Distributed Ledger Technology for an Improved Index-Based Insurance in Agriculture

Oleksandr Sushchenko ¹ and Reimund Schwarze ¹

Received: 06/05/2020 / Accepted: 14/01/2021 / Published online: 31/03/2021

Abstract Climate insurance is already a hot topic due to the increased number of climate-related catastrophic events accompanied by associated losses for the economy in general and insurance companies, in particular. The extremely hot and dry summer of 2018 in some European countries highlighted existing weaknesses of the agricultural insurance mechanisms in Europe, where the farmers had to wait for months before compensation payments could be made. Our paper aims to compare features of the yield-based insurance² and the index-based insurance (IBI)³ in agriculture in the light of new developments and trends in information technologies (IT). The results show that an application of the distributed ledger technologies (DLT) in combination with IBI could not only resolve existing problems, but also facilitate development of the innovative insurance mechanisms at the EU level – providing effective protection against climate-related risks and preventing a systemic risk escalation.

Keywords: distributed ledger technologies, index-based insurance, climate insurance, systemic risk, European Risk Transfer Mechanism, European Stabilization Mechanism.

JEL Classification: G22, L8, O52.

¹ Economics, Helmholtz Center for Environmental Research
   Email: sushchenko@europa-uni.de

² Yield-based insurance provides compensation equivalent to the difference between the obtained yield and the yield guaranteed at the pre-defined rate at the beginning of the contract (Atlas Magazine, 2017).

³ Index insurance is a relatively new but innovative approach to insurance provision that pays out benefits on the basis of a predetermined index (e.g. rainfall level) for loss of assets and investments, primarily working capital, resulting from weather and catastrophic events (IFC, 2020).
1. INTRODUCTION

Climate Change is associated with certain negative consequences (e.g. extreme weather events, natural disasters, etc.) – it poses risks to economic development and requires additional expenditures to prevent catastrophic events or to compensate the damages already caused. The World Economic Forum's (WEF) Global Risk Report 2020 recognizes climate change and its disruptive consequences as the greatest risks to economic activity (WEF 2020). Due to the increased number of climate-related extreme weather events, natural disasters and the associated losses, climate insurance has already gained considerable attention and become an important topic for the economy in general and for the insurance industry in particular. The extremely hot summer of 2018 in Europe proved that existing agricultural insurance approaches have numerous bottlenecks (e.g. farmers had to wait for months to settle the claim, the settlement of claims proved to be too bureaucratic). For the insurance companies, climate change poses new challenges, but at the same time opens up new opportunities for the development of innovative financial products. Moreover, hedge funds, reinsurance companies and institutional investors (e.g. pension and mutual funds) offer innovative instruments (e.g. catastrophe bonds) that provide an opportunity for a transfer of climate-related risks to the financial market (Hagendorff et al., 2014; Morana et al., 2019). Sometimes, however, these new market instruments conflict with existing traditional insurance products. From the insurance industry’s point of view there is a large number of so-called index-based insurance solutions (IBI) as an alternative to yield-based insurance. The main advantage of IBI is the use of an independent and objective physical indicator to overcome existing problems in agricultural insurance and to achieve potential cost savings (Kath et al., 2018). Nevertheless, some technical aspects of IBI application in agriculture (e.g. data collection and processing) remain largely unsolved problems. These bottlenecks of IBI could be resolved through the implementation of the Distributed Ledger Technologies (DLT). The now widespread use of DLT in the crypto-currency market has highlighted some positive features of this IT solution and opened up possible ways for its application as a technical facilitator in the financial market (e.g. insurance services) (Hughes et al., 2019). DLT could be considered as one of the key technical solutions that could assist in connecting technologies on the corporate level with such innovations like wearables, drones and Internet-of-Things connected devices. Also, this IT-solution could accelerate transformations across insurance services and capital distribution (KPMG 2017). Additionally, application of the DLT-based platforms could improve resilience and speed up recovery efforts in a disaster through decentralized storage of the critical information to file the claims (FEMA 2019). This aspect is important due to the fact that around 30% of the humanitarian aid did not reach its intended target (Ki-Moon 2012). Moreover, only 27% of the climate-related losses are covered by the insurance services in the EU (EEA 2020). 

In this regard, a set of research questions arise. Our first research question is whether IBI is a better solution for agricultural risks than the yield-based insurance or not. Secondly, could the DLT application result in substantial time and cost savings for insurance services? And if this is the case, could an IBI-based climate insurance scheme (with application of DLT) in
agriculture on the EU level improve existing European Agricultural Policy and reduce systemic risk for the entire European Financial System?

2. DATA DESCRIPTION

For the purpose of this research the authors have established a set of data on the following aspects: economic damages from weather and climate-related extreme events for the period 1997-2017 in the EU-28 countries; insurance and compensation systems in the EU and Switzerland as for 2019; DLT-related cost and time savings for the insurance services.

The first set of data has been retrieved from the European Environmental Agency (EEA) and is based on its methodology elaborated to disclose the damages with regard to geothermal (e.g. earthquakes, tsunamis, volcanic eruptions); meteorological (e.g. storms); hydrological (e.g. floods, mass movements); and climatological events (e.g. heatwaves, cold waves, droughts, forest fires). The second set of data on the insurance and compensation systems in the EU and Switzerland has been adopted from available scientific researches and publications (e.g. Palka, 2019:2 and Vroege et al., 2019:105). The third set of data relates to the savings associated with applications of the DLT-based solutions and has been compiled from the reports prepared by various consulting agencies and research institutions (e.g. PwC, 2016).

