Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 18, Issue 3, 2018
PRINT ISSN 284-7995, E-ISSN 2285-3952

BLOCKCHAIN TECHNOLOGY IN FOOD - CHAIN MANAGEMENT - AN INSTITUTIONAL ECONOMIC PERSPECTIVE

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Abstract

Blockchain became known as the technology underlying the cryptocurrency bitcoin. While here this technology has received quite controversial attention, its proponents expect much more promising applications in other fields. One of these concerns food-chain management, where it is said to have the potential to revolutionise it. This paper looks at this case from an institutional economic perspective. For this, it first clarifies how a straight application of this technology matches basic microeconomic thinking, as restricted to private goods and prices, and thus also the market optimism associated with it. The paper then analyses the role of institutions in the food system as it has so far been organised and how this institutional setting might be changed in order to incorporate this new technology while safeguarding the objective of an overall economic optimum. In order to sketch out some ways in which these conceptual considerations might actually be put to the test, a cursory introduction is given to some options relating to the situation in Romania. Some orientation might thereby be provided for further work.

Key words**:** *blockchain, food chain management, institutional economics*

INTRODUCTION

Blockchain technology (BCT) mostly became known as underlying the cryptocurrency bitcoin. While controversially discussed for its technical features, and also for its implications for monetary policy, BCT offers options for the supply chain, and thus for food-chain management (FCM) as well. What is new about this is the concept of distributed data management. Its organisation contrasts with the hierarchical structures of centralised databases typically used by companies, or public authorities so far. Contrary to what one may associate with "distributed" or "decentralised" IT structures, namely the disadvantages of all too fragmented food chains, BCT is said to offer an insight into production and delivery at any part of the chain. Final consumers are promised access to all information from primary production, processing and distribution, and thus indeed make their decisions on the basis of complete information. So market failures due to information asymmetries, possibly occurring in older food-chain architectures, are excluded by design. Full transparency is also expected to prevent fraud, which is also a major issue for food safety, as it would otherwise have called for stricter control mechanisms ultimately enforced by some leviathan state. Middlemen, in their function of controlling information and possibly exerting undue market power, or third-party institutions safeguarding rules, are no longer needed. Traceability would practically be given as an intrinsic feature of this technology; for this reason, efforts for the development of the respective food laws as well as the establishment of public authorities applying them may well be rendered redundant. On the whole, direct consumer sovereignty is expected to be realised at last, while transaction costs would decrease dramatically. In this sense, Casey and Wong [5] promise the evolution of "*dynamic* demand chains in place of *rigid* supply chains." BCT is said to be the game changer of the coming years. Will future developments indeed live up these expectations?

After all, there has so far been a lot of work and effort on improvement of FCM as well.

Food safety – as mentioned above, supposedly no real problem anymore with BCT – was essentially considered a public concern.

Current EU food safety policy

In contrast to what BCT proponents suggest, the EU's current policy on food safety does not rely on the collection of all information of all stages of a food chain. Instead, the policy is based on the one hand simply on postal addresses for traceability, but on the other hand ubiquitously applicable quality standards (Regulation (EC) No 178/2002): Traceability (article 18), according to this regulation, is restricted to the ability to identify the origin (i.e. the trading partner) of all individual charges of inputs used for food production. It does not include any further information on the product delivered (as BCT would suggest). As all products (including those imported) have to comply with all EU food-safety criteria. Adding information from any or each production stage to traded charges would simply be redundant as long as the case is just for food safety. If it was for more information, beyond safety of food, like on organic character of production or geographic indications, the respective certification could be added, supported by the respective EU legislation and international trade agreements. By referring to the importance of risk assessment and communication, the regulation makes clear that it is meant to cover 100% of production, but that it can do so only on the basis of drawing samples only. (cf. points (15) to (22), article 3, points 9-13, and article 6, but also other parts of the regulation. The word "risk" is used 105 times in this regulation.) At the same time, the optional application of the precautionary principle allows for restrictive measures before proven evidence of any risk is given.

Retailers were consistently on alert, trying to avoid any kind food scandal, as the media would prominently highlight any violation of food regulations.

The development of globally applicable food standards, while not calling regional cultural habits into question, was key to this. Furthermore, incentive alignment, i.e. fair prices, in the sense that prices reflect marginal cost, were an objective promoted by anti-trust policies.

Mergers and acquisitions were an option for business in a globalising market, used mainly by processors and retailers. Vertical mergers were less common, as the downstream end of the chain would rather seek to take advantage of its position as principal and of competitive pressure between its suppliers. Linear programming over the whole food chain could principally be a standard helping to avoid technical and economic inefficiencies. The BSE crises of the 1990s added another requirement; while ideally the market would reside in the sufficiency of checks of quality on each level of the chain, keeping transaction costs low, major policy action had to be taken to establish traceability (from fork-, or a least trough-to-plate) as a standard. Technically, at the time, this called for centralised data management – precisely opposed to what BCT promises. After all, it is not only BCT that pushes for further digitisation all along the supply chain, down to primary production; e.g. SAP offers cloud-based *rural sourcing management* solutions, following its own standards, even integrating smallholders all over the world with mobile communications, tracking produce from farm to factory and organising complementing financial service infrastructure. [27]

Others again would call for a shortening of supply chains in the first place; this is either for ecological reasons or to avoid middlemen and superfluous processing and packaging. This may happen via regular farmers' markets or other forms of direct marketing. Modern logistics and marketing via the internet may lead the way, following the success stories of e-bay, Amazon, Alibaba et al., but this was not what Lorenz in a series of articles pointed to as *digital shortening* of the supply chain. [24]

This paper will ask whether BCT can indeed improve the working of the food chain. The criteria will be whether the situation of consumers can be improved, ultimately measured by higher welfare, and/or whether producers achieve higher levels of income.

This will be elaborated on the basis of transaction-cost theory and corresponding institutional arrangements. Special attention will be given to the issue of food safety. For an outlook, this paper will offer an outline of the situation in Romania. So what has been elaborated here in general terms should also be applicable considering the specificities of Romanian farmers, processors, retailers and ultimate consumers. Further work may empirically test whether supporting BCT would be appropriate.

Blockchain technology in recent publications

FCM has been a prominent topic in research since the 1980s. It could be categorised as part of industrial organisation, while game theory, transaction-cost analysis, and mathematical programming have also played an important role. While primarily developed only from a company perspective, issues like the alignment of incentives, Pareto-efficiency and options of collaborative supply chains are raised in some of the literature. [3] Research and policies on food safety are also concerned with the food chain. With a long history this had always been a matter of public concern, not only for private business. While the beginnings of food safety policies were largely designed as prescriptions and proscriptions, in recent decades, incentive structures have been incorporated more explicitly, harnessing business interests for the achievement of policy goals. However, food safety has remained a public good, a matter of public health. [11] [2]

Nevertheless, in practical terms, it was largely standards for product quality and respective prices, contractually agreed that were important for FCM. These were and are set by governmental regulation as far as food safety is concerned (with the FAO *codex alimentarius* offering an international reference) or privately by company prescriptions. Observing and controlling the chain in real time and thus reducing storage requirements became ever more widespread, requiring suitable computational capacities. The task for managers therefore goes beyond a firm's boundaries, covering complete value-added chains, thus also beyond the boundaries of the theory of the firm. Market failures due to information asymmetries and monopolisation became issues that were addressed by considering jointly designed formal or informal rules. The development of interfaces between firms, overall contractual arrangements and the evolution of attitudes towards informal cooperation also became important, alongside simple production decisions and pricing policies.

Considering this integrated management of the food chain, it may be argued that its organisational task could be more easily handled within a single hierarchical framework, keeping direct control of transaction cost and pricing as an internal matter.

