility of a fair participation of SME sector in supply chains (Prause, 2014b; Prause & Hunke, 2014; Prause & Hoffmann, 2017). Thus, blockchain technology can contribute to overcome traditional business processes that are controlled by a dominating player's acting as central third-party provider with own standards and their centralized architectures. In this sense, the Industry 4.0 approach also aims to create a horizontal integration through value networks with an end-to-end digital integration of engineering across the entire value chain together with a vertical integration and networked manufacturing systems. These new value chains will also change the roles of physical product suppliers and the interfaces with the customer and their implementation will be accompanied by fragmentation, new structures and new business models and with low entry barriers for SMEs and farms (Prause, 2016).

Suitable business structures are characterised by self-similarity, self-organization, self-optimization, goal-orientation, and dynamics as winning attributes of flexible and adaptable production organizations, called fractals (Olaniyi & Reidolf, 2015). The process of building a fractal structure is based on relations between material, personal and information, whereby inside a fractal structure these relations are closer and more intensive than on the outside, so that fractal building is comparable to mathematical cluster process based on the relationship and weights of the resources. Consequently, the internet access points within a supply chain as well as the cross–company information interfaces together with their surrounding form structures of high internal interaction and exchange of resources, which can be considered as fractals since they are built according to the principle join the parts around an information access point of equal information level and they represent timely, limited, stable, optimal structures that are changing their shape and structure according to their local needs (Prause, 2015; Gjokaj et al., 2017).

Meanwhile many scholars have been inspired by the fractal concept and developed extensions of the fractal model in the direction of flexible relationship networks built of autonomous and interdependent production fragments (Canavesio & Martinez, 2007; Shin et al., 2009). Such organizational expansions bring new responsibilities, new branches and growth, which gives room for the integration of information and manufacturing structures in the context of fractals, especially paving the way to the alliances of the fractals as they work together (Panetto & Molina, 2008; Raye, 2012). Canavesio and Martinez (2007) formulated another viewpoint on fractals by considering a fractal company as a multi-agent system, where each fractal has the ability to observe its environment and make decisions based on the feedback. Blockchain technology together with smart contracts enjoys the ability to coordinate and to execute negotiated agreements among the networked fractals.

Applied to the situation in agricultural sector these ideas gain importance since one reason for strong position of multinational agricultural commodity players lies in small farms and rural enterprises that are rather isolated and their production volumes are too small to be interesting for food industry. These rural SME and farms represent the fractals in the previous discussion and their only chance is to overcome their isolations by cooperation and consolidation of their farming products in order to market them together. But this task requires the organisation of logistics services and the presence at important food markets and access points to food industry. The necessary organisation and execution of underlying agreements and sales activities can be realised by blockchain technology and smart contracts. Thus, these new technologies bear the potential to endanger the market dominance of the big agro-players. Interesting wise, the ABCDs decided to use blockchain technology and artificial intelligence to digitize international grain trading in order to reduce costs and to make their IT systems more efficient and faster (Bitcoin, 2018).

The agriculture trades require paper filings, contracts invoice and other manual payments that make the whole system very inefficient. These technologies that are going to be implemented will be used to automate grain and oilseed post-trade execution processes. In the supply chain, these are very costly and tedious processes. At the same time, the ABCD group would use the technology to improve shipping, storage and customer experience. Besides that, the ABCD quartet says that the Distributed Ledger Technology (DLT) will replace its existing manual payment systems. Thus, this new concept of blockchain, infused into the agricultural industry world, is aimed at making international commodities trades more transparent and cost-effective. These decisions are not coming surprisingly, since according to Pirrong (2018), the ABCDs are going through a rough patch of tight margins and low profits with a pressure on consolidation of players.

Results and Discussion

Smart supply chains in the context of Industry 4.0 are based on transactions between cyber physical systems that cooperate via internet across company borders, i.e. the underlying workflows within the cross-company value creation processes, including automatized objects, have to communicate, to cooperate and to agree and the execute procedures and transactions. This requires M2M communication and agreements among the involved objects in a distributed IT-environment. Blockchain technology and smart contracts are able to deliver a suitable solution offering traceable, transparent and decentralised solutions. Usually, these concepts are discussed in urban manufacturing situations but they are also applicable in rural supply chains utilising delivery robots, as well as other automatized agricultural vehicles. Nevertheless, an indispensable component is the necessity of existence of powerful IT infrastructure and networks on Industry 4.0 level also in rural areas. Dujin et al. (2014) created the Industry 4.0 readiness index for different EU countries and there Bulgaria was ranked at the end (Fig. 1).

An additional closer look to the Digital Economy and Society Index (DESI 2018) reveals the same result, where Bulgaria is the lowest ranked EU country, when it comes to internet-based linked machine-to-machine communication and interaction, hence, all issues placed in the sphere of autonomous delivery robots, smart supply chains and internet linked CPS are complicated to implement in Bulgaria.