3. CLIMATE CHANGE – A “WINDOW OF OPPORTUNITIES” FOR THE INSURANCE SECTOR

Climate change is associated with already noticeable negative consequences: increased temperature regimes, melting of ice and rising sea levels. Against this background, the international community (UN) is paying due attention to this problem by taking steps towards the establishment of a common legal framework and incentives to combat climate change and adapt to its consequences. The signing of the Paris Agreement in 2015 was an important step towards reducing greenhouse gas (GHG) emissions, delivering concrete national and civil society commitments to limit global warming to a maximum of 2° Celsius (UNFCCC 2015). In 2018, the global economy had to face losses of 225 billion USD caused by natural disasters and extreme weather events. This level is ten times higher than in 2000, and the year 2018 itself was the third year in a row with actual losses in excess of 200 billion USD. It is important to note that only 40% of these losses were covered and compensated by the insurers (Aon Benfield 2019a).

Currently, we are on a pathway to 3° Celsius of global warming (UNEP 2018). Hence, not only adaptation to climate change, but also reduction of the exposure to natural hazards and extreme weather events is of particular importance and requires appropriate measures, as well as sufficient financial resources. According to estimates of the United Nations (UN), the global
annual expenditures for adaptation to climate change are ranging between 140 billion USD and 300 billion USD. By 2050, the cost of adaptation to climate change could reach a level of 280-500 billion USD. In fact, annually only 22 billion USD are being collected for the purpose of adaptation to climate change (Micale et al., 2018). At the same time, climate-related disasters are associated with almost 100 billion USD in annual losses. Moreover, such events could have serious social and economic consequences. For example, the number of climate-induced migrants is steadily increasing, and with regard to the actual path of global warming, we may face millions of people in the coming decades who will be forced to change their place of residence due to the adverse environmental conditions (IOM 2009). As a result, to reduce the risks of climate-related disasters another important agreement was signed in 2015 under the auspices of the UN: The Sendai Framework on Disaster Risk Reduction (SFDRR) which covers the time horizon of 2015-2030 and is aimed at protecting people’s lives as well as critical infrastructure (e.g. the energy sector, transport, agriculture, etc.) (UNISDR 2015).

According to the methodology offered by the European Environmental Agency (EEA), there are four major groups of weather and climate-related extreme events that might cause economic damages: geothermal (e.g. earthquakes, tsunamis, volcanic eruptions); meteorological (e.g. storms); hydrological (e.g. floods, mass movements); and climatological events (e.g. heatwaves, cold waves, droughts, forest fires) (see figure 1). Of particular importance is the fact that climate change indirectly affects other extreme weather events that have been classified as meteorological or hydrological. Hence, climate change is responsible for the vast majority of damages experienced by the economy, financial markets and the society at large. In other words, climate change requires more effective measures to prevent the global economy and the financial system from losses and damages, and improve the resilience of the infrastructure (especially, critical infrastructure) to climate-related risks. Additionally, there is an urgent need for innovative financial products and instruments to support the above-mentioned measures with the overarching aim of providing access to the market of private climate finance.

In fact, according to the data provided by NatCatSERVICE, Eurostat and MunichRe, the extent to which climate-related losses are covered is insufficient and the best results in 2017 were achieved by the United Kingdom (UK), where insured losses accounted for over 70% of the total losses. The most critical situation in covering climate-related risks and losses was identified in Greece, Portugal, Poland and Italy – where damages from climate-related events remained almost uncovered. At the same time, very good rates were achieved by Belgium, Denmark, Lichtenstein and Luxembourg – where over 58% of the losses were insured. Additionally, Germany, France, Ireland, Iceland and Switzerland were able to cover almost 50% of the damages caused by climate-related extreme events and natural disasters (EEA 2019).
4. A YIELD-BASED INSURANCE – PROSPECTS FOR THE EUROPEAN UNION

Three-quarters of the EU countries, including France, Italy, Spain, Austria and the Netherlands, deliver subsidies for so-called multi-risk policies of the insurers which cover weather-related risks including droughts (see table 1). Additionally, financial support comes from the EU (Peters 2018). For example, in the Netherlands and Luxembourg, agricultural yield losses in the field are determined by evaluating the dried parts of the plant, the size of the cobs or the weight of the grains. In the Netherlands, more than a quarter, in Luxembourg almost every second hectare of the affected areas, is already insured against drought damage. Demand is high, since a risk premium subsidy of 50-70% on the insurance premium is granted from national and/or EU funds. In Germany, however, a lack of subsidies and an insurance tax of 19% on insurance premiums for droughts make risk protection completely uninteresting. In almost all other EU countries, the tax rate is near zero, and the state also provides support to risk provisioning (Rittershaus 2018).

In addition, Italy protects its farmers against weather risks with around 1.6 billion EUR, France with 600 million EUR. Only Germany, Ireland, Great Britain and a few others leave this risk to their farmers (Krohn 2018).
Table 1: Insurance and compensation systems in the EU and Switzerland.

|                | Hail | Storm | Heavy Rainfall | Frost | Drought |
|----------------|------|-------|---------------|-------|---------|
| Belgium        | X    | X     | X             |       | X       |
| Denmark        | X    | X     | X             |       | X       |
| Germany²      | X    | X     | X             | X     | X       |
| Italy¹³⁵      | X    | X     | X             | X     | X       |
| Croatia¹³⁵    | X    | X     | X             |       | X       |
| Luxembourg¹³⁵ | X    | X     | X             | X     | X       |
| Latvia¹³⁵     | X    | X     | X             |       |         |
| Lithuania¹³⁵  | X    | X     | X             | X     | X       |
| Netherlands¹  | X    | X     | X             | X     |         |
| Austria¹²³    | X    | X     | X             |       |         |
| Poland¹³⁵     | X    | X     | X             |       | X       |
| Spain¹²³      | X    | X     | X             | X     | X       |
| Switzerland¹²³| X    | X     | X             | X⁴    | X       |

Note: 1) multi-peril insurance, 2) IBI, 3) state subsidies [45-60%], 4) Snow pressure
Source: Own compilation based on Grant (2010). Austria and Switzerland adopted from Palka (2019:2) and Vroege et al. (2019:105).