Obviously, there has always been a certain tension between the option of centralised and de-centralised organisation of the food chain. A single hierarchical framework may show advantages in keeping direct control of transaction cost and pricing as an internal matter. The disadvantage from the perspective of the overall economy would be a lack of competition. [4] Realistically, even if companies exist independently along the chain, collaboration between peers or settlement of prices may be dominated by prescriptions imposed by one leading company. With all this, imbalances and monopoly pressure in the supply chain are high on the research agenda. Restricting negative outcomes is often considered a public task, namely a task for appropriate anti-trust laws. With respect to policies focusing on sustainability or working conditions, monitoring will be called for. Interestingly, *public* standards for quality of products, fairness and working conditions are hardly addressed in the business literature on the supply chain, while they have remained key to the literature on food safety (cf. [11] and [2] again).

Just in recent months it was BCT as applicable to supply-chain management that has also entered the stage for food. Companies like Deloitte [20], [28] and IBM [16] [17],[23] have picked up on it and are presenting it as game changer. Food Logistics, an information provider, is similarly euphoric about it [33].

The *New Food Magazine*, another business-intelligence service provider, offers 28 hits when selected for "blockchain" [25], *Food Safety News* [19]] offers nine hits, all of them with an optimistic stance towards this technology, namely with respect to traceability and fraud. In a paper by Reyna et al. [15], published in a scientific journal, the terms "revolution" or "revolutionise" are used no less than nine times; the fact that BCT is a "disruptive" technology is mentioned six times. In October 2017 Ahmed and ten Broek brought a comment on the issue into *Nature*, one of the most prestigious scientific journals [1]. Specifically, it is presented as a new option for small-scale farmers in developing countries, along with micro-credit systems. [26] A clear signal of business interests in the issue is the publication of straightforward commercials. (Walmart and IBM, August 2017 [32]; IBM on apples, coffee, March 2018 [21], April 2018 [22]). To put it briefly, all the problems of FCM, that had been so diligently addressed over the last 30 years in research, business administration, and respective public policies are now supposed to be overcome with this supposedly cutting-edge technology. The realisation of the textbook ideal of consumer sovereignty, with consumer preferences immediately steering production decisions, is promised without any impediment. Those preferring other technologies, in differing institutional settings, have to see themselves categorised as die-hards, possible luddites, unable to face some disruptive, but in a Schumpeterian sense creative, forward-looking technology.

Wageningen University and Research (WUR) pushes the case as well: "Blockchain technology is now on the radar of all major players in the food chain." WUR says it is necessary to recognise BCT not only as a powerful enabler, but also as a challenge and potential threat. There is a business model and a challenge to governance to be observed: organising the trust ecosystem. WUR is thus not only going into it with research and observation, but is actively organising events ("cases") called "Food Integrity Blockchained" at which they discuss BCT publicly and support start-ups in the field. (e.g. case 4 [31])

For all that, it is not only a mix of business administration, engineering, or some entrenched computer nerds trying not to miss this envisioned bandwagon of technological progress. The BCT principle of decentralisation also seems to be attractive from some political perspectives. On the one hand there is the libertarian stance, as often found with IT pioneers, favouring BCT just for its anti-hierarchical thrust. On the other hand, *New Food Magazine* also sees the anti-globalisation political activist and sharing protagonist Rachel Botsman as being on board: "According to Botsman, we are beginning to move from an institutional system of trust to a distributed system, a natural progression in her eyes as 'institutional trust is not designed for the digital age'." [7] So, there is considerable preference for BCT from what may be grouped as technological modernisers of business relations. This also finds some support from political groups critical of hierarchal structures, whether they are encountered with the classical nation state or any hierarchically dominated developments of globalisation, including the respective firms. In the context of the development of the internet, this kind optimism, in particular the preference for lean structures and an emphasis of open peer-to-peer communication has occasionally been criticised as technological solutionism, showing too narrow a view of social developments. [35] However, despite notice being taken of this lacuna, there has been hardly any specific social science work with regard to filling it. From this research environment, only some judgements of principle can be derived from work on digitisation. Following the introductory texts and tables of contents of two handbooks on BCT that have been published [13], [14] the term is introduced here mainly as an option to overcome bureaucratic hindrances in national governance, or banking systems. However, a social-science approach to the issue has not been applied. A combination of "socioeconomic" and "blockchain" offers no more than 26 hits in sciencedirect.com of

which only eight are research articles. Most of these are again concerned primarily with technical aspects of BCT. Hinings et al. (cf. [10] are the only ones exploring the issue with respect to changes in institutional settings.

Tracing an epidemic outbreak

In 2011 an epidemic outbreak of a food-borne illness, caused by EHEC (Escherichia coli O104:H4), affected no less than 3,950 people, of which 53 died. 800 were in danger of permanent kidney damage. The main region affected was Hamburg and its surrounding area, but also other parts northern Germany and neighbouring countries. The search for the origin of the pathogenic bacteria first led to presumption that cucumber imported from Andalusia may have carried it. However, no supporting evidence was found in greenhouses that the cucumbers were supposed to have come from. Cross-contamination during transport could not be excluded, but was not supported by evidence either. After that, sprouting seeds, added to cucumber dishes, pointed to a restaurant in Lübeck (60 km from Hamburg) as the starting point of the epidemic. Sprouting seeds were indeed found to have carried the bacteria. A relative hotspot of an outbreak (15 cases) was Bordeaux, to which no connection could be identified whatsoever. An organic farm close to Lüneburg (roughly 60 km from Lübeck and Hamburg) was served with an official closure order, as it was growing sprouts, even though no bacteria were found there. Only finally were sprouts imported from Egypt named as the most likely source. While the death toll and human suffering remain the most deplorable part of these events, the economic damage should not go unmentioned either. Even in Austria large parts of cucumber and other vegetable production was disposed of as demand collapsed. (cf. Wikipedia on 2011 Germany E. coli O104:H4 outbreak, Elga [40], ORF [34], AZ [36] all retrieved 5 July 2018)
The case of this epidemic outbreak shows what "traceability" may actually call for. It should not be considered as a matter that could be handled in an all too, easy way. It is rather something that has to rely on highly developed probabilistic studies, tenacious searching and cooperative communication. If traceability is thought of as serving a marketing strategy, the case will of course look easier, but should not be mistaken for a complete answer to the problems of food safety.

According to its proponents referred to above, two areas will be disrupted by this new technology. Firstly, in a technical sense it is information management based on central databases, secondly, concerning institutions, it is the bureaucratic effort of certification of origin and of quality that will have to face major changes, if not complete redundancy.
While they are not explicitly mentioned, one may also envisage that not only would state-run bureaucracies be concerned, but also those in bigger companies, multinationals with their sometimes considerable overheads. In another respect, but without elaborating on it any further, Kshetri [12] also states that "NGOs and others that monitor the fair-trade use 'antiquated' techniques." For this he refers to 25 million coffee growers worldwide, and the positive effects BCT could have in social and economic terms. The extent to which and in what way BCT in FCM will be disruptive for agricultural industry remains to be seen.

MATERIALS AND METHODS

Approaches to analysis

As mentioned above, most papers on BCT applied to FCM introduce it as a given option, showing relative advantages from a technical point of view. Those explicitly addressing economic criteria mention cost, quality, speed, dependability, risk reduction and/or flexibility as criteria (cf. Kshetri [12]). The paper presented here will go beyond company perspectives and call for the achievement of Pareto optimality. With Pareto optimality as a criterion in mind, the work done with this paper will analyse transaction cost in the context of differing institutional settings, primarily based on standard microeconomic theory, but embedded in the more comprehensive approach of New Institutional Economics (NIE). The paper approaches the case only analytically, with some concrete examples to illustrate the case rather than indicating any quantitative proof.
An alternative to the economic approach used here is offered by Kshetri [12] in that it develops a theory on the basis of a number of case studies available for current BCT in supply-chain management. Yet another approach is used by Hinings et al. [10], who approach the issue explicitly from an institutional perspective as well, but based rather on management than on standard microeconomic theories. Most other available

publications (introduced above) do not use theory or methods used for testing hypotheses, but present well developed IT architectures and considerations for possible applications, typically supported by reference to pioneering activities. A strictly micro-institutional economic approach to the analysis of BCT in FCM, as selected for this paper, has not previously been available.