But the existing IT infrastructure represents only one aspect, also the level of development of e-services in a country is important since the e-service infrastructure facilitates M2M transactions and represents an important part of the national e-business systems. Prause (2016) discussed the well-developed e-governmental infrastructure of Estonia together with its impact on entrepreneurial activities. Prause and Boevsky (2015) took a closer look to e-services as driver for smart rural development and finally, Hoffmann and Prause (2018) highlighted the importance of the Estonian e-government system for the development of autonomous delivery robots. The case of the Estonian e-governance systems reveals how a highly developed public e-business and e-administration system facilitates the use of autonomous delivery robots at the client interface so that it is no surprise that a company like Starship Technologies emerged in Estonia.

In a smart supply chain scenario, the related workflows and cross-company value processes can be understood as an internet-linked smart manufacturing network or supply chain where goods and services are produced and delivered downstream and information and finance flows upstream and where smart contracts execute computerized transaction protocols in both directions. Hence, blockchain technology together with smart contract solutions bears the potential to foster entrepreneurial collaborations in logistics networks even across international borders and complements the already existing basis technology towards smart supply chain solutions. In contrast to traditional business processes based on central trusted third-party providers with their own standards and architectures dominated by big players, blockchain technology enables these processes to be executed in a distributed way, minimising entry barriers and spurring process innovation. This deploys additional trust within the company networks and supply chains and fosters the entrepreneurial activities (Prause et al., 2013).

Additionally, blockchains are usually open and transparent, i.e. blockchain implementations enable all supply chain participants to access, add and check the data, while changing or deleting of blockchain secured data is nearly impossible and thereby increase transparency of all transactions in the supply chain. Thus, supply chain providers could transparently display their availability to the whole market, which capacities they have, foster their market position and makes them more independent from transport brokers. Especially for smaller suppliers and SME participating in a supply chain, this bears the opportunity

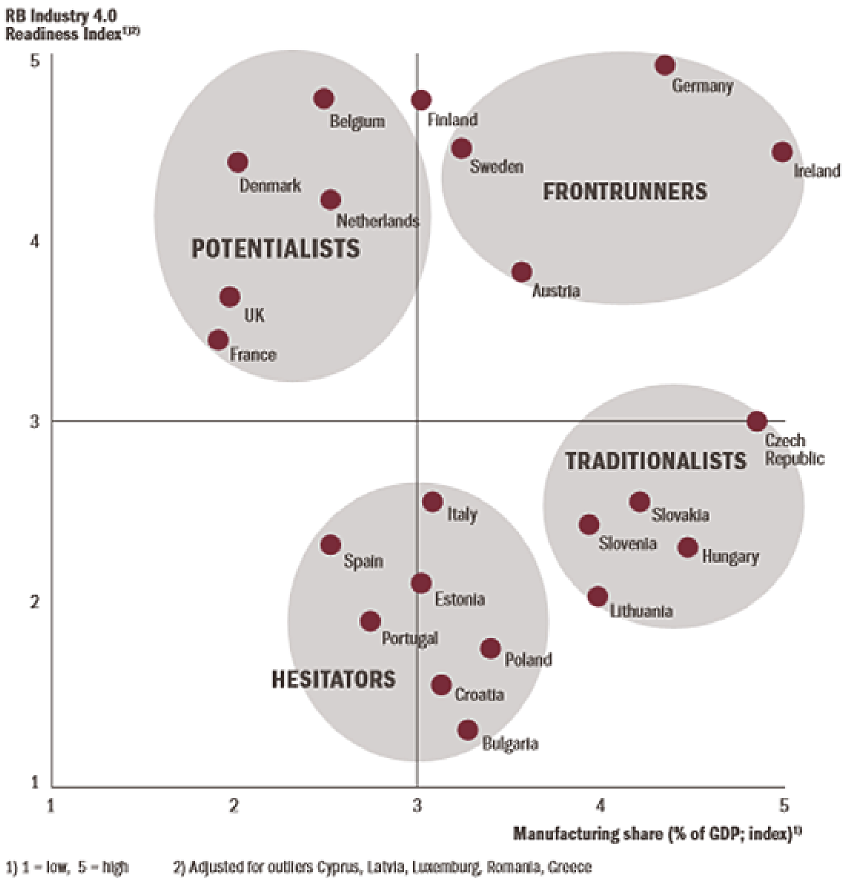

Fig. 1. RB Industry 4.0 Readiness Index for European countries
Source: Dujin et al., 2014

to consolidate their production outcomes in order to fulfil volume orders, so that they are empowered to sell directly to the retailers or final clients instead of using middlemen. Wu (2018) designed a blockchain based smart contract for logistics and showed that blockchain technology can supplement or replace centralised fourth-party logistics providers through contract automation, and thus, reduces the layers of middlemen or traders within supply chains by linking suppliers, retailers and logistics providers directly. All these considerations are applicable and transferable without any restrictions into the area of smart rural supply chains.