5. YIELD-BASED VS. INDEX-BASED INSURANCE

As a rule, climate catastrophes hit unexpectedly and the damage caused by such events is not precisely predictable. The “classical” insurance techniques and instruments are often not effective enough to solve the problem as the contractual compensation mechanism works on the basis of yield losses that have been observed in the past. In practice, the main claims management problem is that it often takes months to determine and settle the refunds – months during which the losses can rise further. For instance, a long-lasting moisture penetration could affect infrastructure conditions – e.g. reduce their drying capacity and make them vulnerable to the possible subsequent frost damages. Existing yield-based approaches to the insurance of climate-related risks in agriculture have two main drawbacks: fraud detection and risk modeling. The agricultural firms and farmers tend to overestimate their real losses and claim higher compensation from the insurance companies. Hence, claims management becomes very difficult and requires additional expenditures (both in terms of cost and time) to determine and verify an appropriate amount of compensation for the clients. The second negative feature of a yield-based insurance relates to the modeling of risks, especially when the average surface temperature on Earth rises faster than expected – making forecasting unprecedentedly difficult.
Nowadays, ex-post and ad hoc compensations are becoming more and more expensive – in the period 2014-2020 more than 65% of the insurance premiums have been paid by the EU within the Common Agricultural Policy (Hochrainer-Stingler and Hanger-Kopp 2017). In addition, yield-based insurance may not even be applicable in certain areas – for example, grasslands have different number of harvests per year and a very small difference in damages depending on the seasonal frequency of extreme weather events. Therefore, in such cases IBI could be considered as the most appropriate solution (Hochrainer-Stingler and Hanger-Kopp 2017).

IBI relies on the application of physical indicators (e.g. temperature or soil moisture, etc.) as a “trigger” for compensations. Compared to yield-based insurance, IBI has some positive features. Firstly, this approach is more objective due to the fact that indicators depend only on the physical properties of the environment. In addition, compensation is limited to a predetermined amount of money calculated on the basis of the previous events and associated losses. Another important advantage of IBI is an improved trust between insurance companies and their clients. At the same time, IBI could simplify field loss assessment, reduce bureaucracy and increase transparency – thus making it less costly for small customers like farmers (Gommes and Kayitakire 2013). Despite all the positive features, implementation of IBI is associated with certain obstacles: lack of reliable data, existing basis risk and some technical requirements. The changing risk pattern in the abrupt climate change could also jeopardize the IBI application. Additionally, the premiums per farmer are small and the insurance companies usually have to aggregate risks to transfer them to the reinsurer (Hess and Syroka 2005).

There are three different types of IBI: crop, grassland and livestock insurance. For the crop insurance we can distinguish the following types of indexes: meteorological trigger, area yield trigger, vegetation index and the combination of different factors within the crop growth model. For the grassland insurance we can identify the following types of indexes: meteorological trigger and vegetation index (remote sensing). In case of the livestock IBI, products are based on the measured livestock mortality and vegetation indexes (The World Bank Group 2011). In order to implement the most effective indicator for a crop-related IBI product several studies have been carried out examining different conditions and options. One of the studies suggests that the Normalized Drought Vegetation Index (NDVI) could be introduced in Europe, where summer temperatures are above 16º Celsius (CGLO 2020). In fact, the reaction of vegetation in summer could only be attributed to fluctuations in drought stress and not to the temperature level (Peled et al., 2010). More recent developments show that the application of satellite observations provides a good opportunity for innovative insurance products. For instance, in 2001 the Agriculture Financial Services Corporation (AFSC) introduced the first-of-a-kind NDVI-based pasture insurance product (Hohl 2018). In 2013, the Government of Kenya implemented the first index-based livestock insurance intervention as a component of the Kenya Livestock Insurance Program (KLIP). As a result, Andrew Mude, the inventor of this tool, received the 2016 World Food Prize (Russell 2020).

Another option is to use the so-called Combined Drought Indicator, which consists of the Standardized Precipitation Index (SPI) and fraction anomalies for the absorbed photosynthetically active radiation (APAR). The SPI is based on the data collected at the European level from different weather stations situated in the member states (Sepulcre-Canto
at al. 2012). Additionally, a Hydrological Drought Index Insurance (HDII) for irrigation districts has been elaborated for Spain, where indemnity is based on the Drought Index (DI), which, in turn, is multiplied by a uniform water value for the region. Important is the fact that a transfer of water rights should be prohibited under such scheme – otherwise, the farmers could request double compensation (e.g. yield-based approach). However, if indemnity is based on the objective physical trigger, voluntary exchange of water rights is possible (as well as water banking) (Maestro et al., 2016). The international financial institutions actively offer a wide range of mechanisms to cover climate-related risks, especially for developing countries with limited access to financial resources and mechanisms. For example, the International Financial Corporation (IFC) offers the Global Index Insurance Facility (GIIF) as an opportunity to facilitate access to the financial resources for SMEs, catastrophe risk transfer solutions and IBI in developing countries. From the EU’s perspective, IBI could bring more benefits than negative consequences. However, there is no market for related futures across Europe and risk management is not unified across the EU (Ramsey and Santaremo 2017). In other words, on the way to the EU-wide IBI application, two problems should be kept in mind: the cost of implementation could be enormous and basis risk could sharpen the problems of market acceptance (IFAD, 2017).