Using welfare economic categories for this paper may expose it to the criticism of being normative. However, careful reading would make it possible to separate the part in which the analysis remains purely positive and the point from which conclusions are indeed normative in the way that welfare economics and utilitarianism are indeed normative. An open discussion of implicitly or explicitly normative content is further supported by Hinings et al., indicating that also the development of – only at first sight purely – technical infrastructure is orchestrated by private actors according to their values. "Creators of digital infrastructures seek to infuse their norms, values, or institutional logics, into the infrastructure" [10].

RESULTS AND DISCUSSIONS

Micro- and institutional economic theory for analysis of BCT

Orthodox economic theory is just a price theory: it is prices, that explain quantities supplied and demanded in the framework of functional relationships. In that prices mirror relative scarcities, they steer human activities and thus the allocation of resources to their optimal use, i.e. maximum utility, which everybody is assumed to seek. Ultimately, all human activity is explained on the basis of prices (reflecting scarcities) and preferences. So according to this theory – natural conditions and available technology assumed to be given – no further factors are needed to coordinate human activity, striving for well-conceived, long-term maximum of utility, i.e. life as good as it can possibly be. Further factors interfering with this mechanism, even if well-intended, would only and necessarily lead to lower levels of welfare.

BCT, as put forward by its proponents, fully matches the described ideal of this price theory. For both BCT and fundamental micro-economics, there are uniquely measurable and tradeable items, namely land, commodities, products, services or property rights. All their characteristics, as well as their current, earlier or later ownership can be well captured in blocks, just like they are captured in a system of price/quantity relations. All communication and mutual agreements required for the smooth working of markets are guaranteed by BCT. Thus BCT is the ideal technical complement to the principle of market exchange as captured by pure price theory.

What is more, BCT may claim to maintain the notional world of microeconomics, when microeconomists themselves begin to struggle with possible violations of the axiomatic foundations of their theory. Violations, first of all of the axiom of complete, and particularly of asymmetric information, are said to be overcome by BCT. The problem of incomplete contracts could thereby also be solved, in that "smart" contracts are generated in a food chain accompanied by BCT. However, this kind of solution to the problem only reflects the fact that the problem itself is essentially seen as merely technical: former communication systems (based on paper, e-mail communication, centralised databases with restricted accessibility, etc.) would simply be too slow and too rigid to serve their purpose as well as BCT could. (The problem of "unknown unknowns" is not addressed in the literature on BCT). The axiom concerning rationality and thus limitations of cognitive capacities of individuals is hardly addressed by BCT, probably because the availability of information and IT tools for rational optimisation make this appear a less important problem. The axiom of well-defined property rights in items processed, traded etc. is implicitly seen as taken for granted, as they are easily documented in the blockchain. Concerning property rights in information and access to blockchains, some of its proponents (cf. interview partners of Sommer [35]) push for solutions following an open-access philosophy. In theoretical terms, this again actually matches basic microeconomics, typically found in later chapters of textbooks, where the categories of club or public goods are introduced. However, BCT proponents thereby rather skip the intricacies of forms of governance as discussed by institutional

economics, in that their radical solutions seem to cut through such Gordian knots. In a similar way, the role of economies of scale is either neglected or seen as a matter only of the "disruptive" period of the introduction of any new technology, ultimately leading to new, stable, and welfare-enhanced equilibria. Thus the axiomatically important role of convexity of production and consumption functions (i.e. essentially, of substitutability), or the way in which more advanced microeconomics, namely industrial organisation, deals with violations of it, seems rather negligible from the perspective of BCT proponents in the first place.

What may help to recognise the joint pattern of thinking that underlies BCT and basic micro-economics, is a look at a third concept, namely of the internet of things (IoT), as it also follows just this pattern. (A look at the papers of Kshetri cf. [12] or Chen and Xu [6] and the literature quoted there in fact proves a considerable ancestry of BCT in work on the IoT.) Here again, and here most explicitly, it is revealed that clearly identifiable and measurable *things* form the ontological basis of this concept. In that the pure price theory of microeconomics, BCT and the IoT do so, they avoid any confrontation with complexities of the real world that cannot be captured by this atomistic thinking. Atomistic thinking as it underlies the methodological individualism of microeconomics may often help analysing real world phenomena, but it cannot always be re-transferred as such to the real world for policy design. Institutions – which may themselves be captured as public goods – are a case in point. The IoT, by definition, cannot comprehend public goods.

Of course, any scientific approach will have to reduce the complexity of the real world. However, while the respective limitations of pure price theory can well be made explicit when teaching economics by checking for possible violations of its axioms, and in that different optional forms of governance are introduced, BCT proponents implicitly take this problem for null and void in that they either claim that BCT overcomes these limitations, or in that they simply ignore them.

To what extent can this notional world underlying BCT claim validity? For economics. a violation of its axiomatic foundations will call for institutions (rules of behaviour), offsetting the failure that accompanies the violation. But for BCT? To explain the issue, firstly an institution that seems in any case to be taken for granted is discussed here: well-defined property rights. It is an institution that – at least for introductory microeconomics – has itself achieved the status of an axiom. Of course it is not given by itself, but a hard-fought issue of what is called a *social contract*, i.e. a matter, political economics was concerned with from its beginnings. Unfortunately, for today's economists this issue was somehow lost when economic and political sciences separated as academic disciplines.

If well-defined property rights are not given or violated, the respective resource may run the danger of being overused, or it may not be created in the first place. So the way it can possibly be established and enforced deserves the utmost scrutiny (which it is not given in standard introductory courses). Such scrutiny will include the option that this kind of institution does not offer the best choice for a social contract, but that other forms of governance may be superior.

Enforceability of the institution of property rights presupposes, that the resource in question can indeed be identified as a fungible, and thereby directly measurable item. If this precondition is not given in the first place, the resource may possibly be transformed ("commodified") to make it meet this requirement. Examples where this process has proved possible are land, or radio bandwidth. The distributive effects of such a transformation can be problematic but are in principle resolvable. In other cases, an attempted commodification may in fact destroy the very characteristics of the resource concerned, namely in the case of essentially social resources. One example of such a resource is culture, as it cannot sensibly be reduced to commodities to e.g. visits at a theatre, pictures in a gallery or the like, as some parts of the existing literature suggest. [9] Similarly, security can hardly be

commodified into security services or the enhanced barring of windows, let alone in a welfare-maximising way. Institutions themselves, relying on political agreements or at least grudging acceptance, offer other examples of essentially social resources. For all these cases more complex institutional settings or – in other words – more complex forms of governance have to be established. A concrete example is provided by the various forms of governance of water supply and sewage systems. Mobility schemes, which include not only private but also public transport, are another example; here, aspects from convenience to the death toll resulting from different mobility schemes indicate the challenge that comes with the respective social decision-making. The establishment of complex institutional settings – whether socially emerging or consciously designed – are discussed by institutional economics. Neoclassical microeconomics with its axiomatic basis remains a cornerstone of all this, if not reduced to the typical introductory course content of pure price theory. The conclusion up to this point is that as axioms are violated more or less complex sets of institutions may be observed (if given already – e.g. in the case of traditional alpine pastures), or they may have to be developed in a given social context, possibly leading to an overall optimum, or – if not well designed – to a politically biased outcome. In general terms, these aspects are presented in introductory textbooks as the problem of open-access goods. Important contributions, now enjoying the status of milestones in history of economic thinking, came from Harold Demsetz (on property rights), Garret Hardin (on the "tragedy of the commons"), Ronald Coase (trying to re-direct economists' attention to the role of transaction cost and thus to the law and forms of governance, not – as a reduced view went – to their principle containment) and at later stage Elinor Ostrom (observing and analysing the functionality of institutional settings for the management of natural resources.) In recent years it is the author trio of Acemoglu, D., Johnson, S., Robinson, J. A. who became known for working on systematically biased outcomes, such as colonial structures, leading to comprehensive questions like "Why do nations fail?"