The transparency and openness of blockchain oriented supply chains also offers the opportunity to improve and optimise the cross-company business processes. Nyhuis and Wiendahl (2009) developed logistic operation curve theory and throughput-oriented lot, sizing to control and optimize operations management and supply chain processes. But empiric results reveal that these theoretic concepts are not working well in business life so that an adaption of the underlying theoretical models is necessary (Schmidt et al., 2015). Here, smart contracts can be used to initiate transactions among the units of a supply chain to coordinate and optimise the full supply chain. This concerns time issues like throughput, cycle and lead time as well as financial flows through the supply chain.

So by summing up the findings it turns out that the biggest opportunity of blockchain technology and smart contracts in rural supply chain sector lays in the restructuring of agricultural commodity trading market. Currently, the big agro-dealers like ABCD group use their market power to dominate the commodity markets. By consolidating, transporting and marketing the small volumes of farmers the big players are able to dictate the rules and process in agricultural sector. One important tool is the use of their own IT systems and organisational structures forcing the small farmers to integrate into game. This mechanism is possible to overcome by the use of blockchain technology if farmers use their IT systems and blockchain technology integrates the underlying distributed databases into common ones. The needed cargo transport for consolidating the agricultural commodities of the farmers can be organised by smart contracts and realised by agricultural delivery robots. Thus, the consolidation of fractal farming commodities requires and highly developed transport system to move the distributed volumes to one place if needed, as well as a trusted and automatized execution of transactions and information and money streams is then safeguarded by the smart contracts.

The regional consolidated agricultural commodity volumes can be handled on information, as well as on organisational level, as a unique charge since they are composed of fractal commodity volumes from the different farms representing the fractal. But the regional consolidated volumes can then also be marketed as one unique charge or even further consolidated with other regional charges to larger volumes. By doing so, this bottom-up approach using blockchain technology to construct larger charges, built of small fractal charges, strengthens the power of small farms and deliver through blockchain technology the organisational, legal and financial unification to significant volumes on the agricultural commodity market since consolidated supply means more volume, which tends to increase revenue, and higher volume also means that handling the capacity comes along with higher utilization degrees in storage, transport, logistics and processing contributing firmer margins and increasing additionally the revenues.

Thus, through the adoption of blockchain technology, rural SMEs are able to transparently display their availability to the whole market, which makes them more independent from agricultural brokers and traders, and different smaller rural SMEs or farmers could be more visible to the market and consolidate their productions in order to fulfil volume orders, so that they are empowered to sell directly to the retailers instead of a middleman. These research results are in line with reflections of Casado-Vara et al. (2018) who described in a case study the implementation of blockchain technology including smart contracts in an agriculture supply chain. However, next to these examples the current research on the adoption of blockchains and smart contracts in rural smart supply chains is still limited or just at the beginning (Liao & Wang, 2018), despite the advantages of authentication of traded products, disintermediation, and decrease of transaction costs (Nowiński & Kozma, 2017).

Conclusions

Smart contracts are computerized transaction protocols created for executing and enforcing underlying legal contracts by using blockchain technologies for distributed data bases. They are designed to fulfil self-enforcing contractual conditions like payments and legal obligations, without the need of an existing trusted third party. Thus, smart contracts target to reduce transaction and enforcement costs by realizing trackable and irreversible transactions. But the research also reveals that the potential of smart contracts goes far beyond cost reductions by facilitating entrepreneurial collaboration of cross-organizational business-processes and empowering SME within smart supply chains. The research results also reveal that all these concepts are also applicable and transferable to smart rural supply chains.

Surprisingly, some big multinational agricultural trading firms took already first steps to initiated blockchain applications in agricultural business, despite that fact that blockchain technology and smart contracts bear the opportunity to break the market dominance of the big players, since through the adoption of blockchain technology rural SMEs are able to transparently display their availability to the whole market, making them more independent from agricultural brokers and traders. Thus, by doing so, the different rural SMEs or farmers could be more visible to the market and consolidate their productions in order to fulfil volume orders to achieve better prices and sell to the retailers or final clients by avoiding middlemen. The case of the autonomous delivery robots furthermore highlights that the underlying logistics services can be realised also in smart way with the advantage that delivery robots can work more easily in rural areas than in urban environment, as well as with additional benefits for smart rural development coming along with the robot use.

Finally, it has to be mentioned that the deployment and application of smart technologies like blockchains and smart contracts are strongly linked to the development level of the IT infrastructure and e-services in rural areas together with the access possibilities of rural players. Here, the evaluation of the existing and needed development levels can be done based on the Industry 4.0 standards.

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