6. DLT FOR A BETTER AGRIBUSINESS AND RELATED INSURANCE PRODUCTS

In recent decades, precision technologies and smart contracts have entered the agri-food systems (AFS) of this world (Xu et al., 2020; Stranieri et al., 2021). The origin of modern agricultural technology such as sensors, Internet of Things, enabled smart devices and smart contracts provide a ground for agriculture 4.0, and the foundation of “smart AFS”. Smart AFS aim to improve the efficiency of the agriculture-food-chain in relation to physical (e.g. climate and soil), technical (sensors and machines) and business (sales contracts, insurance) factors. The best, i.e. most efficient response of smart machines to, for example, climate extremes (e.g. water scarcity) depends on communication among enabled smart devices with other intelligent nodes of the production, the sales and the risk management system in the network of agriculture and food production. Smart machines collect information of an unfolding climatic event, broadcast it to other machines in the field and nodes along the supply chain. The goal of the internet-of-agri-food (IoAF) is to broadcast system-threatening event messages such as soil moisture extremes to cropping technologies in usage, crop loss assessment and environmental hazards reports, messages to cooperative financial risk management, sales and storage, neighboring farmers and the insurance as element of smart AFS – in less time with high accuracy, in other words: at lower transaction cost.

Nowadays, a huge amount of data has to be processed to cover the needs of the insurers (as well as the insureds) at least in the two above-mentioned areas. Moreover, in the modern world, data protection becomes increasingly important for all economic agents. For this reason, companies and governments from different countries are looking more precisely at the
opportunities of DLT. A starting point (being currently the most popular type of solution) has been elaborated on the basis of Blockchain. Despite the fact that this technology has some limitations (e.g. amount of the operations within a specific time horizon), the level of data protection is high enough to reduce significantly the risks of external interventions (e.g. “hacking”) to get the data or important business information. Additionally, a combination of DLT with Artificial Intelligence (AI), the Internet of Things (IoT), Big Data and other innovations could give unprecedented breakthroughs for the entire insurance sector. That is why, “InsureTech” is not just a modern trend, but has already become an important part of the daily business activities of different economic sectors (see table 2).

Several important benefits could be identified for a DLT-based application of IBI, such as improved real-time exposure assessment and enhanced accident and risk prediction. Those benefits contribute to the improvement of data processing and facilitate understanding of the scenario-based assessments of different changing parameters in a real-time mode.

DLT could bring significant cost and time savings, i.e. reduce transaction costs (e.g. time for negotiations and quotations). According to the available estimations, an implementation of DLT solutions for the insurance sector could reduce time for negotiations and quotations by up to 90% (Generali 2018). As a result, reinsurers could make the process of reserve estimations easier and establish the so-called “streamlined reinsurance” operations. However, the most important advantage for all insurers is improved liquidity control.

InsurTech facilitates deeper risk assessment, offers more sophisticated preventive models, improves interactions, enhances operational capabilities, and makes efficient use of ecosystem and market resources (i.e., lower transaction costs). According to the findings provided by PwC (2016), the most important opportunity for the insurers arises from self-directed services (e.g. customer acquisition and customer services) and usage-based insurance (e.g. pay-as-you-go).

Moreover, a variety of operational benefits for the agricultural insurance relates to an improved claims management: coordinated and synchronized view and verification of the transactions and other information; enhanced third-party transactions (e.g. “claim leakage”); enforced fraud detection and better alignment with the new legal requirements for the financial institutions. Such improvements could create additional benefits through behavior-based underwriting (e.g. pay-as-you-go). Additionally, existing enhanced requirements for the financial market (e.g. Basel III, Directives 2016/2341, 2017/828) impose certain limitations on the activities of financial institutions (European Parliament; Council 2016, 2017). In this case, not only the insurance companies should comply with the existing requirements while providing their services, but also other institutional investors should pay attention to the existing limitations. In fact, new legal requirements on the financial market force institutional investors to analyze and evaluate non-financial risks while making their investment decision.
Table 2: DLT-related cost and time savings for insurance services.

| Area of application                  | Practical cases                                      | Time/money savings                  |
|--------------------------------------|------------------------------------------------------|-------------------------------------|
| Signing the contract and execution  | Smart contracts R3, CatBonds, CatSwaps                | up to 2-3 days, no escrow cost⁴     |
| Microfinancing                       | Peer-to-peer insurance Lydia                         | Average cashback of 30% of the premiums⁵ |
| Claim management                     | Fraud detection Shift Technology (Claims automation)  | “hit-rate” more than 2.5 times better than standards⁶ reduction of annual losses for up to 10% |
| Underwriting                         | Behavior-based underwriting Atidot                   | identification of up to 25% underinsured policies⁷ |
| Parametric insurance                 | Mechanism selection Kenyan Livestock Insurance Program (KLIP) | up to 2-3 months                   |
| KYC (“Know your client”) and AML (Anti-Money Laundering Laws) | Due diligence InterchainZ                          | up to 90% of time                   |
| Risk transfer                        | Reinsurance B3i (Aegon, Allianz, Munich Re, Swiss Re and Zurich Re) | 15-20% expenses⁹                   |

Source: Own compilation.