As it is presented by its proponents, BCT is largely restricted to what microeconomics offers in its basic form, as if its axioms could not be violated. Promising to overcome all problems linked to information asymmetries etc. must seem overstretched, considering real-world situations. Other limitations (violation of convexity assumptions, actor rationality etc.) of a concept reducing the real world to one of *things* are not even addressed by BCT proponents. However, this does not mean that BCT might not prove to be a tool supporting efficiency of FCM in some forms of implementation.

Limits of blockchains applicability

For BCT, with its ontology of *things*, the degree of granulation of these produced and consumed things is considered critical. The size of a unit consumed would of course be critical in that the promise to consumers is that they could trace products back to their origins. In most cases it will be part of a batch of produce that can be traced back to a previous stage of the food chain, where again batches purchased as inputs will be traced back to the next previous stage and so on. Depending on the kind of processing, the size and composition of batches may change. The information that will have to be made available will multiply with the variety of inputs used and the number of their suppliers. The number of stages (and thus blocks) in the chain as such will possibly add less to the volume of information but rather to the effort needed to represent the respective contracts electronically within the blocks. Apart from this, the mining (generating and adding) of blocks is computationally a rather intensive matter, calling not least for considerable energy input. The issue or energy requirement of bitcoin has been raised by the blog digiconomist.net and recent research [8] on the topic found widespread attention also in the media. Whether or not the energy requirements of a blockchain application to supply chains will depend on its specific design, it still seems safe to assume that this problem will not be as serious as with the

bitcoin system. So the mining of blocks will not have to refer to numbers of blocks as large in the bitcoin system and it may not be made up of as many nodes. It is to be expected that new and different designs of blockchains will offer new and more energy-efficient options.

A look at Chen and Xu [6], presenting a computational design of a platform and its application for traceability and supervision of broiler production, may give an idea of what is to be expected. All the details of feeding and feedstuffs, veterinary applications, of death rates etc. all along the respective time line of the fattening process of the herd are covered here as a protocol of real-time operation. All this will have to be continued for slaughtering, packaging, refrigerating, storing, shipping etc. until it reaches the shelves of the retailer. For all of these stages, detailed information is supposed to be measured in real time and documented in the blockchain.

Neither conceptually nor technically would such a procedure have to be considered an insurmountable problem in principle. There is no restriction to the volume of information in the blocks. The question is rather whether it indeed leads to an optimal solution. For the case of broilers as described by Chen and Xu [6], data to be fed into the blockchain are readily available, as the whole production process is computerised in the first place. So considering blockchain technology as a standard presupposes "smart" (i.e. computerised) farming, possibly using drones, detailed soil analysis and the corresponding application of fertiliser, the use of GPS-navigated self-driving equipment for this application and also for tillage, broadcasting seed etc. To really live up to the expectations stipulated by proponents of BCT in FCM, the same level of information would have to be available for the inputs used (namely seed, pesticides etc.). Animal husbandry, crop or vegetable production etc. will all have their own specificities to be captured. Without questioning the possibility of such computerisation in principle, it will still be a long way to realising it. Besides the fact that some ultimate limit to the information gathered will have to be accepted anyhow, the question may be whether this is indeed the best way to go.

Of course, the critical point here is not the fact that the digitised handling of information offers considerable advantages compared to paper- or e-mail-based communication. Nor is it the question of whether a system that is coherent by design (as is BCT) might technically be superior to one that is only made coherent by extra efforts organising respective data exchange between differing company databases. The question is whether the problem of asymmetric information can indeed be solved in this way. Indeed, a nominal lack of information may be overcome, but the information available may not be useful for the two sides of a market to the same extent. What is more, the enormous amount of information promised by this may actually lead to a self-defeating overflow; the cognitive capacity as well as the willingness of people to make use of information is limited. So far, BCT proponents have hardly addressed these questions.

As introduced in section, at this point in the real-world economy it is institutions that come into play, offsetting the violation of the axioms of complete information and rationality. This time the violation may not be due to a lack or a lopsided distribution of information, but due to an overflow of difficult to qualify information. Though not discussed – essentially not wanted – by its proponents, a workable application of BCT will nevertheless have to resort to institutions beyond private property. What is needed for well-informed and not too irrational decisions is consolidated and reliable information. Information is thereby not to be understood as an individual appendage linked to individually traded items, not as almost intrinsically given with this specific good, but as something generated as such and subsequently shared by traded items. Information can be made subject to quality-management programmes, with appropriate institutional settings allowing for the use of decreasing marginal costs. Information can thus be provided as a club or as a public good: certificates, norms, the use of a specific language, or information requirements imposed by food laws are

examples. Brand names in principle fulfil a similar purpose, while they are typically owned by private companies, which can be categorised as specific kinds of clubs. Product warranties – in substance legally enforceable compensation schemes for problems resulting from false information – set incentives for safeguarding announced quality standards.

Communicating information in a sensible way thus relies to a large extent on essentially social agreements, beginning with the establishment of generally accepted metrics in which the quality of a product can be described, all the way to third party intervention that can be called for conflict resolution. There is no way that BCT could be made workable without taking account of the essentially social foundations of efficient communication. Of course, ways may be found to reduce the cost of these systems, but it is obvious that many existing institutionalised information systems are more cost-efficient than strict peer-to-peer information systems. To borrow from Coase's famous paper on the nature of the firm: why, otherwise, would they have emerged as such? Measurability of products and peer-to-peer ways of communication as such may be given in principle, but practically be unrealistic, too cumbersome or simply too expensive.

Food safety is another issue to be addressed here, as it cannot be captured sensibly as matter individual importance. Food regulations are among the oldest institutions of human civilisation; many religious prescriptions relate to this. With food traded between increasingly anonymous partners, it became all too obvious that trust can be a rather fragile and possibly even a deceitfully used resource. Historically, first it was severe penalties that were intended to deter violations of food laws; this deterrence was gradually complemented – which may be recognised as the progress of civilisation – partly substituted by an ever closer system of administrative measures, building up trust in food safety of an impersonal, general character. Food safety became a public good.

Would BCT offer another step in this progress of civilisation? From the BCT proponents' perspective, food safety would actually no longer be such a problematic issue. Complete transparency would automatically lead to food safety, as unsafe food would no longer be marketable. The consumer, and all those participating in the food chain would have the respective information available. Traceability would be an inbuilt feature of the system. So the supply side would provide for the necessary trust in its own interest; suppliers themselves will make sure they are trusted.

Following purely economic criteria, it would simply be a decision between two competing systems. If the BCT system (including all kinds transaction cost) was indeed cheaper than current legislation and its respective enforcement, legislation could switch to enforcing the use of BCT as an obligatory tool for food chains. There is no doubt that the current system is an expensive one, but even if BCT were to be the economically preferable solution, its comprehensive implementation would remain a major challenge. For this, the situation in Romania would have to be scrutinised. A long-term plan could be developed.

Apart from the purely economic approach to decision making, one might reconsider what fundamental a switch to a BCT-based system would be like: food safety (a public good) would be replaced by safe food (private goods). As explained above in the theoretical part of this paper – along with the concept the IoT, or some introductory microeconomics – BCT is essentially concerned with and restricted to private goods. If what used to be food safety is left to BCT, it would no longer be a matter of public responsibility. Access to safe food would become a matter of individual purchasing power. Those unable to afford it would drop out. For now, cheap meat counters (in German it used to be called the *Freibank*), offering meat not matching the criteria of the official – with BCT private – veterinary post-mortem inspection, may seem to be a matter of the past in the developed countries. It is to be expected that this marketing option – not only for meat – would find its place again under a BCT system of only private goods. Keeping both systems going in order to avoid such a development

would not be Pareto optimal, and should thus not be considered as an option.

Considering all this, a caveat may be added: the social capacity to create and maintain institutions such as fairness, honesty, social cohesion and their concrete and modern expressions in the form of the respective policies may gradually erode as they are declared to be inefficient and better replaced by systems like BCT or the IoT. Such an erosion of what may be classified as the institutional capital of society will have effects going beyond FCM.