Also, a set of market benefits associated with the application of DLT in the insurance sector reflects the new business opportunities. The most important improvement could be achieved in facilitating access to the services for small and medium clients. Exactly in this case the insurers could drastically reduce administrative costs and make their services more accessible for those, who were excluded from the classical schemes due to the negative cost-benefit ratios of the

---

⁴ https://hackernoon.com/smrt-contracts-a-time-saving-primer-b3060e3e5667
⁵ https://p2pconference.com/speaker/tim-kunde/
⁶ https://www.digitalinsuranceagenda.com/180/shift-technology-ai-that-understands-insurance-claims/
⁷ http://www.oxbowpartners.com/pdfs/Atidot.pdf
⁸ https://www.jdsupra.com/legalnews/using-blockchain-for-kyc-aml-compliance-25325/
⁹ https://www.disruptordaily.com/blockchain-use-cases-insurance/
insurance products. Also, DLT creates a common platform for all the key participants of the insurance process and improves the efficiency of their communications. Moreover, such a platform could be considered as a common space to follow and understand the quotations workflow. The international financial institutions are trying actively to develop technical solutions for dealing with agricultural risks. For example, the UN created an incentive “New Climate Chain Coalition”, which purpose is to facilitate achievement of the SDGs through implementation of DLT and elaborate better climate-related solutions to avoid frauds and address existing challenges (UNFCCC 2018).

Even despite all the above-mentioned benefits, some bottlenecks are associated with DLT application for the IBI-based agriculture insurance products. Firstly, the so-called privacy challenges emerge while analyzing the data, since data protection in the EU is / the EU countries have very complex and challenging data protection laws. The second important obstacle on the way to an application of DLT for the agricultural insurance services is associated with existing different regulations within the separate jurisdictions – this could impose some obstacles while implying different legal acts to the same operations. Another challenge is associated with the decentralized way of storing the data – no certain person or entity is responsible for the stored data.

7. SYSTEMIC APPROACH FOR CLIMATE INSURANCE IN AGRICULTURE

A pool insurance of the agricultural risks is more appropriate than individual insurance (Villarroya and Agronoma 2016). Moreover, one of the most important reasons for the introduction of a new agricultural insurance scheme at the EU level is the fact that climate change could contribute to the systemic risk escalation for the entire economic and on financial systems (e.g. cascading large scale losses after one climate-related event). According to the report prepared by the European Systemic Risk Board (ESRB), climate change will contribute to systemic risk through several channels. First of all, it is important to consider the macroeconomic impact of the sudden changes in energy use. Moreover, the reassessment of the carbon-intensive assets (e.g. stranded assets) could be an additional source for the systemic risk escalation. Additionally, an increase in the frequency and severity of the natural catastrophes and extreme weather events could lead to an aggravation of the systemic risk. The fact that climate change could increase systemic risk requires an adequate response at the EU level to protect the entire financial and economic system from escalation of the climate-driven systemic risk through establishment of the European Risk Transfer Mechanism (ERTM) (see Figure 3). With this regard, a Special Purpose Vehicle (SPV) is needed to issue debt instruments or swaps and to coordinate the new insurance mechanism in agriculture on the EU level. Furthermore, the existing patterns of reinsurance mechanisms show that the market for the alternative risk transfer capital is being driven mostly by the collateralized reinsurance schemes. Although an alternative segment of the global reinsurance market accounts for less than 20%, it shows very high growth rates in comparison with the traditional reinsurance market (see figure 2).
Within the alternative reinsurance market, the biggest chunk belongs to collateralized reinsurance schemes – 50% of the total global reinsurance capital and the most rapid growth rates in 2008-2018. The fact that synthetic instruments are still playing an important role on the financial market could be considered as a potential additional source of systemic risks (e.g. 2008 on the U.S. mortgage market). Moreover, the recently enacted Solvency II regulation recognizes derivatives or securitization as an effective risk mitigation technic and gives a green light for further application of the alternative approaches in risk transfer (Aon Benfield 2017). The existing EU Common Agricultural Policy (CAP) provides assistance for the agricultural risk management of less than 2% of the Pillar II funds and 0.4% of the total 2014-2020 CAP budget (Bardaji I., et al., 2016). Hence, CAP could contribute to the functioning of the new insurance system at the European level by covering the basis risks. This could be achieved through the facilities of the European Agricultural Fund for Guarantee (EAFG) which is aimed at providing direct payments (e.g. income support) to farmers. In this case, financial resources of the fund could cover the difference between actual losses and compensations.

There are two major bottlenecks in delivering protection of agriculture from climate-related risks: Time and administrative costs. Moreover, possible insurance services for small and medium should be designed to transfer part of the risks to the public or private reinsurance...
providers (Bardaji I., et al., 2016). These two aspects could be considered as evidence that the level of transaction costs is high and requires more adequate solutions at the EU level.

The fact that climate change could increase systemic risk requires an adequate response also at the EU level to protect the entire financial and economic system from escalation of the climate-driven systemic risk through establishment of the European Risk Transfer Mechanism (ERTM) (see figure 3). With this regard, a Special Purpose Vehicle (SPV) is needed to issue debt instruments (e.g. catbonds) or swaps (e.g. catswaps) and to coordinate the new insurance mechanism in agriculture on the EU level. Furthermore, the existing patterns of reinsurance mechanisms show that the market for the alternative risk transfer capital is being driven mostly by the collateralized reinsurance schemes.

A European Stability Mechanism (ESM) already exists in the European Union and is aimed at providing financial assistance to member states with severe debt conditions. It could serve as SPV to issue debt instruments and swaps in order to transfer risks to the financial market. Such an approach could equalize the costs of capital for issued catastrophe bonds (catbonds) as the creditworthiness of the EU is much higher than that of some EU member states (see figure 3, number 1). Another reason for establishing ERTM is the fact that there are different types of actors on the financial market who try to exchange debt instruments and related swaps in order to increase their profits. The example of the last financial crisis in 2008 demonstrated that ESM could not only play an important role in providing relatively cheap financial resources to all member states, but also serve as a contractor for credit default swaps. In fact, ESM should protect against possible speculations with catastrophe swaps (catswaps). After mobilization of the necessary financial resources, sovereign funds or special sovereign climate insurance agencies could use catbonds and catswaps to transfer risks via ESM to the financial market (see figure 3, number 2).

The application of DLT could allow the transfer of information and financial resources between ESM and sovereign insurance funds. Moreover, DLT could not only ensure collection and processing of climate-related information, but also provide a very high level of security and access to insurance products for small clients (e.g. small farmers). Additionally, issuance and management of the financial instruments (e.g. bonds, swaps) with the DLT application could be organized in a more efficient way and thus provide time and cost savings, facilitate the collection of financial resources and relevant data and speed up compensation payments for small and medium economic agents (see figure 3, number 3).

At the same time, the European Parliament has already adopted directives forcing big companies to disclose their level of non-financial risks. Although companies can still choose the way in which they report on their non-financial risks and results, the Sustainable Finance Action Plan and the EU Green Deal (Communication from the Commission to the European Parliament, the European Council, the Council, the European Central Bank, the European Economic and Social Committee and the Committee of the Regions 2018) provide a clear signal that concrete requirements and guidelines on non-financial reporting will be included into the revised versions of the legal acts (e.g. Directive 2013/34/EU, 2014/95/EU) (European
Parliament; Council 2013, 2014). Such amendments could require collection of the relevant data for both non-financial reporting and effective risk management.

**Figure 3:** European Risk Transfer Mechanism (ERTM) with a combined application of IBI and DLT for agriculture.

Source: Own compilation.

Currently, pension funds and insurance companies in the EU have to analyze the level of non-financial risks while making their investment decisions. This means that major
institutional investors are already paying attention to climate-related risks and trying to avoid investments with a high level of the above-mentioned risks (e.g. Directive 2016/2341/EU) (European Parliament; Council 2016).

As a result, an introduction of the DTL-based IBI insurance on the EU level (ERTM) could bring various benefits by solving existing problems in agricultural insurance and offer new opportunities for further improvements. In fact, benefits could be measured both in terms of time and cost savings on each stage and level of the insurance process. ERTM could be built on the already existing IT-solutions and its implementation could be less costly than the creation of a completely new mechanism from zero (see Table 2). The application of the DLT could grant an access for small users/customers to the insurance services on a peer-to-peer basis by reducing transaction costs and facilitating flow of payments. Moreover, in some cases peer-to-peer insurance could generate a cashback of up to 80% (see Table 2). Additionally, such a system could be considered as an effective tool to increase the rate of penetration on the market, which currently does not exceed the level of 40%. The application of smart contracts as a basis of the DLT-based insurance mechanism could not only reduce significantly time cost for signing the contracts but also contribute to time optimization in the execution the contracts (e.g. up to 2-3 days).

The DLT-based IBI on the EU level, as discussed above, is a simplified approach to deliver protection against possible losses. Such an approach allows to save time (see Table 2) and speed up compensation payments without additional verifications and calculations on the ground. An application of DLT could make the process of such payments quicker by arranging direct compensations to the accounts and facilitate risk transfer to the financial market.

8. CONCLUSIONS

The application of yield-based insurance schemes in agriculture has proven to be less effective than index-based solutions. This disadvantage is primarily related to the existing time gaps between an actual event and the compensation payments. Additionally, it is very hard to estimate actual losses. Mistrust between economic operators could be considered as one of the reasons for this. Moreover, yield-based insurance products are relatively expensive and not accessible for small costumers. From the point of view of the underwriting process, there are a number of options to replace yield-based insurance with IBI – solving the above-mentioned problems by introducing an independent and objective physical “trigger” to facilitate quick compensation payments to the clients.

DLT solutions on the crypto-currency market demonstrate some positive features of this technology and offer prospects for its application in other segments of the financial market. When using InsurTech with index-based insurance in agriculture, it is important to consider some of its specific aspects. For instance, DLT application could offer an improved real-time exposure assessment, facilitate accident and/or risk forecasting and assist in reserve
calculations for the reinsurance. Furthermore, this technology could be employed in implementing behavioral underwriting.

Moreover, the application of a DLT-based IBI in agriculture could improve insurance services and facilitate the transition of risks from sovereign climate insurance funds to the financial market. An elaborated concept of ERTM could facilitate access to the services for small customers in different EU countries, improve contract execution, speed up compensation payments, contribute to the basis risk reduction, improve risk transfer and reduce information asymmetry (e.g. transaction costs). Additionally, this approach could prevent speculations on the financial market and equalize the cost of capital for different EU member states on the financial market. At the same time, facilities of some European financial institutions could be used as a Special Purpose Vehicle (e.g. ESM or EIB) to improve access to the financial market and grant control over the transactions. The most important advantage of ERTM is an opportunity to avoid systemic risks (e.g. support for the private insurance companies and sovereign insurance funds) and to protect the European Financial System from the next possible financial turmoil – making it more sustainable to non-financial risks. DLT as a component of ERTM could also facilitate the flow of information in order to facilitate and improve risk management and communication among the different economic agents.

ACKNOWLEDGEMENTS

We are grateful for helpful hints and comments from two anonymous reviewers of this journal and from Anne Wessner of the Helmholtz-Centre for Environmental Research – UFZ in Leipzig.

REFERENCES

Aon Benfield (2017) Reinsurance Market Outlook. Record Capacity Sufficient to Meet Current Demand Increase and Future Innovations. http://thoughtleadership.aonbenfield.com/Documents/20170105-ab-analytics-rmo.pdf.

Aon Benfield (2019a) Weather, Climate & Catastrophe Insights. 2018 Annual report. http://thoughtleadership.aonbenfield.com/Documents/20190122-ab-if-annual-weather-climate-report-2018.pdf.