A place for blockchain technology in the food chain

In order not to waste the undoubtedly given potential of this technology, interfaces will have to be developed between the IoT world of BCT and the real world, being – as a matter of fact – full of cognitive incapacities and currently still underdeveloped digitisation. Thus the critical point is how, in what format and under what conditions information is fed into and released from BCT-supported food chains. The following paragraphs will be dedicated to this more concrete, but still theoretical cases.

To begin with a straightforward example: For the broiler production described by Chen and Xu [6], feeding data into the system should indeed be no problem. The problems begin with production processes that are less easily measurable, even more complex or cannot be considered as appropriate starting point of the chain. For the production of broilers one may thus well ask for the provenance of feedstuff, vaccines etc. One may ask for the integration of all the respective information into yet another block, prior to the block of broiler production. The farther this is taken, the more unrealistic it becomes. The "old technology" solution would instead rely on authorisation schemes, publicly negotiated and enforced, i.e. on institutions offsetting the "failure" of not having achieved perfect information. For food products this would primarily rely on the food regulations.

Of course, the impasse of an exponentially increasing volume of information has not been overlooked by the proponents of BCT. However, if solutions offered by institutions are considered at all, the existence of respective legal conditions continues to be considered rather as an additional bureaucratic nuisance than as an asset. Kshetri [12] acknowledges: "Addressing this challenge may be no small feat." At least Casey and Wong [5] give some accepting, but ultimately interest-oriented turn to the case. They see BCT as confronted with the existence of a complex array of regulations like maritime law and commercial codes governing rights of ownership in a multiplicity of jurisdictions. But instead of taking this as determined by public bodies, they propose the industry should take the lead in defining best practices and standards of technology as well as contract structures, making them applicable internationally, across jurisdictions. In brief, the design of institutions should follow business interests.

Etherum, alongside bitcoin another pioneer in BCT, soon saw the need to capture more in blocks than just information. Sample contracts should also be offered, making it possible to decide on a number of optional terms before fixing them. This corresponds to what is needed when institutions are also to be incorporated into blockchains, being constitutive for an interface. Nevertheless, when presenting its service, Etherum does not emphasise this as an institutional turn in BCT development, which would be of most interest here, but leaves it at what is typically seen as an advantage of BCT. So Etherum offers applications for "smart" contracting "that run exactly as programmed without any possibility of downtime, censorship, fraud or third-party interference." [18] While this statement discloses some of the libertarian impulse often encountered with IT specialists, matching the principle dismissal of public authority by private business, it nevertheless confirms the need for contracting. Even complex contracts can be concluded in the blockchain, with standard contracts being lodged there, serving as blueprints to be written out with specific content. In the same way, the "legal conditions" that Casey and Wong [5] refer to, i.e. laws and regulations, could be lodged in blocks, serving as building blocks for contracts. Technically, there is no

reason why the role of a third party, a public body or democratic principles underlying standards of contracts would have to be excluded from this.

While it may be no "small feat" (see above), the option of lodging laws and regulations in blocks may help to clarify the character of entrance points for block chains. Thus entrance points could be established not only for trivial cases with their easily verifiable criteria, but also for cases based on complex production processes, possibly overly complex bundles of inputs, or simply non-computerised farms, i.e. cases falling short of what blockchain technologists may presuppose as a state-of-*their*-art agriculture. In this way blockchains would not have to rely on fictional entrance points beginning seamlessly with primary, perfectly monitored production. It would rather be sufficient to begin and end with interfaces to the world of "old" technologies and institutions.

Now the critical question should no longer be whether standards (i.e. institutions) are needed at all. They are needed, as long as the world is not 100% shaped according to the ontology of BCT; and it never will be, if it is intended to persist. The critical question will rather be what guidance these standards are formulated under, which again predetermines by whom, to whom, and in what form they will be applied – or enforced if needed. Possible monopolisation of, or arbitrarily determined access to food chains, as well as lock-in situations may well occur and lead to losses of welfare. Anti-trust regulations will have to be in place to prevent this. The fact that market access may not be barred if Pareto efficiency is to be achieved is basic textbook economics. On the other hand, it is clear that only standards – which are selective and thus restrict access – can avoid adverse selection and an ultimate implosion of the respective market itself. So two opposing effects will have to be kept in productive balance. Inasmuch as standards may limit market access or lead to lock-in-situations etc. they are a matter of public concern and will have to be dealt with as such. So designing standards and thus defining entrance points to a system of food chains cannot be left to just one side of the entrance.

Beginning with a realistic entrance point – e.g. today's typical agrarian trade and warehouses – an important aspect will be the format in which data on products and production will have to be provided in order to qualify for a particular standard, possibly lodged as a certificate in the blockchain. Will it have to be most detailed information, amounting to a de facto electronic, real-time monitoring of production, or will a proven visit by a representative of a certifying organisation suffice? If it is detailed information, i.e. de facto "smart" farming, is presupposed, a potential bias towards farm size and thus enforced structural change will have to expected, calling for a prior technological impact assessment. Changing economies of scale will have to be scrutinised for each product group. Information technology might possibly be supportive for small producers, but it may also put them at a disadvantage. If standards were to be set by retailers or the processing industry ("taking the lead", as proposed by Casey and Wong [6], see also above), farmers may not have much of a choice. Farmers investing to make their products eligible for specific food chains may end up in a lock-in situation. So what will call for sober assessment is whether the cost of the expected disruption, i.e. of the sudden depreciation of earlier investments in equipment, software, training etc., can be covered otherwise. Textbook economics – following the Pareto criterion – considers compensations for farmers concerned. The question would be whether there is indeed an option to negotiate this and whether there are indeed sufficient extra profits available to compensate for losses.

Having now – at least conceptually – established defined and defining entrance points of the blockchain, additional information can be added to it, real-world-step-by-real-word-step, block-by-block. From this point onwards, advantage can be taken of the fact that these parts of the chain typically consist of industrial processing and logistics, which is much more suited to digitised organisation and documentation in the first

place. However, this part of the chain will also require critical attention. Inasmuch as the companies in the food chain rely on external service providers for the blockchain, the latter may build up a strong negotiating position vis-à-vis not only farmers, but also processors, wholesalers etc. Other than for producers of physical products, the axiomatic law of diminishing marginal productivity, safeguarding upward-sloping supply curves and thus the emergence of a market equilibrium, does not hold for IT services. The resulting tendency to monopolisation (as for farmers, queuing up at the entrance points) will call for a degree of scepticism with respect to the formation of markets under the auspices of BCT.

Finally, an interface is also needed for the exit point in the blockchain, transforming all the accumulated information into what consumers can find useful for their decisions. QR codes, just making all this information as such accessible by mobile phone apps, as envisaged by some BCT proponents, will not be up to the task.

"Old" technology solutions offer certificates, brand names, information on selected substances for consumers to base their decisions on. These systems are far from perfect. A longstanding debate on an excessive number of food labels, etc., i.e. the information overload that consumers are confronted with even in this way, makes their functionality questionable. What is more, the image, created and supported by commercials, will often override substance.

Here BCT can indeed contribute to a solution. For this, the possibly vast volume of information accumulated on the blockchain should be made available in a structured way. Based on this information, apps on a mobile phone or appropriate equipment on the retailers' shelves could check the information for compliance with any variety of seals or certification criteria. Personal profiles could be developed and used for this, but also simplified food labelling (e.g. just using "traffic lights", giving a rather rough indication for consumers to choose) could be provided in this way. (So, paradoxically, BCT might ultimately give a push to certification schemes – something that is typically regarded with contempt by its proponents.) Structured portraits could be generated for those seeking more information. In this way, one of the typical violations of neoclassical axioms – assuming the perfectly informed actor – caused by either an overload or a lack of information could be solved or at least be reduced.

A critical requirement of this is that the information available on the blockchain is indeed offered in a publicly available format. If, otherwise, access to the information remained a proprietary matter of specific wholesalers, retailers or the supporting IT companies only, the problem of asymmetric information would return, consumers would be left manipulated or possibly refrain from purchasing at all. Nothing short of general agreements on standards for public access to data will be needed to achieve the promised progress. Arguments referring to privacy policies put forward in this context will be no more than thinly camouflaged business interests. In concrete terms, consumers' organisations, fair-trade organisations, trade unions, the health ministry, anyone else, or any coalition of them, could actually "rent" a place (of some lines of code) in the final block. (How this could be organised technically should be left to experts. Possibly, the evaluation process would not be run within the last block itself, but may be triggered by providing the respective information and request to the cloud, or the evaluation would be done only once for a batch of products and stored as such in the block.) The consumer may select the preferred provider of an evaluation – possibly liable to some payment. The way in which typically private foundations or associations check and compare products for their quality may be exemplary for this: in Germany it is the Stiftung Warentest [29], in Austria the Verein für Konsumenteninformation [30], in the United Kingdom it is the Consumers' Association, known from *Which?* Magazine [39]. All of these are bipartisan organisations, meaning there are representatives of producers and consumers etc. on their boards. In any case, providing

this additional, processed information could be left to suppliers doing just that, offering this information on the retailer's shelf on the consumer's demand. With that, an additional marketplace for provision of information is created. Consumer organisations will "rent" their place there, like at a fair, like any other provider of information consumers might ask for. As one should not take the establishment of such a market for granted – the retailers will probably want to make use of their a priori given monopoly power – legislation may have to force them to do so. There is no possible argument that this would not bring the overall economy closer to its Pareto optimum.

For all that, and possibly to the disappointment of many blockchain proponents, what has been introduced above will bring BCT back into the world of private and public law, of third parties and public arbitrators. Only the careful development of institutions, i.e. in this case of appropriate standards, enforcing functionality of the interfaces as discussed, will offset the deficiencies of BCT with respect to social organisation. In a similar way, economics will have to go beyond its purely price-theory approach and incorporate into its analysis optional institutional settings in which BCT could be organised, and thus in which the price mechanism itself can indeed bring about optimal results. In very general terms, BCT and standard economics will both have to *overcome their ontology of things*. Also *institutions matter*, i.e. in this case standards for the interfaces between the real world and what may be manageable by BCT.

Situation and perspectives for Romania

Ultimately, all theoretical reasoning will have to be put to the empirical test. As developments in this field are rapid, and thus a proof of workability of BCT for FCM appears like going for a real-time experiment, this paper can only propose taking a closer look at existing efforts and actual options of the farmers and consumers concerned. For this, specific types of case can be identified here. Further work may then explore it in greater depth.

Criteria for the identification of specific types of case have been developed in the earlier parts of this paper. From the farmers' perspective, accessibility to the food chain is critical, and thus what will have to be to defined as interfaces between the blockchain and the "old" world of mostly non-digitised farming. In purely economic terms it would be the transaction cost that arises for participating in the "new" format of food chains compared to collecting and marketing via existing agricultural trade organisations, possibly supported by certification (labels organic farming, geographical indications etc.)

Table 1. Romanian farm structure 2016

	Number (000)	UAA (000)	AWU (000)	>50 hhc %
Total	3.422	12.503	1.588	2.956.380
Zero ha	80	0	25	73.720
Less than 2 ha	2.401	1.540	816	2.202.900
From 2 to 4,9 ha	660	2.049	416	539.530
From 5 to 9,9 ha	194	1.304	173	123.460
From 10 to 19,9 ha	50	666	60	15.160
From 20 to 29,9 ha	11	263	16	1.150
From 30 to 49,9 ha	8	289	13	350
From 50 to 99,9 ha	6	418	12	100
100 ha or over	12	5.973	57	10

Source: EC, Eurostat, retrieved 24 September 2018. UAA: Utilised agricultural area – '000 hectare, AWU: '000 Annual Work Units, >50 hhc: Farms whose household consumes more than 50% of the final production - number

It seems quite obvious that the upfront cost of digitisation is not affordable for most smaller farms, producing in rather traditional ways. What is more is the fact that with such anyhow limited digitisation the border with the "old", non-digitised world is shifted only by one step. Real compatibility with what makes BCT so attractive, namely for bigger investors, is provided by what is called "smart" farming, i.e. completely digitised farming. Thus the adoption of digitised farming technology is usually limited to large farms, as its high cost makes it not only unaffordable but often also just inappropriate for most smaller farmers. Elements of digitisation can especially be observed in the dairy farming, crop production and greenhouses. These techniques and technologies include GPS (global positioning systems), GIS (geographic information

systems), remote sensors to manage the use of water, fertilisers [38] and pesticides, as well as the use of drone monitoring systems. Dairy farmers in Romania (especially farms larger than 200 dairy cows) have adopted technologies for monitoring and sustaining cows' health and performance, such as positioning, precision feeding, automatic calf feeders, milk analysis and also heat detection, mastitis sensors, or temperature sensors [37]. Currently, the use of such technologies is still a matter of a number of pioneering farms, but it may shape the overall picture of commercial agriculture in Romania within just a few years.

For some farming sectors – possibly wine, some specific dairy products, and others – digitisation of their production may offer quite appreciable advantages, even if operating on a smaller scale. This option certainly deserves special attention and will have to be checked for each product group.

Another option may be given for *contract farmers*. As they are getting support for land preparation, seed, pest management, fertilisers, compound feed, etc. from agribusiness firms, to suit the requirements of BCT better than other farms. Such farming may also be dubbed "franchising", as farmers become franchisees, if only on their own land, while the franchisor can assure lower overall transaction costs. Today, the number of farmers in Romania following this pattern is relatively low. It is an option, most obviously for smaller farmers, producing eggs, poultry or pigs. For some medium and large-scale arable farms integrated into overall agribusiness in this way, the decision to do so is confirmed and reinforced by their investment strategy. Here the surplus is not used for diversification or for establishing any other value-adding activities on-farm, let alone for independent marketing activities. Instead it is typically used for to extend the current production pattern, i.e. purchasing more land and labour as the only factors this kind of farming critically contributes to the overall production process.

In any case, whether for poultry or crops, marketing and quality control of all inputs and outputs is left to the contracting partners as service providers, making use economies of scale in this area of the business. These economies are also based on technical and logistical capacities, as well as on the lower transaction costs associated with quantities much larger than individual farms could achieve, and of course also better negotiating positions. It is obvious that such an integration into a comprehensive organisation of production suits the requirements of FCM supported by BCT much more easily than any other, rather fragmented form of organisation. Whether this will also lead to an economic optimum, i.e. an alignment of resources with prices equilibrating marginal cost and productivity, will depend on the ability of farmers to select between competing contracting partners. Obviously there is a certain likelihood that the latter will be in a stronger position than the farmers.

Before the transformation began in Romania, the respective agri-business activities were under uniform state control; in Western European countries it was often dominated by cooperatives. Thus the situation for farmers will not really be new; the extent to which upstream and downstream partners could be described as efficient service providers or as all-powerful firms, squeezing farmers, is a long standing debate. The effect of digitisation will largely depend on the accessibility of a possibly larger number BCT-supported food chains. Anti-trust policies will be seen in charge of providing for competition between firms and technological options, whether centralised data management, or blockchain.

All farms that are integrated in a broader context of production and distribution, whether as contract farms or independently, will either produce only commodities, or they may – if higher value is to be achieved – opt for branded products. Typically, *brand names* (as a matter of intellectual property rights to be considered private goods) are owned and maintained not by agricultural units but rather by downstream processors or retailers. So it is to be expected that the extra margins will accrue to the latter. For farmers themselves, the situation is therefore not much different from supplying the market for commodities.