Aon Benfield (2019b) Reinsurance Market outlook. April 2019. http://thoughtleadership.aonbenfield.com/Documents/20190403-ab-analytics-rmo-april-2019.pdf.

Atlas Magazine (2017) Agricultural insurance: products and schemes https://www.atlas-mag.net/en/article/agricultural-insurance-products-and-schemes

Bardaji I., Garrido A., Blanco I., Felis A., Sumps J.M. and Garcia-Azcarate T. (2016) State of play of risk management tools implemented by Member States during the period 2014-
2020: national and European frameworks. https://www.europarl.europa.eu/RegData/etudes/STUD/2016/573415/IPOL_STU%282016%29573415_EN.pdf

CGLO (2020) Copernicus Global Land Operations “Vegetation and Energy”. Framework Service Contract Nº 199494 (JRC). Scientific Quality Evaluation. Normalized Difference Vegetation Index (NDVI). https://land.copernicus.eu/global/sites/cgls.vito.be/files/products/CGLOPS1_SQE2019_NDV300m-V1_I1.01.pdf.

Communication from the Commission to the European Parliament, the European Council, the Council, the European Central Bank, the European Economic and Social Committee and the Committee of the Regions. (2018) Action Plan: Financing Sustainable Growth. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52018DC0097&from=EN.

EEA (2020) Economic losses insured (1980-2019). https://www.eea.europa.eu/data-and-maps/indicators/figures/impacts-of-extreme-weather-and-2

European Parliament; Council (2016) DIRECTIVE (EU) 2016/2341 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 14 December 2016 on the activities and supervision of institutions for occupational retirement provision (IORPs). Official Journal of the European Union. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32016L2341&from=EN.

European Parliament; Council (2017) DIRECTIVE (EU) 2017/828 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 17 May 2017 amending Directive 2007/36/EC as regards the encouragement of long-term shareholder engagement. Official Journal of the European Union. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32017L0828

European Parliament; Council (2013) DIRECTIVE 2013/34/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 26 June 2013 on the annual financial statements, consolidated financial statements and related reports of certain types of undertakings, amending Directive 2006/43/EC of the European Parliament and of the Council and repealing Council Directives 78/660/EEC and 83/349/EEC. Official Journal of the European Union. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32013L0034&from=EN.

European Parliament; Council (2014) DIRECTIVE 2014/95/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 22 October 2014 amending Directive 2013/34/EU as regards disclosure of non-financial and diversity information by certain large undertakings and groups. Official Journal of the European Union. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32014L0095&from=EN.

FEMA (2019) National Advisory Council. DRAFT Report to the FEMA Administrator, FEMA NAC Report, November 2019. https://www.fema.gov/sites/default/files/2020-08/fema_nac-report_11-2019.pdf
Generali (2018) Generali Global Corporate & Commercial Italy promotes the initiative to optimize corporate risks quotation, negotiation and binding processes through blockchain technology. https://www.generaliglobalcorporate.com/doc/jcr:d1076099-3628-4d67-a813-3060b7f2ca54/lang:en/PressRelease_Blockchain_Ottimizzazione_vf_ENGLISH.pdf

Grant, W. (2010) Policy Instruments in the Common Agricultural Policy. West European Politics, Vol. 33, Issue 1, pp. 22-38.

Gommes R. and Kayitakire F. (2013) The challenges of IBI for food security in developing countries. Luxembourg: Publications Office of the European Union. Proceedings of a technical workshop organised by the EC Joint Research Centre (JRC) and the International Research Institute for Climate and Society (IRI, Earth Institute, Columbia University).

Hagendorff, B., Hagendorf, J., Keasey, K., and Gonzalez, A. (2014) The risk implications of insurance securitization: The case of catastrophe bonds. Journal of Corporate Finance, Vol. 25, pp. 387-402.

Hess U., Syroka J. (2005) Weather-based Insurance in Southern Africa. The Case of Malawy. Agriculture and Rural Development Discussion Paper 13, p. 38.

Hochrainer-Stigler, S. and Hanger-Kopp, S. (2017) Subsidized Drought Insurance in Austria: Recent Reforms and Future Challenges. Wirtschaftspolitische Blätter, 6(4), pp. 599-614.

Hohl, R.M. (2018) Agricultural Risk Transfer: From Insurance to Reinsurance to Capital Market. John Wiley&Sons, pp. 440.

Hughes, A., Park, A., Kietzmann, J. and Archer-Brown, C. (2019) Beyond Bitcoin: What blockchain and distributed ledger technologies mean for firms, in: Business Horizons, Vol. 62, Issue 3, pp. 273-281.

IFAD (2017) Remote sensing for index insurance. An overview of findings and lessons learned for smallholder agriculture, 60 p.

IFC (2020) Index Insurance – Frequently Asked Questions https://www.ifc.org/wps/wcm/connect/industry_ext_content/ifc_external_corporate_site/financial+institutions/priorities/access_essential+financial+services/giif+frequently-asked-questions

IOM (2009) Disaster risk reduction, climate change adaptation and environmental migration. A policy perspective. https://publications.iom.int/system/files/pdf/ddr_cca_report.pdf.

Kath J., Mushtaq S., Henry R., Adeyinka A. and Stone R. (2018) Index insurance benefits agricultural producers exposed to excessive rainfall. Weather and Climate Extremes 22 (2018): 1-9.

Ki-Moon, B. (2012) Secretary-General’s closing remarks at High-Level Panel on Accountability, Transparency and Sustainable Development. https://www.un.org/sg/en/content/sg/statement/2012-07-09/secretary-generals-closing-remarks-high-level-panel-accountability
KPMG (2017) Blockchain accelerates insurance transformation. https://assets.kpmg/content/dam/kpmg/xx/pdf/2017/01/blockchain-accelerates-insurance-transformation-fs.pdf

Krohn P. (2018) Bauern scheuen Kosten einer Dürre-Versicherung. https://www.faz.net/aktuelles/wirtschaft/bauern-scheuen-die-kosten-einer-duerre-versicherung-15725414.html

Maestro, T., Bialza, M., Garrido. A. (2016) Hydrological drought index insurance for irrigation districts in Spain. *Spanish Journal of Agricultural Research* 14(3), e0105, 14 p.

Micale, V., Tonkonogy, B., and Mazza, F. (2018) Understanding and Increasing Finance for Climate Adaptation in Developing Countries. https://www.international-climate-initiative.com/fileadmin/Dokumente/2019/20190225_Understanding-and-Increasing-Finance-for-Climate-Adaptation-in-Developing-Countries.pdf.

Morana, C. and Sbrana, G. (2019) Climate change implications for the catastrophe bonds market: An empirical analysis. *Economic Modelling, Vol. 81*, pp. 274-294.

Palka, M. and Hanger-Kopp, S. (2019) Agricultural crop insurance in Switzerland, focusing on drought. Crop Insurance in Switzerland. IIASA FACTSHEET, 6 p.

Peled, E., Dutra, E., Viterbo, P. and Angert, A. (2010) Technical Note: Comparing and ranking soil drought indices performance over Europe, through remote-sensing of vegetation. *Hydrology. Earth Syst. Sciences.*, Vol. 14(2), pp. 271-277.

Peters L. (2018) Deutsche Bauern können sich keine Dürreversicherung leisten – Dürre 2018. https://www.topagrar.com/management-und-politik/news/deutsche-bauern-koennen-sich-k eine-duerreversicherung-leisten-duerre2018-9842034.html

PwC (2016) Opportunities await: How InsurTech is reshaping insurance. https://www.pwc.lu/en/fintech/docs/pwc-insurtech.pdf

Ramsey, A. F. and Santaremo, F.G. (2017) Crop Insurance in the European Union: Lessons and Caution from the United States. https://mpra.ub.uni-muenchen.de/79164/1/MPRA_paper_79164.pdf

Rittershaus, D. (2018) Oft gestellte Fragen zum Thema Trockenheit und Versicherung. https://www.vereinigte-hagel.net/de/2018/08/oft-gestellte-fragen-zum-thema-trockenheit-und-ver sicherung/

Russell, A. (2020) How NDVI Transformed Insurance as a Tool to Build Resilience. https://www.agrilinks.org/post/how-ndvi-transformed-insurance-tool-build-resilience.

Sepulcre-Canto, G., Horion, S., Singleton, A., Carro, H. and Vogt, J. (2012) Developing a Combined Drought Indicator to detect agricultural drought in Europe. *Nat. Hazards Earth Syst. Sci., Vol. 12*, Issue 11, pp. 3519-3531.
Stranieri S., Riccardi F., Meuwissen M., and Soregaroli C. (2021) Exploring the impact of blockchain on the performance of agri-food supply chains. *Food Control, Volume 119*, 107495 (forthcoming).

The World Bank Group (2011) Weather Index Insurance for Agriculture: Guidance for Development Practitioners. [http://documents.worldbank.org/curated/en/590721468155130451/pdf/662740NWP0Box30or0Ag020110final0web.pdf](http://documents.worldbank.org/curated/en/590721468155130451/pdf/662740NWP0Box30or0Ag020110final0web.pdf)

UNEP (2018) Emissions Gap Report 2018. [http://wedocs.unep.org/bitstream/handle/20.500.11822/26895/EGR2018_FullReport_EN.pdf](http://wedocs.unep.org/bitstream/handle/20.500.11822/26895/EGR2018_FullReport_EN.pdf)

UNFCCC (2015) The Paris Agreement – main page. [http://unfccc.int/paris_agreement/items/9485.php](http://unfccc.int/paris_agreement/items/9485.php)

UNFCCC (2018) UN Supports Blockchain Technology for Climate Action. [https://unfccc.int/news/un-supports-blockchain-technology-for-climate-action](https://unfccc.int/news/un-supports-blockchain-technology-for-climate-action)

UNISDR (2015) Sendai Framework for Disaster Risk Reduction 2015–2030. [http://www.un.org/en/development/desa/population/migration/generalassembly/docs/globalcompact/A_RES_69_283.pdf](http://www.un.org/en/development/desa/population/migration/generalassembly/docs/globalcompact/A_RES_69_283.pdf)

Villarroya, T.M., and Agrónoma, I. (2016) Hydrological Drought Index Insurance for Irrigated Agriculture, Tesis Doctoral. [http://www.ceigram.upm.es/wp-content/uploads/2016/10/Tesis_T_Maestro_final-2.pdf](http://www.ceigram.upm.es/wp-content/uploads/2016/10/Tesis_T_Maestro_final-2.pdf)

Vroege, W., Dalhaus, T. and Finger, R. (2019) Index insurance for grasslands – A review for Europe and North-America. *Agricultural Systems 168* (2019), pp. 101-111.

WEF (2020) The Global Risks Report 2020. 15th Edition. [https://www.zurich.com/-/media/project/zurich/dotcom/industry-knowledge/global-risks/docs/the-global-risks-report-2020.pdf?la=en&hash=56178CE883A92B151A1789846492230C](https://www.zurich.com/-/media/project/zurich/dotcom/industry-knowledge/global-risks/docs/the-global-risks-report-2020.pdf?la=en&hash=56178CE883A92B151A1789846492230C)

Xu, J., Guo, S., Xie, D., and Yan, Y. (2020) Blockchain: A new safeguard for agri-foods. *Artificial Intelligence in Agriculture, Volume 4*, pp. 153-161.