There is no reason to assume that this will change with introduction of BCT in Romania.
For farmers, the alternative to producing commodities is going for higher value-added products, which will then rely on *certification* such as *geographical indication* or *labels for organic production*. In contrast to brand names, these are classified as club goods. As long as the members of this club do not opt for a complete digitisation of their own production, which would include the option of digitised certification, they will have to strive for entrance points to BCT-supported food chains, that actually lodge the respective certificates as qualification for admission. This is where the dissimilarity between the genuine BCT world of big data on the one hand and the "old" world supported by institutions on the other calls for an interface. The BCT world relies solely on an ontology of things, whereas in the "old" world a role is attributed to institutions. The development of this interface is now a matter institution-building itself.
In Romania, there are four registered geographical indication schemes and six other designations are listed as applying. [cf. Table 2] As with all other product groups, it will have to be checked what advantages digitisation might offer for farmers in the production and the certification process. Again, this will depend on the kind of product and on the scale of production.

Table 2. Romanian designation schemes

Designation	Status	Type	Product Categrory
Salată cu icre de ştiucă de Tulcea	Applied	PGI	Fresh fish, molluscs, and crustaceans and …
Telemea de Sibiu	Applied	PGI	Cheeses
Scrumbie de Dunăre afumată	Published	PGI	Fresh fish, molluscs, and crustaceans and …
Caşcaval de Săveni	Applied	PGI	Cheeses
Novac afumat din Ţara Bârsei	Registered	PGI	Fresh fish, molluscs, and crustaceans and …
Magiun de Prune Topoloveni	Applied	PGI	Fruit, vegetables and cereals fresh or processe
Cârnaţi de Pleşcoi	Applied	PGI	Meat products (cooked, salted, smoked, etc.)
Telemea de Ibăneşti	Registered	PDO	Cheeses
Salam de Sibiu	Registered	PGI	Meat products (cooked, salted, smoked, etc.)
Magiun de prune Topoloveni	Registered	PGI	Fruit, vegetables and cereals fresh or processe

Source: EC, DOOR databank, Retrieved 18 September 2018.

Here, with trust built on institutions (certification) vs. trust built on digitised monitoring of production, the key question of the whole debate on the advantages of BCT (or SAP's and others' ways of digitised monitoring, for that matter) is clearly expressed: there are two competing trust-building mechanisms that differ from each other in principle. The degree of trust they achieve, and possibly also the differing levels of sympathy consumers will feel for them, are decisive. On the other hand, the respective cost they incur is critical to the consumers' decision. This can well be approached as typical case for transaction-cost analysis.
From an individual consumer's perspective, the critical question will be whether retailers offer information at the exit point of the food chain that indeed supports decision-making. As explained above, this final interface should not be defined in a proprietary way. Instead, the accumulated information should be accessible to all those who want to evaluate it according to any possible set of criteria that consumers may consider relevant for them. A market for this information, taking account of specific informational preferences of consumers. would be the keystone of the edifice of the whole digitisation exercise. As retailers may consider this to be interference in business affairs – which it is – legislation may be needed to enforce it. As food chains of the kind discussed here do not restrict themselves to national borders, the EU should be seen as responsible for providing a respective regulation.

CONCLUSIONS

Over the last two years, blockchain technology (BCT) has been presented by its proponents as a game changer not only for the finance industry, where it originated, but also for supply-chain management and – as considered in this paper – explicitly also for food-chain management (FCM). Indeed, only with respect to these new applications, would BCT be able to unfold its real strength.
In fact, BCT very much complies with the world of standard microeconomic textbooks, i.e. pure price theory. The expectations raised by its proponents, that BCT might generally help to overcome the need for institutions, third-party interventions etc., may find some reason in that institutions are often perceived as allowing only second-best solutions compared to an economy driven by price

alone. Information asymmetries as a recurrent violation of one of the microeconomic axioms would namely be overcome practically by design. Ultimately, it could indeed be left to prices to equilibrate individual utilities and resource scarcities.

In this sense BCT can claim to offer the ideal technical complement to market-economy optimism. However, when delving deeper into it and trying to apply it to more concrete and complex cases, the violation of micro-economic axioms and thus failures to achieve Pareto-optima turn out to be inescapable. The proposition that such failures could be overcome by BCT is clearly overstretched. Information asymmetries will continue to be a problem, if only in different forms; violations of the axioms of rationality, convexity etc. will also remain a matter of concern, while they are not even addressed by BCT proponents.

While recognising overshooting technological solutionism in what its proponents put forward, BCT may nevertheless find a productive place in FCM. This may be brought about by replacing the presupposition of fictional entrance points by clearly defined ones, serving as interfaces between a BCT-supported part of the food chain and the "old" world of primary production, limited cognitive capacities of consumers, foodregulations, certificates and other institutions. In order to optimise this, these interfaces should be based – like other institutions – on commonly agreed (or at least agreeable) standards. Accessibility is thereby guaranteed in principle, lock-in situations are to be avoided etc. As IT services show the characteristics of natural monopolies, anti-trust regulation will have to be put in place. Information accumulated at the very end of the food chain may not be proprietary. Instead, evaluation schemes would be lodged in the final block as an additional service, directly left to what consumers – possibly liable to payment – select as the preferred criteria for decision-making.

Some parts of the Romanian food and agribusiness may prove to be early adopters of BCT. This is mainly due to that fact that this sector is still in the process of reconstituting itself after the changes since 1989. Namely with respect to the production of agricultural commodities the new technology encounters favourable conditions, as large-scale farming also shaped large parts of the sector before 1989. On the other hand, it is the large number of small-scale farmers who may experience growing pressure from these changes. Their integration into digitised food chains will call for a set of appropriate institutions: agreed food standards, access to the food chain and anti-trust regulations will have to provide for options to safeguard their potential. While digitised food chains may indeed offer a wealth of information in support of consumer decision-making, it is again only food standards and appropriate evaluations that will really benefit consumers. Considering the integration of European food markets, there will need to be appropriate EU regulations to take account of this. More than in other countries, the public matter of food safety maybe overrun by an ill-considered approval of blockchain as a determining technology.

Summarising all this, the analysis conducted here suggests that *changing* technology may call for *changing* institutional settings, but that institutions will *not be made redundant* altogether. BCT will call for new institutional settings precisely to the extent that new kinds of market failures are to be observed. In some cases, the new settings may offer more leeway for the price mechanism to allocate resources, in others an optimal outcome will call for a more closely knit set of institutions defining the space in which the price mechanism can be put to full use. Contrary to what proponents of BCT suggest, this technology does not live up to the expectations they have raised, in just the same way – as has been shown –introductory microeconomics does not live up real-world problems. Institutions – i.e. contracts, certificates, anti-trust regulations etc. – and their enforcement by third-party intervention *matter*. Stated quite generally, developments of relative scarcity of resources, of technology, and of institutions always have to be well synchronised if harm is to be avoided. A food chain without an appropriate institutional framework will rather

leave the outcome biased in – possibly only relative – favour of the group pushing for it. On the other side of the spectrum, those relying existentially on food safety as public good would suffer most.

The Economist, 1 September 2018, dedicated a whole series of articles to BCT. It concluded that most attempts to make use of this technology remained tentative, if not disappointing. So "managing expectations" is said to be essential in continuing work on it, namely as much of what has surfaced so far has shown all characteristics of just another hype. Some proponents are quoted as saying: "We are but a few bright-eyed technologists with a special hammer, looking for the right nail." So, first of all, some sober expectation-management is needed. Whether BCT will ultimately find its proper place in FCM, whether it may possibly cause more disruption than create added value, or whether it will fade without trace remains to be seen. This paper has merely sought to contribute some consideration from the perspective of institutional economics.

ACKNOWLEDGEMENTS

This paper was developed in the context of the project ENHANCE (Building an Excellency Network for Heightening Agricultural ecoNomic researCh and Education in Romania), Grant Agreement No. 691681 / H2020-Twinning-2015.

REFERENCES

Academic and research related literature

[1]Ahmed, S., Broek, N.T, 2017, Food supply: Blockchain could boost food security, Nature 550 (7674), 43

[2]Antle, J. M., 2000, No Such Thing as a Free Safe Lunch: The Cost of Food Safety Regulation in the Meat Industry. American Journal of Agricultural Economics, 82/2: 310–22

[3]Ashenbaum, B., 2018, From market to hierarchy: An empirical assessment of a supply chain governance typology, Journal of Purchasing and Supply Management 2010, 24, 59-67

[4]Carlton, D.W., Perloff, J.M., 2015, Modern Industrial Organisation, 4. Edition, Bosten, Pearson.

[5]Casey, M. J., Wong, P., 2017, Global supply chains are about to get better, thanks to blockchain, Harvard business review. https://hbr.org/2017/03/global-supply-chains-are-about-to-get-better-thanks-to-blockchain, Retrieved 22 September 2018.

[6]Chen, C., Xu, X., 2017, Design and application of traceability and supervision platform for broiler based on Internet of Things, Nongye Gongcheng Xuebao, Transactions of the Chinese Society of Agricultural Engineering, Volume 33, Issue 5, 1 March 2017, 224-231.

[7]Crossey, S., 2018, Food supply: Blockchain could boost food security, New Food Magazine, 17 May 2018

[8]De Fries, Alexis, 2018, Bitcoin's Growing Energy Problem, Jule, Volume 2, Issue 5, 16 May 2018, 801-805

[9]Frey, B.S., 1990, Ökonomie ist Sozialwissenschaft – Die Anwendung der Ökonomie auf neue Gebiete, Verlag Franz Vahlen

[10]Hinings, B., Gegenhuber T., Greenwooda, G., 2018, Digital innovation and transformation: An institutional perspective, Information and Organization, Vol. 28, Issue 1, 52-61

[11]Hoffmann, S., Harder, W., 2010, Food Safety and Risk Governance in Globalized Markets, Health Matrix: Journal of Law Medicine Vol. 20, Issue 1.

[12]Kshetri, N., 2018, Blockchain's roles in meeting key supply chain management objectives, International Journal of Information Management, Volume 39, April 2018, 80-89.

[13]Lee Kuo Chuen, D., Deng, R., 2017, Handbook of Blockchain, Digital Finance, and Inclusion, Volume 2, 1st edition, Elsevier https://www.elsevier.com/books/handbook-of-blockchain-digital-finance-and-inclusion-volume-2/lee-kuo-chuen/978-0-12-812282-2, Retrieved 22 September 2018).

[14]Marke, A., 2017, Transforming Climate Finance and Green Investment with Blockchains, https://www.sciencedirect.com/science/article/pii/B9780128144473000331?via%3Dihub. Retrieved 22 September 2018)

[15]Reyna, A., Martín, C., Chen, J., Soler, E., Díaz, M., 2018, On blockchain and its integration with IoT. Challenges and opportunities, in: Future Generation Computer Systems 88 (2018) 173–190

Publications of firms, industry services and consultings

[16]Cohn, J., 2017, Genius of Things: Blockchain and Food Safety with IBM and Walmart IBM, Watson Internet of Things, Youtube, https://www.youtube.com/watch?v=MMOF0G_2H0A, Retrieved 22 September 2018.

[17]Corno, E., 2018, The Food Chain. Presentation at The Boeing Centre, Youtube https://www.youtube.com/watch?v=-7Dayowkz-I, Retrieved 22 September 2018.

[18]Ethterum Blockchain APP Platform, https://www.ethereum.org/, Retrieved 22 Sept. 2018.

[19]Food Safety News, https://www.foodsafetynews.com/2018/05/make-leafy-greens-high-risk-and-chase-them-down-quickly-say-consumer-groups/#.WzuVo_ZuJlY, Retrieved 3 July 2018.

[20]Deloitte, 2016, Blockchain in the food chain - Is blockchain a game changer in Agrifood? https://www2.deloitte.com/content/dam/Deloitte/nl/Documents/consumer-business/deloitte-nl-cb-blockchain-in-the-food-chain.pdf, Retrieved 22 September 2018.
[21]IBM, 2018, Smart Supply Chain, Commercial on apples, Youtube, https://www.youtube.com/watch?v=D5oH_xODP5M, Retrieved 22 September 2018.
[22]IBM, 2018, Smart Supply Chain, Commercial on Coffee, Youtube, https://www.youtube.com/watch?v=-VQsMwNCqZ8, Retrieved 22 September 2018.
[23]IBM, s.a., Blockchain in Food Safety, IBM Blockchain Blog, https://www.ibm.com/blogs/blockchain/category/blockchain-in-food-safety/, Retrieved 22 September 2018)
[24]Lorenz, A., 2018, The digital farmers' market, Euroactive.de, https://www.euractiv.com/section/agriculture-food/news/ the-digital-farmers-market/?utm_source=EURACTIV&utm_campaign=eb1a7b22ee-RSS_EMAIL_EN_AgriFood&utm_medium=email&utm_term=0_c59e2fd7a9-eb1a7b22ee-114711443, Retrieved 22 September 2018.
[25]New Food Magazine, Russel Publishing, https://www.newfoodmagazine.com/, Retrieved 22 Sept. 2018.
[26]Rodrigues, H., 2017, Blockchain's Agricultural Application. Youtube, https://www.youtube.com/watch?v=9PIzV5KnA0g, Retrieved 22 September 2018.
[27]SAP Deutschland, 2018, SAP Rural Sourcing Management, https://www.sap.com/germany/products/agriculture-supply-chain-mgmt.html, Retrieved 22 September 2018.
[28]Schunk, P., Bakhshi, N., 2017, How supply chain analytics can change your agri & food perspective, Deloitte, https://www2.deloitte.com/nl/nl/pages/consumer-industrial-products/articles/supply-chain-analytics-in-agri-food.html, Retrieved 22 Sept.2018.
[29]Stiftung Warentest, https://www.test.de/, Retrieved 22 September 2018.
[30]Verein für Konsumenteninformation (https://vki.at/, retrieved 22 September 2018)
[31]Wageningen University & Research, 2017, Food Integrity Blockchained. Seminar documented on video. https://www.wur.nl/en/show/Food-Integrity-Blockchained-Case-4.htm, Retrieved 22 September 2018.
[32]Yiannes, F., 2017, Walmart's food safety solution using IBM Food Trust built on the IBM Blockchain Platform. Youtube, https://www.youtube.com/watch?v=SV0KXBxSoio, Retrieved 22 September 2018.
[33]Yuva, R.Y., 2017, Blockchain Next on Food Supply Chain Menu, Foodlogistics, https://www.foodlogistics.com/technology/article/12382466/blockchain-next-on-food-supply-chain-menu, Retrieved 22 September 2018)
.]ORF, 2011, EHEC: Gewaltiger Schaden für heimische Bauern, https://oesv1.orf.at/stories/518888, Retrieved 22 September 2018.
[35]Sommer, S., 2018, Chain Reactions, brand eins (https://www.brandeins.de/magazine/brand-eins-wirtschaftsmagazin/2018/geld/blockchain-vertraut-den-daten?utm_source=zeit&utm_medium=parket t, Retrieved 22 September 2018.
[36] Stermitzke, G., 2014, EHEC: "Wir sind froh, dass es vorbei ist", in: Allgemeine Zeitung/az-online (https://www.az-online.de/uelzen/bienenbuettel/drei-jahre-nach-ehec-epidemie-besuch-klaus-verbeck-gaertnerhof-bienenbuettel-3766126.html, Retrieved 22 September 2018.
[37]Profitul agricol, 12 September 2018, http://agrinet.ro/content.jsp?page=908&language=1, Retrieved 18 September 2018.
[38]Revista Fermierului, 27 June 2018, https://www.revistafermierului.ro/tombola/itemlist/tag/protectia%20plantelor.html, Retrieved 18 September 2018.
[39]Which? Magazine, https://web.aboutus.product.which.co.uk/about-which/who-we-are, Retrieved 22 September 2018.

Official publications

[40]Elga, 2011, Informationen zu EHEC, https://www.gesundheit.gv.at/aktuelles/archiv-2011/ehec, Retrieved 22 September 2018.